

AMBS

Doctoral Research Conference

Programme of Events

2nd and 3rd June 2025

Alliance Manchester Business School The University of Manchester

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2025 AMBS Doctoral Research

Conference Programme

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**Management Sciences and Marketing Session 1:**

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**People, Management and Organisations**

Oluwabusayo Durojaiye Xiangyu Sheng

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Conference Schedule

**Monday 2 June**

|  |  |  |
| --- | --- | --- |
| **Time** | **Session** | **Room** |
| 10.00 - 10.30 | Coffee and registration | The Hive 3.004 |
| 10.30 - 10.45 | Welcome from **Professor Lloyd C. Harris** | Theatre 2.008 |
| 10.45 - 11.45 | Keynote Speaker: **Dr David J. Houghton, University of Leicester** | Theatre 2.008 |
| 11.45 - 12.45 | Lunch | Hive Café (second floor) |
| 1.00 - 3.00 | Year 1 Abstract presentations (parallel sessions)  **10 minutes plus 5 minutes for Q&A. See below for session timings** |  |
| 1.00 - 3.00 | A&F Abstract Presentations (Year 1).  **Chair: Hening Liu** | 3.013a |
| 1.00 - 2.00 | PMO Abstract Presentations (Year 1).  **Chair: Kara Ng** | 3.013b |
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| 1.00 - 2.30 | MSM Abstract Presentations (Year 1). Two parallel sessions  **Chairs: Session 1: Sumin Kim Session 2: Georgios Bekos** | Session 1: 3.014b  Session 2: 3.015a |
| 3.00 - 3.30 | Coffee Break | The Hive 3.004 |
| 3.30 - 4.30 | Researcher Development: Careers session **(Dr Antoinette McKane**) | 3.009 |
| 4.30 - 5.30 | Wine Reception (including announcement of Best Abstract winners) | The Hive 3.004 |

**Tuesday 3 June**

|  |  |  |
| --- | --- | --- |
| **Time** | **Session** | **Room** |
| 10.00 - 10.30 | Coffee and registration | The Hive 3.004 |
| 10.30 - 11.30 | Job Interview Q&A  **Panel: Kara Ng, Sumin Kim, Ben Tsou, Gianluigi Giustiziero** | 3.009 |
| 11.30 – 11.45 | Coffee Break | The Hive 3.004 |
| 11.45 - 1.30 | Year 2 Paper Presentations (parallel sessions)  ***10 minutes plus 5 minutes for Q&A. See below for session timings*** |  |
| 11.45 – 1.00 | IMP Paper Presentations (Year 2).  **Chair: Gianluigi Giustiziero** | 3.014a |
| 11.45 – 1.30 | MSM Paper Presentations (Year 2).  **Chair: Georgios Bekos** | 3.014b |
| 11.45 - 12.30 | PMO Paper Presentations (Year 2).  **Chair: Kara Ng** | 3.013b |
| 11.45 - 1.15 | A&F Paper Presentations (Year 2).  **Chair: Hening Liu** | 3.013a |
| 1.30 - 2.15 | Lunch | Hive Café (second floor) |
| 2.15 – 3.00 | Peer Mentoring Discussion  **Panel:** Mennatullah Muhammad Elsaye, Ozioma Paul, Shubhanghi Sharma, Rui Zheng | 3.009 |
| 3.00 – 3.45 | Divisional Talks (parallel sessions) **IMP: Dr Gianluigi Giustiziero MSM: Prof Judy Zolkiewski PMO: Dr Stephen Mustchin A&F: Dr Sumair Hussain** | IMP: 3.014a MSM: 3.014b PMO: 3.013b A&F: 3.013a |
| 3.45 – 4.00 | Closing address: Professor Stuart Hyde (and announcement of Best Paper winners) | The Hive 3.004 |

About the conference

**Welcome**

We are delighted to welcome you to the 2025 Alliance Manchester Business School Doctoral Research Conference!

During the Doctoral Research Conference, we will have talks from academics within AMBS featuring Dr Gianluigi Giustiziero, Professor Judy Zolkiewski, Dr Stephen Mustchin and Dr Sumair Hussain, a session from Dr Antoinette McKane on Academic Careers and our opening keynote address will be given by Dr David J. Houghton, University of Leicester.

We have also scheduled a panel of PGRs talking about what their programme meant to them, what they have learnt along the way and to take your questions.

On Day 1, we have Year 1 PhD abstract presentations organised by Division. On Day 2, our second year PGRs will be presenting a paper.

These sessions will:

1. Provide feedback on the PGRs’ ongoing thesis research;
2. Offer inspiration on how to conduct engaged management research; and
3. Build a network of collaboration amongst PGRs and faculty members.

We know that everyone is incredibly busy and will have to pick and choose what sessions of the Doctoral Research Conference they can attend, so we invite you to look through this programme and identify those sessions of most suitability and interest. First years will be attending all sessions with second years attending a selected few.

At the end of the first day, we have a drinks reception where our Best Divisional Abstracts will be announced. Best Divisional Papers will claim their prize at the end of Day 2.

We look forward to seeing you at the conference. All the best,



**Professor Lloyd C. Harris, School PGR Director**

**School organisation**

As a School, AMBS is organised by four Divisions of research studies. Depending upon focus of research and study, all AMBS academics and PGRs reside within the AMBS’s four Divisions: Accounting and Finance (A&F); Innovation, Management and Policy (IMP); Management Sciences and Marketing (MSM); or People Management and Organisations (PMO).

Accounting - A calculator  

ACCOUNTING AND FINANCE (A&F)

An outline of a person's head with a lightbulb inside  

INNOVATION, MANAGEMENT AND POLICY (IMP)

An arrow hitting a bullsey  

MANAGEMENT SCIENCES AND MARKETING (MSM)

The outlines of peoples heads  

PEOPLE, MANAGEMENT AND ORGANISATIONS (PMO)

Many of the presentation allocations of the conference will align within these divisions; others are School- wide PGR events. Everyone is welcome at the Conference, although **Year 1 PGRs *must* attend all sessions as a compulsory part of their programme**

**Session speakers**

Keynote

**Dr David J. Houghton, University of Leicester**

David is a research active Associate Professor in Marketing with several collaborations internally and externally. His research centres on the examination of behaviour related to the use of technology, for individuals, groups, businesses and society. More specifically, he is interested in the behavioral processes underlying consumer interaction with, and through, digital technology, and how this impacts consumers, brands, organisations and wider society. Although he focuses on researching how people engage with others online, his wider research area includes data analysis techniques and data analytics - where he focuses on the use of different data collection methods and analysis techniques to capture new, difficult to reach data to benefit the development of knowledge - engagement, new technology and privacy.

Visit David’s [Google Scholar](https://scholar.google.com/citations?user=hrOKHn0AAAAJ&hl=en) profile for up-to-date information on publications and research.

**Keynote:**

*The Ultimate Career Companion: Non-Significant Results*

**Synopsis**:

The PhD. is just the beginning. The fun of academia continues beyond, and is both rewarding and perplexing. This talk provides an open and frank look at the challenges, trials and tribulations of a career academic, from signing up for a doctorate, changing focus during the PhD., failing in publishing, learning to write, moving field, developing leadership skills, and working in interdisciplinary and multi-motivational teams. You *can* have it all, just not at the same time.

**Divisional Talks**

**A&F Divisional Talk: Dr Sumair Hussain**

**Biography**



**Synopsis:**

Sumair is an Assistant Professor in Accounting at the Alliance Manchester Business School (AMBS). His research broadly focuses on financial accounting, with particular interests in corporate disclosures and international accounting. In the area of disclosures, he examines both the content of corporate disclosures and the manner in which they are presented, analyzing the determinants and consequences of managerial discretion in financial reporting. His interest in international accounting lies in understanding how accounting standards influence financial reporting outcomes, particularly in terms of transparency, comparability, and decision usefulness across different regulatory environments.

My research on disclosures explores how firms communicate financial and non-financial information and how these disclosures influence different stakeholders, such as investors, auditors, or regulators. When possible, I consider counterfactual comparisons, which involve analysing hypothetical scenarios to assess what could have happened under different disclosure conditions. While not always feasible, this approach helps distinguish correlation from potential causal effects, providing clearer insights into the economic consequences of disclosure policies. This perspective contributes to a more nuanced understanding of financial reporting

**IMP Divisional Talk: Dr Gianluigi Giustiziero**

**Biography**



I am a Senior Lecturer (equivalent to Associate Professor) in Strategy at Alliance Manchester Business School, University of Manchester. I received my PhD in Strategy from the University of Michigan.

Inspired by the classical work of Adam Smith and George Stigler, I study the impact of resource attributes and demand characteristics on the division of labour. At the time of their writing Adam Smith drew insights from butchers, bakers and brewers in the Highlands of Scotland in 1776, and George Stigler from the Lancashire textile industry in 1951; nowadays the productive system in developed economies is mainly devoted to the tertiary and quaternary sectors. Moving with the times, I apply and extend the classic theories to service and high-tech industries.

**Synopsis:**

In this talk, I explore foundational insights into academic life, distilling essential lessons and practical guidance I wish I'd known earlier in my career. Drawing upon personal experience, I highlight the underlying economics of knowledge work, including strategies for efficiently managing research, teaching, and service responsibilities. Additionally, I provide candid reflections and actionable advice about navigating the complexities of the academic job market, emphasizing how aspiring academics can position themselves effectively. This session aims to equip early-career researchers with clarity, confidence, and tools to thrive in academia.

**PMO Divisional Talk: Dr Stephen Mustchin Biography**

Stephen is a member of the Work and Equalities Institute at Alliance Manchester Business School, University of Manchester. His research interests are in the political economy and sociology of work, with a particular focus on industrial relations, trade unions and HRM. He has conducted research on regulation and state enforcement of labour standards, changing union strategies including international worker representation, union involvement in learning, skills and employment in the NHS, industrial relations in postal services, union responses to vulnerable work in the construction industry, and historical research on industrial conflict and industrial relations reform.

Current research includes projects on public procurement and employment conditions, and employment in the context of regional devolution in Greater Manchester.

**Synopsis:**

**Developing your research interests and networks in an intellectually diverse, multi-disciplinary division**

This talk will focus on how to build a career and a broader programme of research, and the opportunities that become available when conducting postgraduate research in an intellectually diverse and multi-disciplinary environment, as is the case with the People, Management and Organisations division within AMBS. This will include discussion of the tensions and dilemmas of developing a publication strategy alongside an evolving research focus, academic citizenship, engagement with teaching, and engagement with wider networks from beyond your institution. Dr Stephen Mustchin is head of the Human Resource Management, Employment Relations and Law subject area group within PMO and a member of the Work and Equalities Institute’s steering committee, and the talk will draw on his own experiences as a researcher, in supporting early career researcher colleagues, and from experience of shortlisting, interviewing and recruitment processes.

**MSM Divisional Talk: Dr Judy Zolkiewski Biography**

Dr Judy Zolkiewski is a Professor of Marketing at Alliance Manchester Business School, UK. She received her PhD in 1999 from UMIST. Before becoming a full- time academic in 1999 she had considerable industrial experience working for 15 years at Ferranti Computer Systems Ltd. She is an internationally-recognized scholar with research interests focussing on understanding the operation of business-to-business marketing and purchasing, both in the traditional manufacturing and engineering industries and in the evolving business-to- business services sector. She publishes in the leading international journals in her area and is also on the editorial boards of these journals. Professor Zolkiewski's research interests have centred on the application of marketing and management theory in business-to-business markets and the services sector.

**Synopsis:**

“**A Research and Knowledge Transfer Journey - Prof Judy Zolkiewski**”

My research interests are focussed on understanding business markets, relationships and networks both in the traditional manufacturing and engineering industries and in the evolving business-to-business services sector with specific focus on relationship and network dynamics, servitization, strategy and technology. In this talk I will explain my research journey and how I have combined research with knowledge transfer projects with industry and discuss the challenges and opportunities that come with and from engaging in knowledge transfer.

**Academic Careers, Dr Antoinette McKane**

As a researcher developer, I am passionate about the importance of community building among researchers and strongly believe that shaping a supportive and inclusive research culture starts at postgraduate level. I find it hugely rewarding to support postgraduate researchers (PGRs) in developing the varied range professional skills and personal attributes required to navigate their doctoral research journey and to take the first steps on their chosen career path beyond the PhD.

Before joining the University of Manchester Researcher Development team in January 2024, I worked as a researcher developer at the University of Liverpool

(where, incidentally, I completed my own PhD). At Liverpool, I played a key role in the design and delivery of a comprehensive new PGR development programme and the establishment of a new peer-led doctoral development network.

Prior to this, I held a permanent lectureship at Liverpool Hope University for several years, in which time I developed a strong interest and significant expertise in facilitating peer-led learning and in the process of co- designing academic programmes with students, educators, researchers and industry partners.

I am a Fellow of the Higher Education Academy (FHEA), committed to continuously developing my own practice through learning about tools and techniques that I can employ in the design and delivery of researcher development sessions and resources. I am open to opportunities to collaborate, consult, and contribute to the wider researcher development community.

**Appendix**

**Year 1 Abstracts**

**Year 2 Papers**

Abstract - Yuran Chen

A growing literature highlights the importance of disclosure on intangible assets and innova7on, calling for studies to measure and inves7gate innova7ng organisa7ons’ disclosure strategies. One of the key economic characteris7cs that diﬀeren7ate innova7on from other types of assets is referred to as par7al excludability, where innova7on owners are not able to fully limit other ﬁrms from taking advantage of the innova7on. This lack of exclusivity may poten7ally incen7vize a ﬁrm to engage in impression management by freeriding on news of innova7on development of other ﬁrms without substan7ve eﬀorts of their own. This study exploits the booming space economy and the innova7on in the space industry as research seCng to examine corporate disclosure and investor valua7on of innova7on and intangibles. Using textual analysis of the 10-K reports pertaining to S&P 500 ﬁrms from 2010 to 2024, the study explores whether and how the hype in space ac7vi7es leads ﬁrms to adjust their disclosure strategies, and if such impression management through space-related disclosures can inﬂuence ﬁrms’ capital market valua7on. This study mul7ple contribu7ons to the literature. First, it contributes to the literature on innova7on and intangible assets by examining how industry-wide technological advancements impact ﬁrm-level disclosure strategies, par7cularly in industries where par7al exclusivity and intellectual property costs are high. Second, this study extends the growing literature of space accoun7ng by introducing a quan7ta7ve approach to analyzing disclosures within the space sector. Finally, this study sheds light on the role of media coverage in shaping investor sen7ment and market reac7ons, oﬀering new insights into the integra7on of non-ﬁnancial intangible disclosures with ﬁnancial informa7on.

Year 1 – Abstract – Finance & Accounting - PhD Lun Hai 11578046

Hybrid Foundation Time Series Models for Multi-Factor Stock Returns Prediction

Stock returns emerge from a multifaceted interplay of firm-specific attributes, macroeconomic dynamics, and investor sentiment, yet traditional linear factor models capture only a fraction of this complexity. Meanwhile, large-scale transformer-based architectures— often called foundation models—excel at learning long-range dependencies in sequential data but seldom embed domain-specific financial insights. To address these limitations, this proposal introduces a hybrid framework that integrates automated factor discovery methods with a foundation time-series model. The hybrid approach first leverages high-dimensional searches to identify latent factors that systematically explain cross-sectional stock returns under theoretical constraints. These economically grounded factors are then fused with the broad representational power of transformer-based deep networks, enabling rich, non-linear interactions and regime-dependent relationships to be learned. By uniting factor-based modeling and deep sequence architectures, the framework aims to achieve superior predictive accuracy, enhanced interpretability regarding latent economic drivers, and robust out-of- sample generalization across different sectors and market conditions. This research stands to benefit both scholars and practitioners by offering a replicable workflow that situates advanced machine learning methods firmly within financial theory, ultimately uncovering deeper insights into the forces governing equity return predictability.

**DOES GOVERNMENT CROWD-OUT PRIVATE VENTURE CAPITALISTS? EVIDENCE FROM A FRENCH POLICY REFORM**

|  |  |  |
| --- | --- | --- |
| **Fábio M. V. Sousa** | **Amedeo De Cesari** | **Konstantinos Stathopoulos** |
| PhD Student (First Year) | Chair in Finance | Chair in Accounting and Finance |

March 21, 2025

**ABSTRACT**

The Draghi (2024) Report placed competitiveness at the heart of the European Union (EU) policy debate, describing the current stagnation as an “existential challenge” and calling for urgent reforms to sustain the bloc’s main policies – including its social model, environmental ambitions, and the development of a technologically advanced defence industry. A key concern is Europe’s innovation gap with the US and China. For decades, the EU has sought to catch up in entrepreneurship and technological leadership, aiming to foster companies on par with Apple, Alphabet, and NVIDIA. Innovation, a key driver of economic growth in Schumpeter’s Creative Destruction framework, is central to this challenge.

The ﬁnance literature has established that Venture Capital (VC) plays a crucial role in fostering competitive and innovative start-ups. A strong VC industry can be a powerful engine for economic growth, yet Europe’s VC sector remains underpowered. Recent studies by the EIB (2022), OECD (Berger, Dechezleprêtre, and Fadic, 2024), and IMF (Arnold, Claveres, and Frie, 2024) suggest that Government Venture Capital (GVC) programmes could help strengthen the European VC ecosystem.

However, a burning question remains among policymakers and academics: does GVC crowd-out Private VC (PVC) investment? For example, the French Court of Auditors has raised concerns about potential crowding-out eﬀects, while the OECD highlights a lack of conclusive evidence. Academic literature on the topic is scarce, often limited by data constraints and lacking causality. Brander, Du, and Hellmann (2014) explicitly call for quasi-natural experiments to provide more robust and precise causal identiﬁcation in GVC research. Crowding-out eﬀects risk diverting public funds from more productive uses and limiting the industry’s contribution to growth and jobs by restricting the number of attractive investment opportunities available to PVC.

This study examines the impact of Bpifrance’s (*Banque publique d'investissement*) creation on PVC investment in France, thus pioneering the use of a quasi-natural experiment in this ﬁeld. Our dataset includes transactions from 70,310 investors. A ﬁrst key challenge is categorising investors as either GVC or PVC, given the absence of a reliable classiﬁcation database. Inspired by recent ﬁnancial literature (Spaenjers and Steiner, 2024; Hong and Wei, 2025), we employ ChatGPT-4o to systematically classify investors.

Our study follows a comparative case study approach, where diﬀerence-in-diﬀerences and synthetic control methods are widely used (Arkhangelsky et al., 2021). A major challenge in such studies is constructing a credible counterfactual composed by untreated units that closely resemble the treated unit. To enhance robustness and eliminate ambiguity, we employ data-driven methods.

Our ﬁndings contribute to the broader policy debate on GVC eﬀectiveness by providing causal evidence and, thus, addressing considerable gaps in prior studies. The results oﬀer valuable insights for policymakers aiming to strengthen innovation ecosystems through targeted ﬁnancial interventions, while minimising potential market distortions.

Keywords: Government Venture Capital, Private Venture Capital, Bpifrance, Synthetic Controls, Diﬀerence-in- Diﬀerences.

*JEL (G24, G38, O57)*

1

Dissecting the Equity Term Structure: Cross-Sectional Dynamics of Dividend Strips

A central question in asset pricing is how to discount future cash ﬂows to derive today’s asset values. While the majority of the literature focuses on the aggregate market, recent studies emphasize the importance of examining the individual components of future dividends—dividend strips—at diﬀerent maturities. Van Binsbergen et al. (2012) ﬁrst estimate the prices of S&P 500 dividend strips and show that short-term dividend claims exhibit higher expected returns, volatilities, and Sharpe ratios than the aggregate index, contradicting predictions from leading asset pricing models.

My research extends the literature by shifting attention to the cross-section of dividend strips. I investigate whether short- and long-term dividend claims contribute diﬀerently to equity factor premia. This question is motivated by Gormsen and Lazarus (2023), who argue that the returns to major equity factors (e.g., value, proﬁtability) can be explained by a premium on near-term cash ﬂows, as the long legs of these portfolios consist of ﬁrms with shorter cash-ﬂow duration. However, their analysis relies on a relatively narrow dataset of 190 ﬁrms with single-stock dividend futures between 2010 and 2019. To address this limitation, I propose using option-implied dividend strips for thousands of U.S. ﬁrms from 1996 onwards, thereby enabling a broader and more granular empirical investigation that spans several market cycles.

The identiﬁcation of dividend strips from option prices hinges on put-call parity. However, a key challenge is that most U.S. equity options are American-style and embed early exercise premia, which causes put-call parity to fail in practice. This creates a fundamental problem for identifying dividend strip prices. Further, most option pricing models—such as the binomial tree—assume known dividend payments, which contradicts the aim of recovering dividend values from option prices. At this stage, I have not yet determined the best way to adjust for early exercise premia, making it a central unresolved challenge in the project.

This research provides new insights into the term structure of risk premia and the horizon-speciﬁc behavior of the stochastic discount factor (SDF). In addition, the framework can be used to explore emerging asset pricing topics such as carbon transition risk. If brown ﬁrms are more exposed to long-term policy changes, the equity premium on “brown” portfolios should load more heavily on long-term dividend claims—a hypothesis testable with this approach. Besides, the ﬁndings will inform both theory and practice by highlighting the maturity composition of cash ﬂows behind risk premia and helping investors align portfolios with speciﬁc horizon-based objectives.

**Abstract**

This study examines why and how actors from diﬀerent ﬁelds collaborate to shape the sustainability reporting ﬁeld. Drawing on the evolution of the voluntary Taskforce on Nature-related Financial Disclosures (TNFD), the paper attempts to reveal the relation dynamics during three interrelated phases: preparatory, design and adoption. It puts emphasis on addressing how core tensions were raised and strategies employed by the TNFD at each stage to mobilise a wide range of supporters as well as accommodate competing interest groups who seek to promote their own positions in speciﬁc directions (Gross and Zilber, 2020). While previous reporting initiatives are primarily sector-based, the TNFD adopts an innovative market-led approach that involves a diﬀerent set of stakeholders in its development, including governments, non-governmental organisations, private ﬁnancial institutions, corporations and accounting service providers. The story of the TNFD’s formation extends understanding of how a voluntary reporting recommendation gains legitimacy and the behind-the- scenes interplay of actors. Although the TNFD received great support and endorsements in a relatively short time, we have little understanding of its formation. It also explores how a delicate balance between ambiguity and clariﬁcation has been achieved. Prior research suggests that the emergence of a new institution could beneﬁt from ﬂexibility and ambiguity (O’Sullivan and O’Dwyer, 2015; Baudot, 2014; Fernández Chulián et al., 2024), allowing diverse actors to reach a consensus on a broad level. However, institutions must provide clarity (Wijen, 2014; O’Dwyer et al., 2024) at the same time to support adoption. This paper investigates how the TNFD ensures broad participation without undermining its legitimacy and uniqueness. In general, considering the uniqueness of the TNFD and the massive attention it has received, it deserves in-depth academic scrutiny.

To achieve the research objectives, a single qualitative case study is used for a deeper and richer understanding of context-speciﬁc information (Dyer and Wilkins, 1991; Van Burg et al., 2020). A wide range of documents were the primary data sources of this study, including the TNFD reports, discussion papers, comment letters, press releases, government announcements and webinar transcripts. Firstly, they are often easily retrieved online from oﬃcial websites (Morgan, 2022). This makes it particularly advantageous in research contexts like the TNFD, where extensive publicly available documents exist to support the study of institutional processes. Additionally, documentary records allow researchers to trace the development of frameworks over time and provide valuable insights into how priorities, purposes, and strategies have shifted throughout the TNFD’s evolution. While this research made signiﬁcant eﬀorts to cover viewpoints from key actors involved in the TNFD process, it is extremely diﬃcult to fully unveil power struggles and informal compromises. Triangulating across multiple sources is used to mitigate the potential bias caused by the absence of direct access to internal members (Flick, 2004).

Sisi Wu

**Year 1 – Abstract – AMBS – PhD**

***Forecasting News Sentiment from Implied Volatility Surfaces Using Deep Learning: A Novel Market Signal Extraction Framework***

Implied volatility (IV) encapsulates real-time, risk-neutral expectations of underlying asset returns across option maturities, thereby reflecting market sentiment. Parallel to this, news sentiment (NS)

captures prevailing investor attitudes and has demonstrable effects on asset pricing, particularly in hard-to- value stocks [(Baker & Wurgler, 2006).](https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1540-6261.2006.00885.x) While both IV and NS are forward-looking indicators, their dynamic interplay remains underexplored.

Recent developments in machine learning underscore IV’s predictive value. [Bali et al., 2023](https://academic.oup.com/rfs/article/36/9/3548/7056660) identify IV as a key feature for forecasting option returns using high-dimensional financial data. Building on this, [Kelly et al. (2023)](https://papers.ssrn.com/abstract%3D4531181) demonstrate that implied volatility surface (IVS), when processed through convolutional neural networks (CNNs), contains rich spatial information predictive of future stock returns.

This study advances existing literature in three ways. First, it leverages CNNs to extract spatial features from the full IVS, rather than relying on simplified measures such as skewness or slope. Second, it proposes a novel forecasting framework that uses IVS to predict NS, offering new insights into the causal direction between these market indicators. To enhance interpretability, SHAP values are employed to identify the specific option maturities and moneyness levels that contribute most to forecast accuracy. Third, inspired by [Białkowski et al., 2022,](https://linkinghub.elsevier.com/retrieve/pii/S0304405X21001938) we explore the relationship between S&P 500 IV and U.S. policy sentiment, culminating in the design of a sentiment-driven trading strategy to assess the economic value of the forecasted NS.

Overall, this research contributes to the intersection of behavioural finance, machine learning, and market microstructure by introducing a novel methodology for extracting actionable sentiment signals from high-dimensional option data.

**References:**

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volatility surfaces. SSRN Electronic Journal.

**Yuzhou Zhang**

This research proposal aims to explore the nuanced dynamics of organizational reactivity to performance measurement systems, specifically investigating whether indirect forms of reactivity can exert a more profound influence than direct responses, potentially leading to unintended and detrimental outcomes. While existing scholarship acknowledges both direct and indirect reactivity—the propensity of organizations to alter behavior due to evaluation—the comparative strength and complex interplay of these forms, particularly when driven by pervasive calculative infrastructures, remain underexplored. This study addresses this gap by examining a critical case where the implementation of standardization measures, encompassing categorization, metricization, and tracing work, may have inadvertently undermined core organizational values and performance.

The research will employ a qualitative single-case study methodology, conducting in-depth interviews within a prominent Chinese space company specializing in satellite manufacturing. This context provides a unique opportunity to observe the impact of calculative infrastructures in a high-stakes, precision-driven environment. The study will adopt a "before and after" analytical framework to differentiate the effects of direct and indirect reactivity. Prior to the introduction of extensive metricization, frontline workers in the company exhibited a strong emotional attachment to the satellites they built, primarily ensuring quality through rigorous testing and accumulated experience. This period represents a baseline where intrinsic motivation and tacit knowledge were central to quality assurance.

Following the implementation of new performance and quality measures, involving detailed categorization, metricization, and tracing work, the organization experienced significant behavioral shifts. Direct reactivity might manifest as immediate compliance with the new standardized procedures and numerical targets. However, this research hypothesizes that indirect reactivity will prove to be a more dominant force, leading to unforeseen negative consequences. Specifically, the standardization efforts, by strictly adhering to prescribed metrics and reducing reliance on experiential testing, have inadvertently diminished the frontline workers' emotional attachment to the satellites. This shift from a craftsmanship-oriented approach to a metric-driven one is anticipated to have a counterintuitive effect: a decline in overall quality, despite the ostensible aim of improvement through standardization. The "before and after" comparison will be instrumental in isolating how the introduction of these calculative infrastructures mediated a deeper, systemic change in employee engagement and quality assurance practices, revealing the potentially surprising strength of indirect reactive pathways. This study seeks to contribute to the literature on commensuration and performance evaluation by illustrating how the pursuit of quantifiable control can inadvertently erode critical human elements, leading to a paradoxical degradation of performance.

**Financialization of real estate in China**

Financialization can be broadly defined as a pattern of accumulation in which profit making occurs increasingly through financial channels rather than through trade and commodity production (Krippner, 2005). During the transformation of China’s economic system in the past half century, housing and land transformed from non-traded to traded products and then shifting to objects of investment (Chen and Wu, 2022). Even if the socialist distribution system has been abandoned in favour of a market economy, China's special national conditions and socialist nature make its economy more dependent on government macro-control and policy changes to a certain extent (Zhao, 2009). Moreover, real estate companies that accustomed to high leverage and high debt for years have been faced with market volatility and government policy adjustments, which have greatly challenged their solvency (Ortizs- molina, 2007) and even led to bankruptcy. At present, financialization has been deeply studied by critical accounting researchers from multiple perspectives, such as governance reforms (Modell and Yang, 2018), accounting standard setting ([Müller, 2014;](https://www-sciencedirect-com.bris.idm.oclc.org/science/article/pii/S1045235424000388#b0595) Chahed, 2021), and sustainable development (Chua and Fiedler, 2023*；*Kuokkanen, 2024). However, there are still relatively few studies on real estate financialization (Wu, 2021), especially exploring the drivers of the formation of the financialization trajectory in a specific national context. Therefore, the purpose of the research is to explore the driving factors and their interactions that influence the trajectory of real estate financialization in China. Facing the potential risks posed by the financialization process, it is necessary for the managers of real estate enterprises to adopt accounting tools such as fair value accounting and budgeting reasonably and effectively. Thus, this research also investigates how real estate corporates use accounting tools to cope with the process of real estate financialization in China.

Qualitative research methods are used to understand the views and experiences of participants for data collection and analysis. The research emphasizes the subjectivity and situational dependence of the social phenomenon of real estate financialization based on interpretivism. Semi-structured interviews with financial directors and owners of Chinese real estate firms will be conducted, as well as documentary research to collect data through a number of publicly available Chinese government reports and policy documents. Since the trajectory of financialization of real estate and the use of accounting tools by firms in China are influenced by policies, market expectations and corporate strategies, the researcher need to iterate between data and theories through abduction in order to construct a reasonable explanatory framework. The research aims to expand the role of accounting in relation to financialization, and make contributions to the accounting research of real estate financialization in China. At the same time, it is intended to confer context-specific meaning to the development of financialization in accounting research (Model and Yang, 2017). China's political and economic environment provides a unique and interesting background for exploring the process of real estate financialization and the responses of real estate firms.

**Convergence of Innovation Silos: A Systemic Inquiry into Quadruple Helix Collaboration in Emerging Economies**

Firman Azra (10216715) – 1st Year PhD Science, Technology & Innovation Policy

Supervisors: Prof. Dr. Khaleel Malik

Dr. Mabel Sanchez-Barrioluengo

Over the last decade, there has been a signiﬁcant rise of interest in aligning innovation with sustainable development goals to address the “Grand Challenges”. The Quadruple Helix (QH) model conceptualizes knowledge and innovation co-creation through engagement with four strands of stakeholders that consist of academics, government, industry, and civil society, and hold promises to synergize innovation with sustainability. However, the current knowledge oﬀers a limited understanding of the contextual factors and mechanisms of the QH model that can support the proliferation of sustainable innovation. Furthermore, literature is mostly focused on developed countries which leaves the QH model in developing countries understudied. The foundational assumption in Carayannis and Campbell's (2009) seminal work emphasizes balanced multi-actor dynamics and open interactions, which are crucial for multi-stakeholder knowledge co- creation under the QH model. This assumption raises important issues of power imbalances and diﬀerent values between the stakeholders as highlighted by Nguyen and Marques (2022).

At the theoretical level this research is drawn from Carlsson et al. (2002) works on the system theory approach which describes a set of interrelated components, relationships, and attributes as dimensions for an innovation system. This objective is to uncover the interplay between contextual factors, mechanisms, and dynamics between the QH actors as well as the impact on wider society. Methodologically, it will use qualitative methods by using semi-structured interviews for primary data collection methods. This choice reﬂects the research needs to explain the socially constructed and context-dependent nature of multi-stakeholder collaboration dynamics by probing into diﬀerent stakeholder perceptions and interpretations which are critical to understand the nuances of QH collaboration in emerging economies. The study will focuses on Indonesia as a case of emerging country that undergoing signiﬁcant policy development in recent decade such as reforms in research and innovation policy through establishment of National Research Innovation Agency as well as reform in higher education policy that reshape the role of universities and their engagement with other QH actors.

Several challenges are anticipated in the research which includes diﬃculties in securing interviews from oﬃcials, limited access to secondary data, and conceptual ambiguity in key concepts such as contextual factors and relationship dynamics might pose challenges for the data collection and analysis process.

The research contributions are twofold. From a theoretical perspective, the thesis will contribute to system theory by illuminating the application of system theory in the QH model. From a practitioner's viewpoint the research will contribute to the development of best practice in QH model engagement in the context of a developing country. This contribution is expected to improve the societal and/or economic impact of knowledge and/or innovation from the QH model application.

Abstract - Yihan Deng

This research investigates how nascent entrepreneurs, those in the early, often informal stages of starting a business (Reynolds and White, 1997), adopt and integrate artificial intelligence (AI) tools into their entrepreneurial practices. While AI is widely regarded as one of the most disruptive technologies of the 21st century (Ahmad & Ghapar, 2019), current research has largely focused on its adoption in large firms (McElheran et al., 2024). In contrast, there is limited understanding of how nascent entrepreneurs, such as student-led or first-time ventures, adopt and integrate with AI technologies. This gap is significant given the potential of AI to reduce operational burdens and improve competitive advantages for nascent entrepreneurs.

This topic is both timely and significant. The small business sector plays a crucial role in economic growth, job creation, and innovation (Delmar & Davidsson, 2000). Within this sector, nascent entrepreneurs represent a vital yet often overlooked group. Unlike established firms, they typically operate without extensive capital, technical expertise, or institutional support (Liao, Welsch & Moutray, 2008). What makes this group particularly interesting is the range of personal factors that can influence their adoption of AI, including their age, early life experiences, career aspirations, and even non-business exposure to AI, such as using AI tools in daily life contexts. These cross-domain influences may shape how they perceive the usefulness, legitimacy, or risks of AI in entrepreneurial settings.

This research will be conducted as a three-paper thesis. The first two papers will be empirical studies, using semi- structured interviews and a qualitative case study to understand how nascent entrepreneurs adopt AI tools practically. The final paper will synthesise insights from the empirical work to develop a grounded theoretical model of AI adoption and integration in nascent ventures. Methodologically, interviews with founders of student-led or early-stage ventures will provide rich data on how AI tools are used, adapted, or even resisted. Insights from the interviews will inform the selection and design of the second stage: in-depth case studies of selected ventures. These case studies will allow for a more holistic and longitudinal view of how AI tools are integrated into businesses, capturing the complexity and evolving nature of early-stage ventures, where formal processes may be absent, and learning is highly iterative. The final stage synthesises findings from the interviews and case studies to develop a grounded theoretical framework that explains how nascent entrepreneurs adopt and integrate AI tools.

Challenges include identifying appropriate participants who actively engage with AI in meaningful ways and managing the diversity of AI tools used across different contexts. In addition, the pace of AI development means that tools and applications may evolve during the study, requiring flexible and adaptive research design. These challenges are being addressed through purposive sampling, iterative data collection, and case selection strategies that allow for variation while maintaining analytical depth.

The study aims to extend the existing literature by providing new empirical and theoretical insights into AI adoption within the field of nascent entrepreneurship, an area that remains significantly underexplored. In addition to its academic contribution, the work is expected to assist startup mentors and incubators in better understanding how to support early-stage entrepreneurs utilising AI. Most importantly, this research will empower nascent entrepreneurs to confidently adopt and effectively apply AI tools in their ventures.

**Abstract for AMBS Doctoral Conference 2025**

Title: FinTech in Resource-Constrained Economies: Bridging Innovation, Inclusion, and Global Policy Learning

Author: Muhammad Danish Faisal

Division: Innovation, Management and Policy

Supervisors: Dr. Khaleel Malik & Dr. Adrien Querbes

Financial technology (FinTech), especially if we talk about payment systems, has transformed global economies by enabling swift digital transactions, reducing costs, and fostering ﬁnancial inclusion. More so, with the induction of Emerging Digital Technologies (EDT), a category comprising sophisticated and cutting-edge technologies like Artiﬁcial Intelligence, Blockchain and mobile money, it has become easier to process transactions worth billions of dollars without hassle. According to the World Bank (2023) report, economies with high penetration of ﬁnancial technology have seen a rise of 6-8% in GDP over the years. However, this trend is not visible everywhere and has not eliminated the signiﬁcant access inequality. Over 1.7 billion people worldwide lack formal banking access; 70% of them reside in low-resource countries, including South Asia and Sub-Saharan Africa, where infrastructure is lacking (GSMA, 2023).

Ironically, these constrained economic conditions have encouraged innovations in FinTech. Firms like M-Pesa in Kenya now serve 80% of Kenyan adults using the mobile money app M-Pesa (Tiwasing, Addae, Naab, & Zana Naab, 2024). Similarly, in India, despite internet failures in rural regions, the Uniﬁed Payments Interface (UPI) processes over 15 billion monthly transactions (Cornelli, Frost, Gambacorta, Sinha, & Townsend, 2024). Despite these high numbers and success, traditional innovation management research often overlooks these accomplishments since it disproportionately focuses on high-income countries. This oversight limits the possibility of cross-context learning.

This PhD research seeks to rebalance this narrative by examining how payment technologies evolve under constraints and how these innovations can inform both policy and practice in developed and developing economies. The research consists of three papers, The ﬁrst paper will be a systematic literature review that will act as a guide for a layman to understand what technologies are being used and what they do and then go on to compare payment infrastructures in the UK, Pakistan, and India, analysing how technologies adapt to disparities and varying challenges. This will illustrate how context plays a role in the design of technology by mapping infrastructural gaps, such as the low mobile broadband coverage in Pakistan compared to the high coverage in the United Kingdom. This will be followed by an empirical paper investigating ﬁrms like JazzCash and EasyPaisa in Pakistan. This paper will include qualitative semi-structured interviews with executives of these ﬁrms to understand how they overcome regulatory and infrastructural barriers using a business model innovation perspective. The last paper in this thesis will look at regulatory policies in developing countries including Pakistan's RAAST by the State Bank of Pakistan, India's regulatory sandbox concept and Nigeria's public-private partnerships. This work will provide insights that could prove to be useful for the ﬁnancial innovation ecosystem of the UK via adaptive, experimental policymaking through an analysis of the cost-eﬀectiveness and eﬃciency of these models.

Overall, this research aims to show how ideas from resource-constrained countries may provide useful insights for worldwide FinTech plans by closing the gap between theory and reality, hence promoting more equitable ﬁnancial systems.

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**Abstract**

**Proposed Title:** Home Country Institutions and the Internationalization-Environmental Performance Relationship: A Meta-Analytic Review

**Submitter:** Weifeng Lin; **Current registration:** Ph.D.(1st year) in Business & Management

**Supervisors:** Professor Axèle Giroud & Professor Renfei Gao

1. **Introduction**

Multinational enterprises (MNEs) are both contributors to and potential mitigators of global environmental degradation. Their cross-border activities often involve significant carbon footprints, yet their global scale, access to capital, and advanced technologies position them to lead in sustainable transformation. A growing number of MNEs are adopting environmental strategies, partly in response to increasing stakeholder pressure and global sustainability norms. However, the relationship between internationalization and environmental performance (I–EP) remains theoretically and empirically unsettled. Some studies suggest that internationalization enhances environmental outcomes by diffusing green innovation and raising accountability through global exposure. Others argue it enables environmental arbitrage,shifting polluting activities to weaker regulatory environments. Still others find no consistent pattern or even non-linear effects. These inconsistencies highlight the lack of a comprehensive framework to systematically examine the internationalization-environmental performance (I-EP) nexus and indicate MNE’s behaviors are ultimately the result of both institutional pressures and firm-specific conditions.

The home-country context plays a foundational role in international business (IB) research, as it shapes the institutional environment in which firms compete, develop capabilities, and mobilize resources for international expansion. These domestic institutional conditions influence firms' comparative advantages, the impact of country-of-origin perceptions, and their strategic decision- making, particularly in how they learn, adapt, and respond to foreign market challenges. Despite its importance, relatively few studies have investigated how home-country institutions moderate the relationship between internationalization and environmental performance (I–EP). Institutional environments consist of both formal components, such as economic systems, political governance, and legal frameworks, and informal elements, including cultural values, societal norms, and the degree of cultural distance between home and host countries. However, few studies have systematically analyzed how these multiple institutional dimensions jointly shape environmental performance across diverse national contexts, limiting the generalizability of existing findings.

1. **Methodology & Challenge**

To clarify these theoretical inconsistencies, this research adopts a meta-analytic approach, drawing on empirical findings from management, international economics, and environmental policy literatures. By synthesizing empirical results (e.g. effect size and sample size) from diverse national contexts, this study systematically examines how home country institutions influence the I–EP nexus. Given the technical complexity of meta-analysis and limited formal training resources available, the researcher is acquiring these skills through self-guided learning and methodological literature, ensuring both rigor and transparency in the analytical process.

1. **Potential Contributions**

The contributions of this study are threefold. First, it extends internationalization theory by identifying home country institutions as key boundary conditions that shape sustainability outcomes, thus helping to explain inconsistent findings in prior work. Second, it enriches institution-based perspectives by clarifying the distinct and combined roles of formal institutions (e.g., rule of law, corruption control, economic freedom) and informal institutions (e.g., cultural norms and ethical expectations) in environmental strategy. Third, the study offers timely insights for both scholars and policymakers, emphasizing that effective corporate environmental performance cannot be fully understood without considering the institutional DNA from which firms internationalize.

Student ID:11159201\_Yangtong Liu

#### What drives global innovation?

**Abstract**

Innovation encompasses a company’s capacity to generate ‘novelty’ via product or process advancements, including the development and dissemination of groundbreaking technology (Thakur and Sharma, 2025). More and more companies, especially those in high-tech industries that rely on technology to generate high profits, regard global innovation as an important strategy for the development of companies in an international context. In recent years, research on innovation has increasingly emphasized studying innovation against the background of changing relationships in international production organizations (Marina et al., 2020). The objective of the multinational innovation is to acquire more resources, technologies, and market opportunities to improve the innovative capacity and competitiveness of firms (Abassi and El Elj, 2022; Marina et al., 2020). The existing literature on global innovation suggests various factors for affecting an company’s innovation performance, such as cross-border investments by exporting firms (Salomon, 2006; Valacchi et al., 2021), diversity of innovators or employers (Foley and Kerr, 2013), inventing partner countries (Berry, 2020), ocation for subsidiaries or sub-research institutes(Almeida and Phene, 2004; She et al., 2023), the construction of competitive strategies (Zhang and Guan, 2019), the composition of the parent company's equity structure (Almodóvar et al., 2021), and patent application strategies (Kim and Lee, 2024). From an external perspective, policy factors in different countries also need to be included in the framework for formulating strategies. At the same time, companies hope to enhance their innovation performance through global innovation while reducing the negative impact of knowledge spillovers on their profitability (Kotabe et al., 2007).

Considering facts above, the direction and extent of global innovation are affected by many complex factors. In order to formulate a strategy that accurately achieves the company’s objectives, it is essential to research factors affecting global innovation and the impact mechanism behind it.Although the research on determinants of global innovation keeps increasing, the ascent of emerging economies, advancements in digitalisation including artificial intelligence, shifts in policy and geopolitical dynamics (Daitian et al., 2022), the emergence of new actors in global production and information dissemination (Marina et al., 2020), and the imperative for sustainable innovation (Wang et al., 2023) persist in generating novel research demands for this subject. In one word, research gap exists. Jayasekara and Tan (2024) points out that considering the fact that the cooperation of innovation becomes a trend, it is worth to learn the impact of different social fragmentation of innovation teams on global innavation.

This research will make contributions on the following aspects. First, it will fill the theoretical emptiness of the determinants global innovation based on relevant theory, like knowledge transfer theory, institutional distance theory, etc. Second, novel empirical evidence about the influence of institutional distance will be provided. The mechanism of it will be learned too. Third, the impact of various diversity in innovation teams will be analyzed, including knowledge, cultural, geographical diversity. The research will be helpful for both policy makers and company managers.

**Abstract: Scaling Community Energy through Entrepreneurship Governance and Social Innovation**

**Abdul Wahab Malik**

**Supervisors: Prof. Michael Hodson, Dr. Suneel Kunamaneni and Dr Aarti Krishnan**

Community energy (CE) has appeared as a transformative model within the global energy landscape by enabling local actors to take possession of renewable energy production and distribution. An analytical entrepreneurial challenge lies at the core of these initiatives: building viable, scalable, and sustainable business models under resource-constrained and institutionally diverse environments. CE projects have ongoing challenges with funding, innovation, and operational resilience, despite their ability to democratise energy access and embrace environmental resilience.

This study conceptualises CE through the perspective of sustainable entrepreneurship, emphasising the ways in which entrepreneurial action influences the growth and long-term viability of such initiatives. Sustainable business practices go beyond conventional profitability optimisation to include environmental preservation and social value creation (Schaltegger & Wagner, 2011). CE includes grassroots enterprises, cooperative ownership frameworks, and hybrid finance techniques including crowdsourcing and impact investing. Entrepreneurs usually have to deal with fragmented marketplaces, technical difficulties, and shifting stakeholder expectations without much institutional or financial support. The primary focus of this investigation is on how entrepreneurs in the CE sector use business model innovation to overcome structural issues. These include engagement with national energy networks, decentralised production coordination, and community governance.

This study highlights the wider institutional context in which these programs operate, though the entrepreneurial part is the primary focus. The Political Settlement Framework (Khan, 2010; Hickey, 2013) is used to analyse how political institutions and regulatory frameworks can either help or hinder entrepreneurship in the energy sector. It has been documented that the feasibility, strategy, and risk profile of entrepreneurial actors in CE are influenced by policy volatility, centralised grid control, and unequal incentive systems. This study then integrates Social Innovation Theory to completely understand the importance of civic engagement, trust- building, and cooperative engagement (Moulaert et al., 2013; Seyfang & Smith, 2007). Collaborative governance structures, grassroots mobilisation, and social capital are necessary to overcome institutional inertia and legitimacy barriers.

The study provides a thorough framework for conceptualising CE as an entrepreneurial phenomenon influenced by social and political structures through this multidisciplinary perspective. It contributes new insights for scholars, policymakers, and practitioners seeking to foster resilient, inclusive, and sustainable energy transitions through innovative business models and community-driven engagement.

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**Year 1 – Abstract – IMP – MPhil Tianqi Yang**

**Abstract**

This research examines how institutional governance structures in liberal democracies create a “governance trap,” constraining managers from realizing organizational purpose by perpetuating inefficiencies in balancing economic efficiency with equity. The study seeks to advance strategic management scholarship by identifying pathways to reconcile these competing priorities through a property rights lens, focusing on infrastructure permitting processes as a critical site of institutional contestation.

The problem arises from the theorem of Coase’s paper – the problem of social costs, where he articulated the trade-offs between wealth creation and externalities internalisation – *“What has to be decided is whether the gain from preventing the harm is greater than the loss which would be suffered elsewhere as a result of stopping the action which produces the harm”.* This challenge has trigged the unresolved debate in management scholarships about corporate governance between shareholder primacy and stakeholder oriented. Shareholder primacy advocates business objective is to maximise profit while obeying rules, laws, and social norms of one’s society. Stakeholder theorem promotes a more inclusive approach to value creation, deeming “anyone who can affect or be affected by the objective of the firm” should all be considered as stakeholders, the purpose of the firm is to create value for all stakeholders. While stakeholder theory addresses ethical gaps in shareholder-centric models, it introduces ambiguities in performance measurement, fostering opportunistic behavior and agency costs as managers prioritize symbolic environmental/social gestures over substantive investments. A critical obstacle to resolving this debate is the lack of empirical data on how governance rules shape stakeholder cooperation and welfare outcomes.

This study decomposes corporate governance from a property rights theory perspective. By analysing the delegation of rights to claim income and rights to influence resource allocation among the economic actors, this study focuses on institutional structure redistribute decision-making authority and redefine organisational boundaries. To address the question, this study will examine infrastructure permitting processwhere institutional mandates for stakeholder enfranchisement collide with managerial struggles to sustain cooperation at scale. The topic is critical as liberal democracies increasingly adopt regulatory frameworks that expand stakeholder rights (e.g., the UK Planning Act 2008, EU Green Deal, US NEPA reforms), yet fail to resolve escalating project delays, costs, and contested outcomes. These “wicked problems” reflect a systemic failure to align organisational purpose with evolving societal expectations. Recently, the shift in planning policy across different regions including the UK, EU, and US motivates this study to ground in the institutional environment and its reform, and how the reform in the means of resource allocation and decision rights allocation for further wealth creation and distribution. The analysis on how legislative shifts redefine organizational boundaries and redistribute decision-making authority, creating new constraints and opportunities for managers. The study positions itself at the intersection of stakeholder theory, organisational purpose, and organisational economics literatures.

Methodologically, the study undertakes case study approach to analyse the UK Planning Act 2008 about how rights allocations incentivize or deter stakeholder cooperation. Second, it undertakes comparative policy analysis across the UK, EU, and US to identify patterns in how liberal democracies recalibrate property rights in response to environmental and social pressures whilst sustain economic value creation. This design enables both deep contextual insights and generalisable conclusions about governance under institutional complexities within the liberal democracies systems.

Anticipated challenges include reconciling divergent stakeholder interpretations of “value creation” and navigating data scarcity in cross-jurisdictional policy analysis. However, the property rights lens offers a robust framework to systematically decode the relational dynamics between rules, resource allocation, and organisational outcomes.

This research importance is for theory and practice. It aims at advancing stakeholder theory of governance by empirically testing the institutional framework that grant stakeholder voice and on its outcome at reconciling efficiency and equity. Practically, it provides actionable insights for policymakers designing adaptive regulatory frameworks and for managers seeking to align strategic choices with legislative realities. By illuminating how governance structures shape the viability of profit-social purpose balance, the study aims to inform a more sustainable paradigm for business decision-making in contested institutional environments.

1

The impact of smart technologies on production planning and control: implications for sustainable performance in manufacturing

Yober J. Arteaga Irene, PhD Researcher | Tahir Syed, Supervisor | Fahian Huq, Co-supervisor

The global business landscape is undergoing signiﬁcant transformations, and several factors, such as climate change, global competition, and geopolitical tensions [1], make it increasingly more dynamic and uncertain. In light of this, the manufacturing industry faces a pressing need to devise strategies that not only enhance economic competitiveness but also harmonise operations with environmental and social stewardship. In this context, smart technologies (STs) – including Cloud Computing, Artiﬁcial Intelligence, Internet of Things, Digital Twins, and Advanced Data Analytics – are seen as imperative for assisting manufacturers in building dynamic capabilities [2] that allow them to optimise manufacturing operations and drive sustainability. Consequently, this research aims to examine the impact of STs on production planning and control (PPC) and their implications for sustainable performance in manufacturing.

Despite the rapid evolution of STs, the literature reports some initial attempts to examine the impact of these technologies on manufacturing operations. On the one hand, scholars address some applications of STs in some PPC practices, such as demand forecasting [3], production scheduling [4], and maintenance [5]. However, PPC works as an integrated hierarchical system aiming to ensure the coordination of resources, processes, and schedules at three managerial levels: strategic, tactical, and operational, and not in a disaggregated manner. On the other hand, academics mainly focus on the direct eﬀects on some economic performance metrics, such as cost [6] and quality [7]. Nevertheless, performance in sustainable manufacturing is a broader measure that seeks to capture performance in three dimensions: economic, environmental, and social. Accordingly, there is limited empirical research demonstrating how STs can be systematically embedded within PPC systems to yield measurable sustainability outcomes.

Addressing this gap requires a broad and deep investigation into how manufacturers restructure PPC frameworks in response to technological advancements. To achieve this, a multi-method design is adopted to capture the full complexity of the problem [8]. First, survey research will be conducted to gather broad insights from ﬁrms at various stages of STs adoption, identifying key trends and patterns in their impact on PPC strategies and sustainability. The ﬁndings from this stage will then inform the second phase, a multiple case study, which will provide an in-depth qualitative analysis of selected ﬁrms. This sequential design will ensure broad industry understanding and speciﬁc ﬁrm-level insights across the British manufacturing sector. In doing so, particular challenges are expected, such as low response rates, company access, and sensitive ﬁrm-level data access. To address these issues, personalised invitations, conﬁdentiality measures, and advanced data analysis techniques will be employed to ensure the accuracy and reliability of the ﬁndings.

The expected contribution of this research is twofold. Firstly, from a theoretical perspective, this study will be one of the ﬁrst to examine the interplay between STs and PCC and their synergetic eﬀect on sustainability performance. This will be an important contribution to operations management literature as it will further explore the conduit role of STs capability. Secondly, from a practitioner's point of view, this research will provide valuable insights into how high-performing ﬁrms make PPC decisions leveraging STs. Thus, it will inform management decision-making concerning the development of strategies by harnessing STs to optimise PPC practices and sustainability outcomes.

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Revolutionizing Inﬂuencer Marketing: A Bayesian Network Meta-Analysis of Human, AI, and Pet Inﬂuencers on Consumer Decision-Making

Robi Awaluddin, Bryan Lukas, Christian Homburg

Abstract

The rise of AI-generated and pet inﬂuencers has transformed inﬂuencer marketing, yet research on their comparative eﬀectiveness remains scarce. While previous studies have largely focused on human inﬂuencers, there is limited understanding of how diﬀerent types of inﬂuencers—human, AI, and pet— diﬀer in their ability to build consumer trust and drive purchasing behavior. Addressing this gap, this study employs Bayesian Network Meta-Analysis (NMA) to systematically evaluate and compare the eﬀectiveness of these inﬂuencer types.

Beyond individual eﬀectiveness, this research introduces a novel exploration of inﬂuencer pairings, identifying which combinations of inﬂuencers yield the strongest impact on consumer decision-making. Additionally, this study examines how the ranking of these inﬂuencer combinations ﬂuctuates based on moderator variables, such as credibility and authenticity.

This study makes a theoretical contribution by advancing inﬂuencer marketing theory through a Bayesian probabilistic framework, challenging traditional linear models by incorporating networked interdependencies among inﬂuencers. It also extends credibility and authenticity theories by testing how these factors interact across diverse inﬂuencer types. From a practical standpoint, the ﬁndings oﬀer actionable insights for brands and marketers, enabling data-driven inﬂuencer selection strategies that optimize campaign eﬀectiveness based on probabilistic performance rankings.

By applying Bayesian hierarchical modelling, this research provides a robust and ﬂexible analytical approach, oﬀering richer insights than conventional meta-analysis. These ﬁndings enhance both academic understanding and industry practice, bridging theoretical knowledge and marketing strategy development in the evolving digital landscape.

*Keywords: Human, Pet, Artificial Intelligence, Influencer Marketing, Bayesian Network Meta-Analysis*

**Understanding Post-reject on Regret: The Unexplored Path of Technology Rejection Margaret Barbieri**

Information technology (IT) increasingly deﬁnes how people engage in the day-to-day activities of their communities' (Rama Murthy and Mani, 2013), blurring the boundaries between humanity and technology (Elsner, 2025). This sociotechnical link highlights the reality that individual consumer technology decisions shape social participation (Van Dijk, 2020) and inﬂuence identity formation (Carter and Grover, 2015), especially as social services transition to digital-ﬁrst approaches built with advanced technologies (e.g.Gajjar, 2024); Elsner, 2025). Despite the increasing stakes of personal IT choices, little is known about their rejection. Current conceptualizations of IT rejection do not account for deliberate choices made by experienced, technology-competent individuals who reject IT innovations for rational reasons. In that light, this dissertation examines the complex phenomenon of post-rejection regret, deﬁned as a negative emotion arising when individuals who deliberately rejected an innovative technology later imagine how their lives might be better “if only” they had not made that choice. Drawing on the Functional Theory of Counterfactual Thinking, Life Course Theory, and IT Identity, the research explores a paradox: how individuals at the height of their competency may be especially vulnerable to rejecting innovative technologies precisely because of their expertise. Introducing the concept of a "competency trap," where expertise in current sociotechnical systems creates cognitive blind spots that prevent recognition of transformative IT innovations, this dissertation seeks to uncover post- rejection outcomes regarding disruptive innovations like smartphones, which evolve from optional conveniences to essential tools. The research addresses two overarching questions: *How does post-rejection regret shape the technological trajectories of individuals who are at their peak competency when they reject innovative technologies? What are the long-term participatory and emotional consequences for digital and social inclusion among innovative technology rejectors?*

Methodologically, the dissertation will employ a three-paper, multiparadigm approach integrating qualitative and quantitative methods (Gioia and Pitre, 1990) to develop and test a model of post-rejection regret considering two innovative consumer technologies. This approach will challenge the adoption-centric paradigm in Information Systems research (Burton-Jones, Stein and Mishra, 2017) while oﬀering a more complete understanding of the aftermath of technology rejection. In so doing, this dissertation seeks to contribute to both theory and practice by highlighting post-rejection regret outcomes. For theory, this work has the potential to broaden the ﬁeld's nomological network of technology rejection and expand the conceptualization of post-rejection regret. By introducing the "peak competency paradox," these studies may provide a more complete understanding of IT decision-making outcomes while also illuminating pathways for future innovative technology adoption, particularly for individuals vulnerable to technological rejection and consequent social exclusion. This work may also contribute to regret literature by oﬀering a new perspective on the underlying mechanisms and content of counterfactual thinking in relation to rejected innovative technologies. By testing the boundaries of current theorizing, this research challenges the prevailing assumption that rejection is simply a behaviour of less tech-savvy individuals who do not identify with technology. For practice, it seeks to oﬀer technology designers, policymakers, and organizations a deeper understanding of who may be vulnerable to rejecting IT innovations in support of more inclusive digital systems to help address the growing global risk of digital exclusion and inequity.

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##### Automatic Algorithm Configuration under Streaming Problem Instances - Margherita Battistotti

Nowadays, hardly any optimisation problem remains unsolved due to a lack of resolution methods. For most of these problems, whether continuous or combinatorial, many different algorithms are available. This multiplicity gives rise to the meta-problem of selecting, from a set of candidates, the algorithm best suited to solving a specific instance of an optimisation problem. This challenge is known as the Algorithm Selection Problem. A closely related and equally important challenge is Algorithm Configuration, which involves setting the values of an algorithm’s internal parameters to enhance its performance, either across a set of problem instances or specifically for each instance, as in the case of selection. In the past, selection and configuration were performed manually by human experts, which rarely led to the optimal choices. Recently, many automated procedures have been developed, giving rise to Automatic Algorithm Selection (AAS) and

Automatic Algorithm Configuration (AAC).

Most of these approaches operate under the assumption that a set of training instances is available – that is, a set of instances that can be used in an a priori phase to capture the relationship between problem characteristics and algorithm performance. During the training phase of an AAS approach, a model learns how to predict the best algorithm for each problem instance, while an AAC approach typically searches for a single configuration that performs well on average across the training set. What is learnt and found can be generalised to unseen problem instances under the additional assumption that they are similar to the training

ones.

However, when problems need to be solved sequentially as they arrive in a continuous stream – a typical scenario in industry – these assumptions no longer hold: the stream is not known a priori, and the characteristics of the problem instances can change drastically over time. This creates the need for novel AAS and AAC methods capable of handling streaming scenarios. To achieve this goal, either an adaptation of existing techniques or the development of a new framework is required. Adaptation would involve gradually relaxing initial assumptions and making corresponding modifications, while building a new framework would require iteratively adding components and assessing their individual impact. In both cases, the methodology adopted in this project will rely on rigorous computational experiments and comparative evaluations against state-of-the-art approaches. One of the main challenges will be to devise an effective way to learn the relationships between instances and algorithms without a proper training phase. Another will involve generating a synthetic stream of problem instances for experimental purposes that realistically simulates a

streaming scenario.

Industries where problems must be solved sequentially stand to benefit from the success of this research, as it promises to optimise performance on a more granular level, rather than on average.

A Personalized Federated Learning Framework with Mixture of Experts for Clinical Decision Support

###### Abstract

Machine learning methods have been widely integrated into Clinical Decision Support Systems (CDSS) to improve diagnostic accuracy and treatment recommendations, and they substantially outperform traditional rule‑based or statistical methods in many applications. These methods require large‑scale centralized data collected from distributed hospitals for model training, which is impractical in healthcare due to patient data sensitivity and strict privacy regulations. Personalized federated learning (PFL) has emerged as a promising privacy-preserving solution compared to traditional federated learning that enables each institution to learn a personalized model tailored to its local data distribution without data sharing. Recent advances in PFL can be broadly categorized into two approaches: global model personalization and learning personalized models. The former involves fine-tuning a shared global model on each hospital’s local data, which is often suboptimal due to limited data availability. The latter adopts a modular approach by partitioning the model into a globally shared component and a client-specific private component, enabling local models to correct representation biases introduced by the global model. This design has shown promising potential in recent PFL studies. However, in real-world healthcare scenarios, data typically follows a long-tailed distribution, where common clinical records significantly exceed those associated with rare or specific diseases. Additionally, variations in patient demographics, medical devices, and institutional protocols contribute to significant data heterogeneity across hospitals. This raises a key research question: how can PFL frameworks effectively address the challenges of data heterogeneity with long-tailed distributions? To address the joint challenges of data heterogeneity and long- tailed distributions in healthcare federated learning, we investigate the integration of Mixture-of-Experts (MoE) architectures into PFL. MoE is a sparse and modular framework that activates a small subset of expert modules for each input, improving both model efficiency and adaptability. This design enables the model to capture diverse patterns by routing different inputs to specialized experts. In our healthcare context, expert modules are intended to specialize in disease-specific features, allowing the model to better represent under-represented or domain-specific classes. The input-dependent gating mechanism dynamically selects relevant experts, enabling personalized predictions while preserving shared global knowledge. In future work, we will further refine the proposed architecture and conduct preliminary experiments on medical image classification tasks to evaluate its effectiveness under varying degrees of data heterogeneity and long-tailed distributions.

keywords: Personalized Federated Learning, Mixture of Experts, Clinical Decision Support Systems, Data Heterogeneity, Long-tailed Distributions

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**Reconﬁguring Supply Chains under Geopolitical Tensions: A Multi-Method Approach**

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**Abstract**

Rising geopolitical tensions, manifested in recent events such as the US–China trade war, the Russia–Ukraine conﬂict, and Brexit, have intensiﬁed political risks and uncertainty in global supply chains (SCs). Trade protectionist measures like tariﬀs exacerbate SC disruptions, while policy uncertainty further complicates decision-making for multinational corporations (MNCs). Consequently, MNCs face increased costs, fractured relationships, and an uncertain environment. Reconﬁguring their SCs to enhance supply chain resilience (SCR) presents a pressing challenge for MNCs.

In operations and supply chain management (OSCM) literature, geopolitical tensions’ impacts on SCs remain nascent. Case studies and conceptual analyses have explored ﬁrms’ strategies like reshoring and supplier diversiﬁcation to mitigate geopolitical risks. Adoption of such strategies by individual ﬁrms can lead to reconﬁguration of the supply network, yet the single-ﬁrm focus may render the outcomes suboptimal from the network perspective. Although quantitative research has begun examining the latter, it largely focuses on antecedents (e.g., geopolitical tensions) and outcomes (e.g., supply base complexity or vertical integration), with limited attention to mediating and moderating factors, such as how perceived uncertainty mediates geopolitical tensions’ eﬀect on supply base complexity or how network structure moderates the adoption of vertical integration. Moreover, existing studies largely overlook the ways in which MNCs’ performance is being aﬀected by competitors’ strategic choices amid political risks. Analytical models capturing dynamic, multi-agent decision- making under geopolitical tensions are rare in OSCM, and new settings such as rapid global expansion of emerging-market MNCs aiming to bypass existing tariﬀs, remain underexplored, particularly in how such ﬁrms collaborate with suppliers and competitors to enhance coordination and eﬃciency.

This study addresses these gaps using a multi-method approach. First, a comprehensive literature review synthesizes existing research on geopolitical tensions in SCs to identify key gaps and theoretical underpinnings. Second, an empirical analysis integrating secondary data from several databases (e.g., FactSet Revere) aims to determine the extent to which various factors inﬂuence reconﬁguration patterns and underlying mechanisms. Third, game-theoretic models will simulate strategic interactions among MNCs, suppliers, and competitors under diﬀerent scenarios, capturing the competitive dynamics often overlooked in empirical studies.

As regards the empirical analysis, available data on SC relationships and network reconﬁguration is often fragmented, posing challenges for causal inference. To address this, this study integrates multiple data sources and conducts rigorous robustness checks. Regarding the game-theoretic analysis, related research is currently limited, and the existing studies involve only a narrow range of factors aﬀecting the choice of reconﬁguration strategies. To address this, the game-theoretic modelling will involve a wider range of factors, informed by the empirical analysis, to ensure that theoretical insights can translate into actionable strategies in diverse contexts.

Theoretically, this research advances SCR literature by deepening the understanding of the driving forces leading to reconﬁguration of global supply chains. It also illuminates how emerging-market MNCs leverage new strategies to address geopolitical uncertainty via supplier and competitor collaboration. Practically, it equips ﬁrms with strategies to enhance resilience and adaptability. Insights from the game-theoretic analysis further oﬀer policymakers a framework to anticipate and manage the broader economic impact of geopolitical tensions.

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**A Trustworthy Ensemble Learning Framework for Decision Support**

**through Synergistic Integration of Machine Learning and Evidential Reasoning**

**Abstract:**

Machine learning (ML) methods have gained extensive applications in complex decision-making fields, such as medical diagnosis, financial risk assessment, and industrial optimization, owing to their outstanding predictive performance and efficient data-analysis capabilities. However, ML models typically operate as 'black boxes', lacking transparent decision-making processes, which significantly constrains their credibility and practical applicability, particularly in high-stake domains. In these contexts, users require not only accurate predictions but also clear and logical reasoning to establish trust in AI-driven decisions. Existing research on interpretability mainly focuses on two approaches. Intrinsic interpretable models, such as linear or logistic regression and decision trees, offer transparency but often suffer from limited performance when handling complex, multimodal data. Conversely, explainable machine learning (EML) techniques like SHAP and LIME provide post-hoc explanations but are confined to static analyses without clear, structured, real-time decision processes. Therefore, effectively balancing high performance with interpretability by developing a systematic framework that simultaneously achieves accuracy and transparency has emerged as an essential research challenge.

To bridge this research gap, we propose a trustworthy decision-support ensemble learning framework that integrates high-performance ML models with transparent Evidential Reasoning (ER), aiming to achieve the coordinated optimization of predictive accuracy and interpretability. The proposed framework consists of four core components: a Feature Extraction Unit (FEU), Evidential Reasoning Unit (ERU), Latent Decision Unit (LDU), and Decision Enhancement Unit (DEU). Firstly, the FEU leverages advanced ML techniques to automatically extract semantically meaningful high-level features from multimodal data (e.g., tumor characteristics, key risk scores), effectively replacing traditional manual preliminary analyses. Notably, interpretability is unnecessary in this ML- driven feature extraction stage, as the extracted features themselves hold direct and intuitive significance. Subsequently, the ERU transparently integrates these high-level features into structured, traceable, and comprehensible decision outcomes. To further ensure predictive accuracy, the LDU employs powerful yet non- transparent ML models to derive latent decisions directly from raw multimodal data. Finally, the DEU strategically utilizes these latent decision outputs to enhance the performance of the ERU, thus achieving synergy between interpretability and predictive performance.

The choice of ER is motivated by its superior capability in managing uncertainty and multi-attribute decision-making through structured and principled inference using belief distributions, particularly suitable for high- stake scenarios such as healthcare, finance, and industrial optimization. Key methodological challenges addressed by this study include reducing overfitting risks associated with high-dimensional multimodal data, optimizing ER model parameters effectively, and strategically integrating the high-performance outputs from black-box ML models into the transparent reasoning process without compromising interpretability.

The proposed framework holds significant theoretical value and practical implications. Theoretically, it introduces a novel paradigm that integrates black-box and white-box models to effectively balance predictive accuracy with interpretability. Practically, it offers accurate and transparent decision-making solutions for high-stake scenarios. Experimental validation using real-world medical datasets further demonstrates its feasibility, effectiveness, and practical value.

**Spatial-Aware Decision-Making with Ring Attractors in Reinforcement Learning Systems**

**Marcos Negre Saura**

This research investigates the integration of ring attractors into reinforcement learning (RL) action selection processes. Traditional RL algorithms typically represent action spaces as unstructured collections, discarding potentially valuable spatial relationships between actions. This leads to inefficient learning in environments with inherent spatial structures, such as robotic control or navigation tasks where actions have natural relationships.

This topic is worth studying because incorporating spatial awareness into RL could significantly improve sample efficiency and performance. Biological neural systems effectively encode spatial information through specialized structures like ring attractors, suggesting their potential value in artificial systems. Furthermore, spatial encoding may provide a more interpretable framework for decision-making processes in complex environments.

Literature on neural circuits shows that ring attractors exist in biological systems for encoding directional information (Zhang, 1996; Kim et al., 2017). While spatial representations have been explored in RL through attention mechanisms and relational networks (Zambaldi et al., 2019), the specific integration of ring attractor dynamics represents a novel approach to spatial-aware action selection with biological plausibility.

Our methodology involves developing both an exogenous continuous-time recurrent neural network model and an integrated deep learning implementation. We map actions to specific positions on a ring structure and decode selected actions based on neural activity patterns. We further extend this approach with Bayesian uncertainty quantification to enhance exploration strategies, balancing between exploitation of known good actions and exploration of uncertain options.

We anticipate challenges in computational efficiency, as preliminary tests show significant overhead in our CTRNN implementation. Additionally, adapting ring topologies for environments with multi-dimensional action spaces presents theoretical and implementation difficulties. We are exploring more efficient deep learning implementations and dual-ring configurations to address these issues.

This research could impact multiple domains requiring robust and sample-efficient learning. The biological plausibility of our approach may yield insights into both artificial and natural intelligence. Moreover, the explicit encoding of uncertainty may improve safety and reliability in applied domains like robotics and autonomous systems. By bridging neuroscience-inspired models with practical RL algorithms, we aim to advance both theoretical understanding and practical applications of spatial-aware decision-making.

Beyond monolithic solvers: Solving multidisciplinary optimization problems in a cooperative fashion

Dimitri Rusin

High-stakes applications of multiobjective discrete optimization often require that a system be fully optimized without knowing its full formulation. Instead, the formulation is fragmented into two or more components that depend on each other, yet must be optimized consecutively or in parallel.

Such applications can be formulated as multidisciplinary optimization models, also known as interwoven systems, which can be naturally decomposed into (at least) two components. We seek a set of solutions that is Pareto optimal with respect to both components.

Two components interact: On the one hand, the first component can propose a baseline solution that will allow the second component to be optimized independently. On the other hand, if the first component slightly tweaks its baseline solution, the second component's optimized solution can become suboptimal.

In this talk, we study this interaction in the context of the Travelling Thief Problem. The Travelling Thief Problem famously models an interaction between the Travelling Salesman Problem and the Knapsack Problem. Even if we can solve both of these individual single-objective problems efficiently, it is not obvious how to integrate these efficient solvers into an efficient solver of the aggregated multiobjective optimization problem.

We present first results of our study of the relationship between the number of interaction rounds and the achieved Pareto efficiency gap.

**IMPROVING FERRY PORT OPERATIONS: A STRATEGY FOR QUEUE MANAGEMENT AND VEHICLE LOADING**

**Jobin Varghese**

The demand for more efficient port operations are on the rise which are resulting in ferry systems being increasingly vital in high-traffic corridors and island networks. Through this work we aim to addresses the challenges faced by the port authorities and ferry operators by proposing a solution that comprehensively integrates the concepts of queue management, vehicle loading optimization, and machine learning.

Ferry decks accommodate a heterogeneous mix of vehicles that ranges from heavy freight trucks to small cars and sometimes even small bikes and typically are arranged by their order of their arrival. However, this conventional approach more often than not leads to inefficient space utilisation, poor weight distribution which lead to issues in maintaining the ballast component of the vessel and inadvertently longer loading and unloading time durations. Prior studies done by imminent author have highlighted how suboptimal parking layouts and unorganised loading strategies lead to significant operational costs especially since most of the operations are handled manually by loading masters. But inspite of these studies there is little to no exploration done on a data driven framework for the same. Through this research we aim to find solutions to these important operational challenges by applying concepts from optimization algorithms and machine. The methodology for achieving the results intended involves developing mathematical models that take into consideration the key decision variables which include type of vehicles, arrival times, ferry deck zone limitations, dimensions and the weight limits of the zones inside the ferry.

The significance of this research lies in its ability to drive tangible improvements in ferry operations which would be minimizing turnaround time, increasing vehicle count within the ferries all while making sure that profitability is achieved both in terms of revenue and time. Not only that the desired outcomes have the potential to contribute to the greater green objectives by reducing fuel consumption and aligning with the European Union’s environmental and efficiency goals. The end result findings will hold relevance not just from a port authorities and ferry operators point of view, but also from those stakeholders viewpoint who are in multimodal logistics systems seeking scalable, intelligent transportation solutions.

#### Prosumer Identity in the Sharing Economy

Jiahui Wu-10835899

Abstract

Supervisors: Prof. Hongwei He

& Dr. Sumin Kim

The sharing economy is expanding rapidly, with projections estimating it will reach $600 billion by 2027 (Statista, 2023). This growth has significantly reshaped consumer roles, bringing renewed attention to the long-overlooked figure of the *prosumer*: individuals who simultaneously act as both consumers and providers.

Unlike traditional suppliers, prosumers contribute to platform scalability, flexibility, and credibility (Eckhardt et al., 2019; Lang et al., 2022). Yet, this dual-role participation also generates substantial psychological and identity-related strain. Constantly shifting between roles requires individuals to navigate competing norms and expectations. When left unresolved, such tension may lead to emotional stress, weakened trust, and even prosumer disengagement, threatening the long-term sustainability of platform ecosystems.

Existing literature has predominantly examined prosumers’ initial motivations or usage behaviors (Ertz et al., 2022; Lang et al., 2022; Culiberg et al., 2024). Although scholars have begun to recognize the role-switching nature of prosumers, dual-role engagement is often treated as a temporary behavioral phenomenon, with insufficient attention to how prosumers internalize and navigate the overlapping dual-role at the identity level. However, identity is key to understanding how prosumers navigate dual roles, manage role conﬂict and form commitment to the platform. These are not just behavioral transitions, but identity-based interpretations of prosumer role, which in turn influence ethical choices, relational commitments, and sustained participation.

To address this gap, the present research aims to: (1) define the core components of prosumer identity; (2) conceptualize the structural forms of this identity and examine their evolution over time; and (3) assess how different identity structures influence behavioral outcomes including performance, conflict and harmony, and well-being. Drawing on Social Identity Complexity Theory (Roccas and Brewer, 2002), this study identifies four structural identity forms: Dominance, Compartmentalization, Intersection, and Integration, and describe how individuals cognitively organize and reconcile dual roles in the sharing economy.

Methodologically, this research will employ a mix-method, combining theoretical modeling, qualitative exploration, and quantitative reﬁnement. The framework is ﬁrst developed deductively, drawing on theories of multiple identities and identity conﬂict management. Qualitative data, including in-depth interviews and diaries are used to identify emergent patterns and validate key constructs. These insights inform a subsequent phase of experimental and survey-based testing to assess the inﬂuence of contextual factors (e.g., platform rules, incentives) on identity formation and conﬂict resolution. One key methodological challenge lies in capturing the dynamic evolution of prosumer identity structures over time. As a potential solution, this research considers the use of AI agents to analyze behavioral data and help infer identity trajectories.

In all, this research offers meaningful contributions. Theoretically, it develops a structured model of prosumer identity, providing a foundation for future research on dual-role dynamics in decentralized, peer-driven systems. Additionally, it extends multiple identity management theory into consumer contexts, revealing how identity conflict and structure co-evolve over time. Managerially, it provides a timely and powerful empirical lens for exploring a critical condition: platforms often struggle to retain prosumers not simply due to flawed incentives, but because prosumer identity is fragile and dynamic. Understanding how this identity is constructed and integrated is key to improving platform governance, trust-building, and long-term user commitment.

**Servitization-Driven Supply Chain Transformation: An Integration Strategy Perspective**

**Huaqing Xu**

With increasing market competition and shifting consumer demands, many manufacturers are exploring new business models to stay competitive, with servitization emerging as a key option. This model, focus on services such as maintenance, consulting, and subscriptions, contrasts with traditional models centered on tangible goods and product sales. Servitization enables manufacturers to generate revenue through service contracts, long-term customer relationships, and recurring service fees, while also improving customer satisfaction and diversifying revenue streams. However, implementing servitization requires not only production and delivery but also service support, maintenance, upgrades, and customer relationship management, all of which demand additional resources and collaboration with various stakeholders，especially with service providers. However, how to manage service providers to ensure they provide timely, high-quality services to customers remains a challenge for manufacturers. Effective management of service providers can help manufacturers better integrate resources and provide services to customers.

Current research at the intersection of servitization and supply chain management is still in its nascent stages.While there exists some literature on servitization supply chains, previous scholars have primarily concentrated on theoretical and empirical investigations into the factors influencing servitization, the performance outcomes associated with servitization, the operational strategies employed by companies, and the structural frameworks of servitization supply chains. In terms of stakeholder relationships and governance mechanisms within servitization supply chains, existing scholarship has predominantly examined how manufacturers sustain relationships with suppliers and customers from a manufacturer's perspective. However, there is a relative paucity of research addressing how to maintain and govern relationships with service providers, how to tackle challenges encountered in the implementation of governance mechanisms through organizational restructuring or integration, and how to enhance corporate governance capabilities. Consequently, research in this domain is particularly urgent and warrants further exploration by scholars.

This study will examine how can manufacturers govern service providers in advanced servitization business models to meet customer needs and provide timely, high-quality services? And How can manufacturers adjust their organisational structures in servitised supply chains and adopt integration strategies to enhance digital governance capabilities and address challenges encountered when applying digital technologies? Multiple case studies of manufacturing companies undergoing servitization, and their service partners, will be conducted. Data will be collected through semi-structured interviews and analyzed using NVivo for thematic analysis. The study aims to develop a conceptual framework linking servitization, governance mechanism, and integration strategies to inform strategic decision-making. Challenges include gaining access to supply chain managers and the limited number of companies undergoing servitization. To address this, the researcher will expand the network through industry events like the UK Services Forum. Additionally, data access may be restricted due to the sensitivity of business information. The methodology of case studies presents challenges in time management and methodology proficiency, while qualitative analysis using NVivo requires specialized training.

**Abstract Title:** ‘Embracing Contradictions with The Power of Paradox Mindset’: A Mixed-Method Approach to Examine the Micro-foundations of Organisational Paradox Through the Employee Perspective - Alkiviadis Fioratos

In contemporary dynamic and complex organisational environments, individuals encounter various paradoxical situations, such as autonomy versus control, structure versus ﬂexibility and exploration versus exploitation (Zhang et al., 2015; Keller et al., 2017; Miron-Spektor et al., 2011). These contradictions that co- occur and persist over time (Smith & Lewis, 2011), can aﬀect both individuals’ mental health and performance (Berti & Cunha, 2023), but also organisational eﬀectiveness (Smith & Berg, 1986). The current research explores how paradox mindset (PM)– an individual’s ability to embrace and proactively handle contradictions as interrelated to move beyond them (Miron-Spektor et al., 2018) – enables employees to deal with paradoxical situations.

Prior research highlights the importance of PM at the leader level, oﬀering capacity to handle exploration-exploitation paradox (Andriopoulos & Lewis, 2010; Waldman et al., 2001) or to instil innovation and adaptability in organisational culture (Smith et al., 2017). However,the mechanisms under which employees cultivate PM as well as the beneﬁts they earn from it are largely underexplored (Yoo & Roh, 2024). Leaders and followers often experience diﬀerent paradoxes, and they employ diﬀerent resources, experiences and worldviews to deal with them (Schad et al., 2016). Building on prior research showing variations in organisations on how individuals approach paradoxes (Miron-Spektor et al., 2018), my research aims to provide further insights on hierarchically lower-level employees’ PM.

Todo so, I adopt a mixed methods approach and involve a series of studies. First, although research has systematically reviewed leader’s PM identifying impactful factors and mechanisms (Batool et al., 2023), the same has only been conducted in a descriptive way for employees (Pikl, 2025). Therefore, I am at the process of conducting an integrative mixed method meta-analysis that will ﬁll that gap, by providing more insights on employee’s PM conceptualisation, operationalisation, theorisation, and nomological network. In progressing towards this goal, I have almost identiﬁed the eligible papers to include, and I will soon start coding them to extract the data. Following that, a randomised control trial focusing on providing PM training on employees will be applied. The study will test and reveal individual cognitive and aﬀective mechanisms through which PM strengthens the impact on key individual workplace outcomes. Quantitative data will be gathered before and after the training, and semi-structured interviews are going to provide a richer understanding of participants’ experiences on factors like wellbeing and performance. Finally, I will explore how PM is perceived diﬀerently by leaders and employees by examining several dyads and their daily interactions. Similar to the intervention, both quantitative and qualitative data will be gathered daily for a few days to explore how manager-follower pairs respond to contemporary organisational paradoxes, such as automation-augmentation paradox (Raisch & Krakowski, 2021).

Exploring psychological phenomena such as PM is a complex procedure, therefore by being pragmatic and employing diﬀerent methods I aspire to oﬀer a more robust analysis and practical insights. Nevertheless, several challenges should be considered. Often participant engagement is problematic with longitudinal studies. Therefore, engaging methods, such as rewards or fostering ﬂexible data collection methods (Teague et al., 2018), should be acknowledged to avoid high attrition levels. Further, eﬀectively integrating diﬀerent methodologies is challenging and often researchers treat them as separate studies (Molina-Azorin et al., 2017). Thus, treating the ﬁndings in parallel and intermittently has been recommended as a best practice (Levitt, 2024). Finally, it is highly possible that keeping a diary might aﬀect the dynamics between managers and followers, eventually having also an impact on the study’s results.

Through elucidating the mechanisms by which PM yields to speciﬁc individual outcomes and interactions, the current research oﬀers signiﬁcant contribution to the literature. Theoretically, it provides a deeper understanding on: the concept of employee PM; the underlying mechanisms that boost PM’s impact on eﬀectively navigating organisational paradoxes; how PM is perceived diﬀerently by leaders and employees and its impact on their interactions. From a practical perspective, ﬁndings and conclusions of the research will oﬀer actionable guidance to organisations that seek to foster employee adaptability, performance and wellbeing, by utilising organisational paradoxes.

Research Title: **Leading with AI; How a leader's direct engagement with AI influences technology adoption in the workplace**

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Supervisors: Anita Greenhill, Carlo Cordasco Student ID: 11544477

March 28, 2025

**Abstract**

The incorporation of Artificial Intelligence (AI) in the workplace has garnered attention, particularly with the pervasive nature of digital technologies. AI tools are reported to enhance decision-making, efficiency, productivity, and innovation, impacting managerial, employee, and organisational outcomes such as data-driven decision-making, improved employee experience, increased revenue, and enhanced customer satisfaction (Chowdhury et al., 2023). As organisations invest in AI, adoption becomes critical for fully realising the benefits of AI integration and mitigating potential employee resistance.

Traditionally, individuals appointed in formal roles do not directly engage with workplace technologies, as they aren't viewed as primary users. Consequently, their roles in adoption are seen merely as enablers. This creates a paradox: how can they advocate for AI when they don't use it themselves?

Various studies recognise leadership's role in technology adoption (Almeida, 2023; Frangos, 2022; Lee and Shin, 2020) but often examine it superficially. Leadership trait theories (Buchanan & Huczynski, 2017; Allen, 1998) emphasise human-centric skills such as communication, vision, and empathy, and this is reflected in the role assigned to senior leaders in adoption. Also, the Technology Acceptance Theory (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) position technology adoption as a bottom-up process, with frontline employees as primary users and leaders in a facilitative role. However, AI integration in decision-making is reshaping workplace roles (Watson et al. 2021), and as a result, leaders now need AI competencies alongside strong interpersonal skills. Yet, existing leadership and technology adoption theories neglect how leaders' engagement with AI as primary users affects organisational technology adoption.

This study explores **how leaders use expert power to influence employees' attitudes towards AI adoption.** Utilising the French and Raven power framework (1993), it examines the dynamics between senior leaders and employees and their impact on the intention to use AI in the workplace. By integrating technology adoption theories with leadership power theories develops a new theoretical framework to guide leadership influence on AI adoption, shaping policy and defining senior leaders’ roles to support successful AI integration.

This study is important because technology adoption has been fraught with challenges, with 60% of projects failing to deliver on expected outcomes (Decker et al., 2012; Flood, 2013; Van et al., 2017). Understanding how leaders model the adoption of AI through personal use in the workplace will help to deepen theories of adoption in the workplace.

This study will employ a qualitative research methodology, utilising a case study strategy and semi-structured interviews to examine leaders' unique experiences with AI tools and their impact on workplace adoption. Data accessibility may present challenges due to concerns regarding AI maturity across many organisations; therefore, the focus will be on technology start-ups and multinationals that are early adopters.

**Sociotechnical Narratives of Change: An Actor-Network Theory Perspective - Una Quinn**

Great ideas and good intentions don’t always go to plan. Rather, planned changes are often a set of ideas which never materialise but change beyond recognition (Czarniawska and Joerges 1998). To explore this further, the project at hand will investigate a multi-sector organisational network, including universities, local government bodies and public and private organisations, that are collectively pursuing the ambition of becoming a leading organisational network in regulation technology. This therefore asks, how is this organisational network translating their ideas from ‘reality conceived’ to ‘reality practiced’?

What is particularly distinct about this case is the prominence of emerging technologies, which carry immense potential to transform the existing landscape of work and employment (Bailey and Barley 2020; Scott and Orlikowski 2025). This prominence of new technological actors heightens the tensions between new and existing imaginaries, calling for further understanding into how collective ambitions are organised and realised through sociotechnical practices.

In order to investigate this and represent realities as they genuinely exist, that is “as fundamentally complex, ambiguous, and indeterminate” (Law 2004), an Actor-Network Theory (ANT) lens is adopted. This works to ‘map’ relations between heterogeneous actors and reveal patterns of action and inaction. By doing so, analytical differences between humans and non-humans are dissolved as it is the relations between entities that are appreciated as being more fundamental than the entities themselves (Latour 2005).

This approach enables the articulation of conditions of possibility for multiple, material realities from which further assessments can be made. This includes insights into the role and impact of new technological actors in multi-sector collaborations and the configurations of practice involved in negotiating a shared outcome. For example, understanding the enactment of technological practices within this specific context will work to inform technological policy and the strategic embedding of new technologies across multiple interconnected sectors.

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**Abstract Title: Navigating Workplace Stress: A Mixed-Method Investigation of the ADHD Experience - Rebecca Symonds**

The prevalence of Attention-Deﬁcit/Hyperactivity Disorder (ADHD) in UK adults is estimated to be between

3-4%. Individuals with ADHD are more likely to face occupational diﬃculties, higher rates of work absences or long-term sick leave, and co-occurring mental health conditions (Adamou et al, 2013). With rising ADHD diagnoses and growing recognition of its impact on how individuals navigate workplace demands, understanding the relationship between ADHD and workplace stress is more relevant than ever (Hotte- Meunier et al., 2024; Nagata et al., 2019). Furthermore, the UK government’s recent announcement to reform the welfare system to support disabled and long-term sick individuals in returning to work may inﬂuence how neurominorities enter and sustain employment. This highlights the importance of examining how ADHD aﬀects experiences of workplace stress, the impact on employee wellbeing, and the support systems needed to foster a more inclusive and adaptive work environment.

Previous research highlights challenges and strengths associated with ADHD in the workplace, including diﬃculties with time management, concentration, and self-regulation, as well as strengths such as creative thinking and hyper-focus (Hotte-Meunier et al., 2024). However, far less attention has been given to the underlying processes of workplace stress that shape these experiences. Little research has explored how ADHD-related traits contribute to or mitigate stress responses at work, or the speciﬁc mechanisms that inﬂuence wellbeing and job outcomes. Understanding these processes is essential for developing targeted support strategies.

This research will begin with a meta-synthesis of existing literature to identify key patterns, themes, and gaps in our understanding. Insights from this will inform a qualitative study, involving interviews with individuals with ADHD across diverse demographics and employment contexts to explore lived experiences of workplace stress. A quantitative study will then examine key variables identiﬁed in the qualitative phase. This research will explore the strengths and challenges individuals with ADHD face in the workplace, factors inﬂuencing these, and potential mediators and moderators such as self-regulation, gender, age, and work context. Using qualitative and quantitative methods this study will oﬀer a detailed understanding of ADHD and workplace stress.

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**Consumer Bankruptcy Exemption and Individual Campaign Contribution**

**ABSTRACT**

Consumer bankruptcy exemptions provide implicit insurance to households by protecting assets during financial distress, but their impact on campaign contributions, as a form of ideological consumption, remains unexplored. We examine how personal bankruptcy exemptions influence individual campaign contributions by exploiting state-level variations in homestead exemption reforms using a novel stacked difference-in-differences approach. Following exemption increases, we find that individuals with low and middle-level assets increase their campaign contributions by 5.0-8.2%, while high-asset households show no significant response. This effect is strongest among households newly covered by reformed exemption limits, consistent with bankruptcy protection reducing precautionary savings needs and freeing up disposable income for discretionary political spending. Our findings reveal that bankruptcy exemptions not only serve their intended purpose of providing financial protection but also generate positive spillover effects on democratic participation, highlighting an important channel through which consumer financial legislation shapes civic engagement.

1. ***Introduction***

Consumer bankruptcy filings have increased notably in recent years in the U.S. In 2023, there were 434,064 non-business bankruptcy cases filed nationwide, marking a 16% rise from the previous year's total of 374,240. This upward trend continued into 2024, with non-business filings reaching 494,201, representing a 13.9% increase over 2023 (U.S. Court, 2025). These trends underscore the importance of consumer bankruptcy as a critical financial mechanism, enabling nearly half a million American households each year to legally discharge unsecured debts and achieve a “fresh start.” As a result, debtor-friendly bankruptcy laws play an essential role in helping individuals overcome overwhelming debt burdens and regain financial stability

However, these laws don’t provide only relief from indebtedness, but they also serve as implicit financial insurance by protecting specific consumer assets. For instance, bankruptcy exemptions, such as homestead exemptions, shield real estate equity in primary residences, while wildcard and other exemptions protect personal savings, vehicles, and other personal property.

One of the implications of protecting households from both actual and expected financial distress due to “bad luck” (e.g. job losses, medical emergencies, divorce) is that bankruptcy exemptions might reduce households' incentive for precautionary savings or their reliance on explicit insurance, such as health or unemployment insurance. Essentially, generous bankruptcy protections can decrease the perceived need to maintain savings or insurance coverage as a safeguard against financial misfortune.

Several studies have explored the effects of bankruptcy exemptions on consumption smoothing and credit market outcomes (e.g., Mahoney, 2015; Auclert, Dobbie, & Goldsmith- Pinkham, 2019; Indarte, 2024; Pattison & Hynes, 2020; Roemo & Sandler, 2023). However, the potential impact of such laws on household political behaviors, and in particular, individual

campaign contributions, remains unexplored. This gap is notable given that individual campaign contributions constitute over 90% of the total campaign funds in the U.S., significantly shaping democratic participation and policy outcomes. Understanding how financial protections like bankruptcy exemptions influence political engagement can provide critical insights into the broader social and political implications of consumer financial legislation.

This paper attempts to address this gap by examining whether and how personal bankruptcy exemptions influences individual political contributions. Specifically, we posit that higher exemption limits, which, in turn, reduce households' financial insecurity and precautionary savings needs, might increase discretionary expenditures, including political donations.

To empirically investigate this, we leverage variations in State-level homestead exemption reforms and individual campaign contribution data, adopting a robust stacked difference-in-differences (DID) to estimate the causal effect of state-level homestead exemption reforms on individual campaign contributions. Our analysis compares contributors in states that increased their exemption levels (treated) against those in states that never enacted such reforms (control), within a seven-year observation window surrounding each reform event.

We show that enhanced financial protections through bankruptcy exemptions significantly stimulate political contributions, particularly among low- and middle-asset households, thus highlighting the broader implications of consumer financial protection policies on democratic participation.

The structure of the paper is as follows: the next Section describes the contributions of our paper to the existing literature; Section 3 provides details of the Institutional setting;

Section 4 includes the discussion of the hypotheses; Section 5 and 6 describe the data and the research design of our analysis, respectively; while Section 7 reports the main results; and Section 8 concludes.

1. ***Related Literature***

Our findings contribute to both the individual bankruptcy literature and the growing body of research on political finance, providing new insights into the financial determinants of political engagement. First, the paper adds new evidence on the implicit wealth insurance effect of consumer bankruptcy laws by examining the direct impact of State-level bankruptcy reforms on individual campaign contributions. One strand of the literature focuses on consumer bankruptcy, documenting the causes of bankruptcies (e.g. Fay, Hurst, & White, 2002; Dick & Lehnert, 2010; Ning & Zhu, 2011) and household borrowing behaviors after bankruptcy (e.g.

Han & Li, 2011), On the one hand, some studies document that raising consumer bankruptcy levels have negative effects on the credit markets (e.g. Gropp, Scholz, & White, 1997; Cerqueiro & Penas, 2017; Romeo & Sandler, 2023; Cole, Damm, Hackney, & Suleymanov, 2024) and positive effects on entrepreneurial activities and bankruptcy fillings (e.g. Fan & White, 2003; (Pattison & Hynes, 2020). On the other hand, several other studies have tested how differences in consumer bankruptcy exemptions affect households' ability to smooth consumption, as well as the potential crowding-out effects on explicit insurance coverage such as health insurance— particularly among marginal consumers and those experiencing financial distress (e.g., Livshits, MacGee, & Tertilt, 2007; Grant, 2010; Mahoney, 2015; Auclert, Dobbie, & Goldsmith-Pinkham, 2019; Indarte, 2024).Building upon previous literature, our study is the first one estimating the

effects of consumption smoothing provided by implicit insurance generosity on household political participation and campaign contributions.

Second, this paper provides new empirical evidence to a growing literature studying campaign contribution decisions in the U.S. On one hand, a number of studies investigates either the effects of corporate or political action committee (PAC) contributions on corporate performance and government expenditures (Cooper, Gulen, & Ovtchinnikov, 2010; Duchin & Sosyura, 2012; Fowler, Garro, & Spenkuch, 2020), or the relationship between corporate campaign contributions and political connections (Claessens, Feijen, & Laeven, 2008; Akey, 2015; Aobdia, Koester, & Petacchi, 2024). On the other hand, a few other economic studies explore the motivations behind and the economic implications of individual campaign contributions (Ansolabehere, Figueiredo, & Snyder, 2003; Fremeth, Richter, & Schaufele, 2013; Babenko, Fedaseyeu, & Zhang, 2020; Bouton, Cagé, Dewitte, & Pons, 2024). This paper contributes to this emerging area by examining individual campaign contributions as a form of consumption. Specifically, this work offers novel insights into individual donors' motivations by highlighting the consumption dimension of political giving and disentangling from the strategic or investment-driven explanations.

1. ***Institutional Background***

In the U.S., both federal and State legislation provide legal processes to protect households from extreme indebtedness, allowing them to discharge debt by making no or partial payments to creditors. Individual households primarily have two bankruptcy options: Chapter 7 and Chapter 13. Under Chapter 7 bankruptcy, also known as “fresh start bankruptcy,” filers can discharge most unsecured debts completely without entering repayment plans with creditors.

However, Chapter 7 requires liquidation of non-exempt assets to repay creditors. Alternatively, Chapter 13 bankruptcy, or reorganization bankruptcy, permits debtors to retain their assets and repay debts according to a structured repayment plan typically lasting three to five years. Before 2005, filers can choose which type of type of bankruptcy they file for. The Bankruptcy Abuse Prevention and Consumer Protection Act (BAPCPA) of 2005 introduced significant changes to the bankruptcy framework, adding means-testing to determine eligibility for Chapter 7 bankruptcy and mandating credit counseling as well as financial management courses.

Chapter 7 filers are subject to either federal or State-level exemption laws, which set thresholds below which assets, including equity in homes and other property, are fully protected from creditors. Equity above these exemption limits must be surrendered to creditors. *Homestead exemptions*, which specifically protect equity in primary residences, are particularly important as they provide substantial debt forgiveness during financial distress (Auclert, Dobbie, Goldsmith- Pinkham, 2019). Homestead exemption limits exhibit wide variation across States, ranging from no exemptions in Maryland to unlimited protection in Florida and Texas. More importantly, between 2000 and 2021, many States reformed their homestead exemptions to better shield households from economic shocks. For instance, Illinois increased its homestead exemption from

$7,500 to $15,000 in 2006, and further to $30,000 for single filers and $60,000 for joint filers in 2021; while Rhode Island raised its exemption substantially from $300,000 to $500,000 in 2012.

Other notable State exemptions include wild card exemptions that allow debtors flexibility in protecting various personal assets, such as savings, vehicles, or personal property. This type of protection also varies significantly across States. Retirement accounts, life insurance policies, household goods, vehicles, and tools used for employment are commonly protected

under State-specific exemption categories. Such comprehensive exemption laws significantly impact household financial security and shape economic behaviors related to saving, consumption, and insurance purchases, particularly during economic downturns. We mainly focus on homestead exemptions as it is the highest and most important portion of consumer bankruptcy exemption which covers the real estate property of the borrower.

1. ***Hypotheses Development***

Unlike previous studies arguing that campaign contributions are a form of instrumental investment designed to gain policy benefits, Ansolabehere et al. (2003) argue that individual campaign contributions are a form of consumption driven by personal ideology and preferences. Like any other type of consumption goods, campaign contributions also increase as household income raise.

Consumer bankruptcy exemptions do not directly increase household income. Instead, the exemption provides financial security to consumers by protecting their household assets when filing for bankruptcy. An increase in the homestead exemption means that households whose home equity previously exceeded the exemption limits—and thus had portions of their home value unprotected and at risk during bankruptcy proceedings—are now partially or fully covered. With higher exemption limits, these households gain greater protection for their entire home equity, significantly reducing the financial risk of losing their home or other assets when declaring bankruptcy. As a result, these households may respond by reducing precautionary savings or decreasing spending on other forms of explicit insurance, such as health or unemployment insurance, since the increased exemption itself provides a stronger financial buffer against adverse events like job loss, divorce, or significant medical expenses. Hence,

homestead reforms provide implicit wealth insurance and alleviate liquidity constraints for households that are specifically covered by the new reform exemptions. We argue that this wealth insurance effect should be particularly pronounced for households newly covered by the homestead exemption reforms, as these households experience a direct shift from no to partial or full protection of their home equity. On the other hand, households with sizable assets that already exceed even the increased exemption limits will experience a weaker insurance effect, as their substantial wealth provides inherent protection independent of the exemption reform.

Thus, our first and main hypothesis is as follows:

***H1***: Homestead reforms have positive effects on individual campaign contributions, and the effects are stronger for low- and middle-assets households that are more affected by exemption changes.

1. ***Data Description***
   1. *State Bankruptcy Exemptions*

We follow Indarte (2024) and use a comprehensive bankruptcy exemption dataset for all 50 States, Washington D.C., and federal exemptions across 22 years (2000-2021). It includes two primary types of bankruptcy exemptions: homestead exemptions (HE) and wildcard exemptions (WE), with separate limits for individual and joint filers. Eight States (Arkansas, Washington D.C., Florida, Iowa, Kansas, Oklahoma, South Dakota, and Texas) offered unlimited homestead exemptions, providing complete protection for primary residence equity regardless of value.

There are also States without exemptions, including New Jersey, Maryland, and Delaware. Among States with specific dollar limits, exemptions ranged from $7,500 to $550,000 in

Nevada, with Massachusetts and Rhode Island both offering substantial $500,000 protections. The national average (excluding unlimited values) was $94,090, with a median of $47,500.

Regional patterns were evident, with Northeastern States averaging the highest exemptions of

$170,938, followed by Western States ($124,355), while Southern States had the lowest numerical average ($35,773) despite having several States with unlimited exemptions. Additionally, 19 States allow debtors to choose federal exemptions instead of States exemptions. The dataset also tracks historical changes through statutes and implementation dates, revealing a general trend of increasing exemption amounts over time, particularly for wildcard exemptions, which have more than doubled on average since 2000.

* 1. *Individual Campaign Contribution*

We obtain individual campaign contribution data from OpenSecrets’s database. The OpenSecrets’s database provides a comprehensive database of individual campaign contributions, sourced from the Federal Election Commission (FEC) records and assigns individual contributor IDs for each unique contributor. This dataset includes detailed information on contributions from individuals who donate at least $200 to federal candidates, political action committees (PACs), or party committees. Contributions below this threshold are not part of the public record and, therefore, are not included in the dataset.

The dataset contains various variables, including contributor names, occupation, employer, city, State, 5-digit zip code, amounts contributed, date of the contribution, the recipient’s name, the recipient’s party, and the recipient’s unique ID defined by FEC. Comprehensive information, especially regional information, provided by the dataset allows us to link individual campaign contributions with other databases.

* 1. *Zillow Housing Value*

We use the Zillow Home Value Index, which measures the typical home value in dollar amounts, provided by Zillow housing database. The Zillow housing data encompasses detailed property-level information including listing prices, sale transactions, rental prices, and various housing attributes such as property size, number of bedrooms and bathrooms, property age, and geographic identifiers. We use the Zillow Home Value Index (ZHVI), which represents a smooth, seasonally adjusted estimate of the median home value within specific geographic areas such as ZIP codes, cities, counties, States, and the national level, to capture the housing values of a typical zip address. The ZHVI data is updated monthly, offering timely insights into price movements and housing market dynamics. We aggregate the monthly ZHVI on an annual basis by calculating the mean ZHVI of each year.

1. ***Empirical Design and Identification Strategy***

Early studies on personal bankruptcy reforms generally exploits cross-sectional variations

of exemption levels in the State level (Gropp, Scholz, & White, 1997; Fan & White, 2003). Such empirical strategy estimates the association of exemptions amounts and other economic factors, such as entrepreneurial or credit supply activities. Our paper takes one step further to estimate the causal effect of personal bankruptcy exemption on individual campaign contributions. Our empirical strategy draws on State level variations in homestead personal bankruptcy exemption levels that rise due to homestead reforms. One of the empirical challenges we face is that the homestead reform has staggered across different States over time. To address the potential bias of the average treatment effects in such cases (Goodman-Bacon, 2021; Baker, Larker, & Wang, 2022), we adopt a “stacked DID” estimator. With the stacked DID approach, we restructure the

data by first creating a cohort for each event (reform). Our sample includes several cohorts, each observed for a period of seven years—three years before and three years after a state adopts a homestead exemption reform. We follow Cerqueiro & Penas (2017) and Cole, Damm, Hackney, & Suleymanov (2024) by considering a state "treated" in the first year it increases its homestead exemption level from 2000 to 2021 Because most states enacted their reforms before 2012, fewer cohorts are observed in later years, and our final analysis thus covers the years from 2000 to 2016.

We also exclude States that have reformed its exemption level multiple times within a seven-year period. Within each cohort we compare treated units with never-treated units. The treated units are those contributors living in States that have reformed their consumer bankruptcy exemptions without our sample period. The control units are those contributors living in states that have never reformed their consumer bankruptcy exemptions (as never-treated States). We also exclude States with unlimited homestead exemptions from the control group since those States have different bankruptcy protections and credit supplies than other never-treated States.

We finally stack all cohorts together to form one pooled dataset ready for DID estimation. The specification of our DID estimator is as follows:

𝑌𝑌𝑖𝑖,𝑡𝑡 = 𝛽𝛽(𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑠𝑠 × 𝑃𝑃𝑃𝑃𝑃𝑃𝑇𝑇𝑡𝑡) + 𝑭𝑭𝑖𝑖,𝑠𝑠,𝑡𝑡 + 𝛾𝛾𝑠𝑠,𝑐𝑐,𝑑𝑑,𝑧𝑧,𝑡𝑡 + 𝜖𝜖𝑖𝑖,𝑡𝑡

where 𝑌𝑌𝑖𝑖,𝑡𝑡 is the main dependent variable which measures individual campaign contributions.

𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑠𝑠 is the State level homestead reform which varies by State and time. 𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑠𝑠 equals 1 if the State raises its homestead exemption level and 0 otherwise. 𝑃𝑃𝑃𝑃𝑃𝑃𝑇𝑇𝑡𝑡 is a binary variable and equals 1 for post-treatment period and 0 otherwise. 𝑭𝑭𝑖𝑖,𝑠𝑠,𝑡𝑡 captures individual, State, and year

fixed effects absorbed in our model. 𝛾𝛾𝑠𝑠,𝑐𝑐,𝑑𝑑,𝑧𝑧,𝑡𝑡 is a matrix of State, county, district, and ZIP level controlled variables. 𝛽𝛽is the key coefficient of our interest, and it estimates the differential effect of each event (reform) on campaign donations, representing the causal effect of consumer bankruptcy and exemption reforms on individual campaign contributions.

1. ***Main Results***
   1. *Total Donation Amounts*

In this section, we empirically analyze the causal relationship between homestead reforms and total campaign contributions made by each contributor per year from 2000 to 2016. In our baseline specification, we use the home value measured by Zillow housing value index to proxy for the real estate assets own by each individual contributor. Table 1 below shows the main independent, dependent, and control variables.

**Table 1**: Definition of Variables

|  |  |
| --- | --- |
| Variables | Definition |
| Treated × Post  LnAmount | = 1 if the contributor lives in a treated state and in a post-treatment period  Natural logarithm of total contribution amounts per contributor per year |
| Log GDP | Natural logarithm of state GDP |
| Log Income | Natural logarithm of state per capita disposable income |
| Log PCE | Natural logarithm of state per capita personal consumption expenditure |
| State Inequality | Shares of wealth owned by 10% of the State population |
| Unemployment | County level employment rate |
| Election Closeness | = 1 if the contributor lives in a district where the winning margin was less than 10% of vote shares |
| Republican District | =1 if the contributor lives in a Republican district |
| Debt to Income | County level debt to income ratio |
| HPI | ZIP level housing price index |

**Table 2**: State level changes in homestead exemption amounts

|  |  |  |
| --- | --- | --- |
| State | Reform Year | Change in Homestead Exemption |
| Alaska | 2004 | $13,500 |
| Arizona | 2004 | $50,000 |
| California | 2010 | $25,000 |
| Colorado | 2007 | $15,000 |
| Delaware | 2005 | $50,000 |
| Georgia | 2012 | $11,500 |
| Idaho | 2006 | $50,000 |
| Illinois | 2006 | $7,500 |
| Louisiana | 2009 | $10,000 |
| Maine | 2008 | $12,500 |
| Minnesota | 2007 | $100,000 |
| Missouri | 2007 | $7,000 |
| Nebraska | 2007 | $47,500 |
| New Hampshire | 2004 | $50,000 |
| New Mexico | 2007 | $30,000 |
| New York | 2005 | $40,000 |
| North Dakota | 2009 | $20,000 |
| Oregon | 2005 | $5,000 |
| Rhode Island | 2012 | $200,000 |
| Utah | 2013 | $10,000 |
| Vermont | 2009 | $50,000 |
| Washington | 2007 | $85,000 |
| Wisconsin | 2009 | $35,000 |
| Wyoming | 2012 | $10,000 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 3**: Effect of homestead exemption increase on individual campaign contributions by asset quantiles | | | | | |  |  |
|  | (1)  1st Quantile | (2)  2nd Quantile | (3)  3rd Quantile | (4)  4th Quantile | (5)  5th Quantile |  |
|  | LnAmount | LnAmount | LnAmount | LnAmount | LnAmount |
| Treated × Post | 0.065\*\* | 0.050\*\* | 0.049\*\* | 0.022 | 0.015 |  |
|  | (0.039) | (0.029) | (0.014) | (0.249) | (0.426) |
| Log GDP | -0.915\*\*\* | -2.029\*\*\* | -0.399\* | -0.318 | 0.059 |
|  | (0.009) | (0.000) | (0.091) | (0.168) | (0.826) |
| Log Income | 1.017\* | 1.818\*\*\* | 0.838\*\* | 0.702\*\* | 0.425 |
|  | (0.094) | (0.000) | (0.018) | (0.037) | (0.284) |
| Log PCE | -0.692 | -1.019 | 0.170 | -0.118 | 0.393 |
|  | (0.317) | (0.136) | (0.752) | (0.826) | (0.519) |
| State Inequality | 0.018\*\*\* | 0.020\*\*\* | 0.010\*\*\* | -0.000 | 0.009\*\*\* |
|  | (0.002) | (0.000) | (0.003) | (0.957) | (0.008) |
| Unemployment | -0.024\*\*\* | 0.009 | 0.015\*\* | -0.025\*\*\* | -0.022\*\*\* |
|  | (0.000) | (0.145) | (0.039) | (0.000) | (0.000) |
| Election Closeness | 0.051\*\*\* | 0.053\*\*\* | 0.014 | 0.026\*\*\* | 0.008 |
|  | (0.001) | (0.000) | (0.244) | (0.004) | (0.308) |
| Republican District | 0.031\* | 0.032\*\* | 0.003 | 0.009 | -0.023\*\* |
|  | (0.076) | (0.017) | (0.838) | (0.366) | (0.018) |
| Debt to Income | -0.003 | -0.009 | 0.007 | -0.012 | 0.025\*\* |
|  | (0.906) | (0.693) | (0.649) | (0.297) | (0.028) |
| HPI | 0.000 | 0.001\* | -0.001\*\* | -0.001\*\*\* | -0.000 |
|  | (0.517) | (0.099) | (0.020) | (0.000) | (0.370) |
| Constant | 14.357\*\* | 23.215\*\*\* | 0.844 | 5.109 | -2.752 |
|  | (0.040) | (0.000) | (0.872) | (0.303) | (0.568) |
| N | 98,991 | 149,933 | 238,983 | 425,375 | 1,267,474 |  |
| Adj. R² | 0.611 | 0.614 | 0.634 | 0.621 | 0.606 |
| Fixed Effects | State-Cohort,  Year-Cohort, Donor-Cohort | State-Cohort,  Year-Cohort, Donor-Cohort | State-Cohort,  Year-Cohort, Donor-Cohort | State-Cohort,  Year-Cohort, Donor-Cohort | State-Cohort,  Year-Cohort, Donor-Cohort |
| *p*-values in parentheses  \**p* < 0.10, \*\* *p* < 0.05, \*\*\* *p* < 0.01  Note: This table examines the effect of raising homestead exemption limits on individual campaign contributions. This table tests the baseline specification of 𝑌𝑌𝑖𝑖,𝑡𝑡 = 𝛽𝛽(𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑠𝑠 × 𝑃𝑃𝑃𝑃𝑃𝑃𝑇𝑇𝑡𝑡) + 𝑭𝑭𝑖𝑖,𝑠𝑠,𝑡𝑡 +  𝛾𝛾𝑠𝑠,𝑐𝑐,𝑑𝑑,𝑧𝑧,𝑡𝑡 + 𝜖𝜖𝑖𝑖,𝑡𝑡 and splits the sample into five quantiles based on the percentile rank of zip level home values measured by Zillow home value index each year Definitions of variables are shown in Table 1. Standard errors are clustered at the States by year by stack level. | | | | | |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 4**: Effect of homestead exemption increase on individual campaign contributions by asset quartiles | | | | |  |  |
|  | (1)  1st Quartile | (2)  2nd Quartile | (3)  3rd Quartile | (4)  4th Quartile |  |
|  | LnAmount | LnAmount | LnAmount | LnAmount |
| Treated × Post | 0.056\* | 0.082\*\*\* | 0.020 | 0.018 |  |
|  | (0.052) | (0.000) | (0.253) | (0.320) |
| Log GDP | -0.945\*\*\* | -0.783\*\*\* | -0.515\*\* | 0.025 |
|  | (0.004) | (0.001) | (0.024) | (0.920) |
| Log Income | 1.317\*\*\* | 1.427\*\*\* | 0.883\*\*\* | 0.411 |
|  | (0.006) | (0.000) | (0.008) | (0.257) |
| Log PCE | -1.372\*\* | -1.348\*\* | 0.185 | 0.278 |
|  | (0.041) | (0.020) | (0.740) | (0.630) |
| State Inequality | 0.026\*\*\* | 0.016\*\*\* | 0.001 | 0.009\*\*\* |
|  | (0.000) | (0.000) | (0.825) | (0.006) |
| Unemployment | -0.016\*\*\* | 0.012\*\* | -0.020\*\*\* | -0.022\*\*\* |
|  | (0.003) | (0.045) | (0.002) | (0.000) |
| Election Closeness | 0.083\*\*\* | 0.024\*\* | 0.027\*\*\* | 0.010 |
|  | (0.000) | (0.010) | (0.006) | (0.193) |
| Republican District | 0.037\*\* | 0.025\*\* | -0.017 | -0.016\* |
|  | (0.022) | (0.034) | (0.144) | (0.076) |
| Debt to Income | -0.015 | -0.005 | 0.001 | 0.029\*\*\* |
|  | (0.453) | (0.771) | (0.965) | (0.005) |
| HPI | 0.001 | -0.000 | -0.000 | -0.000 |
|  | (0.132) | (0.957) | (0.252) | (0.778) |
| Constant | 18.242\*\*\* | 15.110\*\*\* | 2.294 | -0.968 |
|  | (0.008) | (0.003) | (0.649) | (0.839) |
| N | 136,513 | 236,635 | 437,340 | 1,411,117 | t |
| Adj. R² | 0.610 | 0.621 | 0.623 | 0.607 |
| Fixed Effects | State-Cohort,  Year-Cohort, Donor-Cohort | State-Cohort,  Year-Cohort, Donor-Cohort | State-Cohort,  Year-Cohort, Donor-Cohort | State-Cohort,  Year-Cohort, Donor-Cohor |
| *p*-values in parentheses  \* *p* < 0.10, \*\* *p* < 0.05, \*\*\* *p* < 0.01  Note: This table examines the effect of raising homestead exemption limits on individual campaign contributions. This table tests the baseline specification of 𝑌𝑌𝑖𝑖,𝑡𝑡 = 𝛽𝛽(𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑇𝑠𝑠 × 𝑃𝑃𝑃𝑃𝑃𝑃𝑇𝑇𝑡𝑡) + 𝑭𝑭𝑖𝑖,𝑠𝑠,𝑡𝑡 +  𝛾𝛾𝑠𝑠,𝑐𝑐,𝑑𝑑,𝑧𝑧,𝑡𝑡 + 𝜖𝜖𝑖𝑖,𝑡𝑡 and splits the sample into five quantiles based on the percentile rank of zip level home values measured by Zillow home value index each year. Definitions of all variables are shown in Table 1. Standard errors are clustered at the States by year by stack level. | | | | |  |

Table 3 and 4 report the baseline results of our analyses with different sub-samples, with Table 3 presenting the results across quintiles of the home value distribution; while Table 4 those across quartiles. Figures indicate that the personal bankruptcy exemption has a positive implicit insurance effect on low- and middle-asset households. The estimates are positive and significant only for low- and middle-asset value households. Additionally, in both Tables, the consumption smoothing effect is stronger for households with middle asset values (2nd quartile and 3rd quantile), and the effect dissipates as households having higher sizable assets. The empirical analysis seems to support our hypothesis that the homestead exemption reforms have positive effects on individual campaign contributions, and the effects are stronger for low- and middle- assets households that are newly covered while having less or no effects on households with higher sizable assets.

1. ***Discussion***

In the last section, our empirical analyses demonstrate that increasing homestead personal bankruptcy exemptions can cause higher individual campaign contributions using a novel stacked DID estimator. The effect is strongest for households having home assets newly covered by the by the new reform and is in line with our hypothesis and prediction. The next step of the research is to conduct other heterogeneous tests to exam if the effects vary for donations to different parties or candidates. Furthermore, we will conduct robust checks and test parallel assumptions to confirm the robustness and validity of our results.

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**Common VC Investment and Inventor Mobility**

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## Introduction

Hiring skilled workers (e.g., inventors) is challenging due to its scarcity and the constraints imposed by noncompete agreements (Chen, Hshieh, and Zhang 2023; Shen 2021). The challenge can be even more severe for startups, as they have less bargaining power in the hiring process compared to established firms (Babina et al. 2020). The “internal labour markets hypothesis” suggests that multi-firm entities can redeploy human capital internally to mitigate these fictions in external labour market, a strategy that is not easily replicable for stand-alone firms (Cestone et al. 2023). However, the prevalent practice of common venture capital (VC) investment, where VC investors invest in multiple firms within the same industry, makes this boundary less clear. Research indicates that common VC investors are associated with more overlapping directorships, which enables them to allocate resources among portfolio firms efficiently (Eldar and Grennan 2023). Given that, this raises the question of whether these investors engage in redeploying skilled human capital among their portfolio firms, similar to the internal processes of multi-firm entities. Exploring this question is essential, particularly in the context of a knowledge economy where skilled human capital act as a crucial input. Efficiently redeploying human capital can not only increase cost efficiency for investors but also benefits social welfare through increased efficiency. Yet, research on both common VC investment and internal labour markets is still limited (Cestone et al. 2023; Eldar and Grennan 2023). This study aims to add to the literature by investigating the role common VC investors play on human capital redeployment. I specifically target inventors and analyse the dynamics of their mobility between startups and existing portfolio firms. In this research, I aim to address the following questions: First, what is the impact of common VC investment on inventor mobility? Second, what are the patterns of inventor mobility? Third, what are the outcomes of this inventor mobility?

Theoretically, VCs have an incentive to reallocate resources from less profitable to more profitable startups (Fulghieri and Sevilir 2009). The incentive for this “winner-picking” can be even stronger for common VC investors. By picking the more promising startup, VCs can avoid cost duplication and create market power for the pioneer (X. Li, Liu, and Taylor 2023). Skilled labour, particularly inventors, is a crucial resource for innovative firms. The scarcity of such talent in the external labour market means that hiring inventors can be both challenging and expensive. Thus, VCs have incentives to reallocate inventors within their portfolio companies to reduce these hiring costs. Moreover, common VC investors are well- positioned to redeploy inventors. That is, common VCs find it easier to persuade inventors to

join other portfolio firms. Unlike real assets, redeploying human capital can be more challenging since human capital is rented, and neither firms nor VCs have full control over it (Zingales 2000). However, startups in the same industry share common knowledge and industry-specific skills, which help inventors quickly familiarize themselves with each other’s technologies, expediting onboarding. I hypothesize that firms receiving common VC investment exhibit higher within-industry inventor mobility to and from existing portfolio firms compared to firms in the same industry that do not receive investments from that VC.

There are two primary motives for VCs to redeploy inventors, which shape the patterns of inventor mobility. The first motive is to overcome labour market rigidities, which are characterized by the strong enforcement of noncompete agreements in external labour markets. Human capital is critical for the development of new firms, especially those competing in high- tech sectors (Hellmann and Puri 2002; Zingales 2000). Both survey and empirical research have documented that VCs play a pivotal role in helping startups recruit key employees, such as R&D leaders (Bottazzi, Rin, and Hellmann 2008; Gompers et al. 2020). However, effectively matching candidates to employers can be challenging, as it involves costly searches and dealing with bilateral asymmetric information (Paul and Scott 2011). This process can be even more challenging when the external labour market is rigid due to noncompete agreements, as skilled workers like inventors are in short supply in a rigid external labour market (Chen, Hshieh, and Zhang 2023). Common VCs can address these issues by recruiting “internally”. For common VC investors, portfolio firms serve as a valuable source of human capital. Through their involvement with these firms, VCs gain deeper insights into inventors’ abilities to add value to specific companies (Amornsiripanitch, Gompers, and Xuan 2019). The related technology and skills among firms, as well as the familiarity between VC and inventors, increase the likelihood of persuading inventors to join other portfolio firms. Hence, common VCs are likely to redeploy inventors to firms facing recruitment challenges. I hypothesize that firms receiving common VC investment exhibit higher within-industry inventor mobility from existing portfolio firms compared to firms in the same industry that do not receive investments from that VC when the labour market is rigid.

Another motive is that common VCs reallocate inventors to save costs. Common VCs are cost-conscious. For example, Li et al. (2023) show that common VC investors are less likely to continue projects if clinical trial costs are higher. For innovative firms, a large portion of R&D expenditures is allocated to hiring and incentivizing innovators (Brav et al. 2018), while human capital investment is often viewed as a “sunk” investment, which can be difficult to recoup if a startup is nearing failure (Hietaniemi et al. 2023). Common VCs are able to alleviate

the concern by recycling human capital. Through ongoing involvement, VCs gain insights into the quality of inventors. By recycling skilled human capital, VCs can retain talented workers and avoid additional hiring costs posed by the external labour market. Similarly, González- Uribe (2020) finds that portfolio firms can reuse human capital assets from other portfolio firms undergoing restructuring, such as mergers or liquidations. Hence, it’s likely that common VCs recycle human capital in firms exhibiting poor performance. I hypothesize that firms receiving common VC investment exhibit higher within-industry inventor mobility to existing portfolio firms compared to firms in the same industry that do not receive investments from that VC when startups experience innovation deterioration.

One challenge of the empirical strategy is that startups were not randomly assigned to receive common VC investments. Here, I exploit the staggered adoption of “angel investor tax credits” (ATC), which provides angel investors investing qualified startups with tax credits, as quasi-random variation in common VC investment. Prior research has found that there is a substitution effect between angel funding and VC funding (Hellmann, Schure, and Vo 2021). The findings in Denes et al. (2023) also indicate that ATCs did not affect aggregate early-stage financing but instead crowded out non-angel investments, typically early-stage VC investments. Hence, I argue that startups in states implementing ATC are less likely to receive common VC investments. This is because, on the one hand, more startups may choose angel investments. On the other hand, the remaining startups may prefer non-common VC investments to avoid the potential risk of competitive information leakage associated with common VC investments. In other words, the relevance condition holds for this instrumental variable (IV).

The instrument needs to not only affect common VC investment, but also satisfy the exclusion restriction. That is, ATC impacts inventor mobility solely through its effect on whether a startup receives common VC investment. There might be omitted variables that are correlated with both common VC investments and the outcomes of interest. For example, ATC might stimulate the regional economy, which could propel inventor mobility and startup innovation. However, this may not be a concern. Denes et al. (2023) show that ATC has no significant effect on local economic activity, including patenting activities, entrepreneurial activities, and employment for new startups. Thus, I argue that these programs are a plausibly exogenous source of variation.

This research contributes to research on the influence of common VC investors on startups. Prior research has shown that startups sharing a common VC are more likely to form alliances (Lindsey 2008), exchange innovation resources (González-Uribe 2020). Recent research has specifically focused on examining competitors within a VC’s portfolio and

uncovering the impact of common VC investors on close competitors. For example, Eldar and Grennan (2023) find common VC investment benefit startups by raising more funding, failing less, and exiting more successfully. Li et al. (2023) demonstrate that common VC investors tend to withhold funding from lagging startups, thereby cutting cost duplication and creating market power for pioneers. My research seeks to investigate mechanisms different from those explored in their study. That is, common VC investors affect startups through human capital redeployment.

This research also contributes to the emerging literature of human capital redeployment. Existing research on human capital redeployment generally focuses on the internal labour market in multi-firm entities. For example, organizations reallocate workers in internal labour market to seize growth opportunities (Cestone et al. 2023; Giroud and Mueller 2015), mitigate supply-side human resource shocks (Chauvin and Poliquin 2024), transfer knowledge (Karim and Williams 2012; Stadler, Helfat, and Verona 2022), and build competitiveness in rigid labour markets (Belenzon and Tsolmon 2016). This research is also related to Brav et al. (2018), who focus on the role of institutional investors and find that hedge fund activism leads to higher rate of inventor departures and arrivals. This research extends current literature on human capital redeployment to venture capital industry.

This research is most related to González-Uribe (2020), who shows that the exchange of innovation resources is prevalent among startups with common VCs (e.g., the exchange of inventors). However, my research diverges in several key areas. First, my research specifically focuses on competitors within a VC’s portfolio and examines the dynamics between them. This context is important for investigating inventor mobility. Inventors are always restricted to move within the same industry (Marx 2011), and such restrictions can negatively affect innovation (Gu et al. 2022). By investigating inventor mobility and its pattern under common VC investment, I can identify a unique value associated with VC involvement. Second, this study tries to extend González-Uribe's by assessing the outcomes of inventor mobility, such as startups’ performance and innovation.

## Literature Review and Hypothesis Development

#### Literature Review

This research intersects with four main areas of existing literature. First, it relates to the literature on the impact of common VC investors on startups. Lindsey (2008) pioneered this area by demonstrating that common VC investors increase the likelihood of firms forming alliances, introducing a novel value-adding facet of VC. González-Uribe (2020) builds on this by showing that exchanges of innovation resources (e.g., patent citation, inventor) are more prevalent for firms with common VCs. More recently, research has started to explore the dynamics of direct competitors within the portfolio. Specifically, Li et al. (2023) show that common ownership leads VCs to shut down underperforming drug projects and withhold funding from lagging startups, thereby cutting down cost duplication and creating market power for pioneers. Their focus on the pharmaceutical sector helps them better identify competitors, yet this emphasis might constrain the generalizability of their results due to the industry’s unique characteristics, like substantial upfront R&D costs and low productivity spillovers of R&D (Benmelech et al. 2021). Eldar and Grennan (2023) span from all industries and find that common VC investment is associated with positive outcomes for startups (e.g., higher probability of IPOs and sale), highlighting overlapping directors as the channel for informal exchanges within VC portfolio. However, common VC investment is still often neglected (Eldar and Grennan 2023). Additionally, existing research does not adequately address the channels through which common investors impact firm performance (M. Antón et al. 2023). My study adds the literature by exploring a different mechanism. That is, common VC investors affect startups through human capital redeployment.

Second, this research is related to the studies on the role of VCs play in their portfolio company. Venture capital research reveals that investors not only provide funds but also add value through strategic oversight, guidance, and governance (Bottazzi, Rin, and Hellmann 2008). Among those nonfinancial activities, human capital management is highlighted in existing research. Hellmann and Puri (2002) suggests that VCs play a pivotal role in professionalizing startups by influencing their human resource strategies. For example, appointing external CEOs and hiring sales and marketing vice president. This finding is expanded by Bottazzi et al. (2008) who report VCs’ assistance in hiring R&D leaders. The survey by Gompers et al. (2020) supplements existing empirical research by confirming the role of VCs in the recruitment processes of startups. They find that VCs, particularly early- stage VCs and California VCs, assist startups in hiring both board members and employees.

Amornsiripanitch et al. (2019) further demonstrate that VCs who serve on the boards of their portfolio companies are likely to become actively involved and use their network connections for recruiting. My study adds the literature by investigating the role of VC in the reallocation of human capital and recognizing portfolio firms as an important source of human capital.

Third, this study is related to the growing literature exploring human capital redeployment. Existing research on human capital redeployment generally focuses on the internal labour market in multi-firm entities. As suggested by Tate and Yang (2023), internal labour markets allow organizations to redeploy human capital to more productive uses while reducing the cost from search, training, or information asymmetry about worker quality. Previous research has shown that organizations reallocate workers in internal labour market to seize growth opportunities (Cestone et al. 2023; Giroud and Mueller 2015), mitigate supply- side human resource shocks (Chauvin and Poliquin 2024), transfer knowledge (Karim and Williams 2012; Stadler, Helfat, and Verona 2022), and build competitiveness in rigid labour markets (Belenzon and Tsolmon 2016). Beyond internal labour market, Brav et al. (2018) find that hedge fund activism leads to higher rate of inventor departures and arrivals. And the redeployed human capital after hedge fund intervention is associated with higher innovation quantity and quality. This research is trying to extend current research on human capital redeployment to venture capital.

Fourth, this study relates to the research on the effect of institutional cross-ownership on firms. Ongoing discussions explore whether cross-ownership results in anticompetitive behaviours. Some empirical studies support the view that cross-ownership reduces product- market competition. For instance, Azar et al. (2018) find a causal relationship between the concentration of common ownership in the airline industry and higher average ticket prices. Similarly, He and Huang (2017) note that institutional cross-ownership can lead to the sharing of technological know-how and coordinated R&D efforts among cross-held firms, thereby improving innovation productivity. However, counterarguments exist. Dennis et al. (2022) argue that common ownership does not causally influence airline ticket prices, suggesting that the correlations observed by Azar et al. (2018) are driven by variations in market shares rather than ownership structures. Additionally, Lewellen and Lowry (2021) critique prior research’s identification strategies and find no evidence linking common ownership to increased corporate coordination activities such as joint ventures, strategic alliances, and mergers. Considerable focus has been placed on analysing the anticompetitive outcomes associated with common ownership, while less effort has been devoted to examining its impacts on areas beyond market competition and its potential positive effects (E. Antón and Giné 2021; X. Li, Liu, and Taylor

2023). Besides, there is scepticism about institutional investors’ ability to affect firms’ management (Eldar and Grennan 2021; Gilje, Gormley, and Levit 2020; Lewellen and Lowry 2021). One reason is that the increase in common ownership coincides with the rise of inattentive institutional investors. These investors may confound the true effects of common ownership (Gilje et al., 2020). Consequently, the impact of common institutional ownership on firm outcomes (e.g., innovation productivity) is still uncertain. The VC setting in this research presents several benefits. VCs are typically active investors, and their significant equity holdings and directorships enable them to influence the strategies of their portfolio companies (Eldar and Grennan 2023; X. Li, Liu, and Taylor 2023). By examining the role of active investors, this research can provide new insights into the impact of common institutional ownership on firms.

#### Hypothesis Development

Based on the existing literature, it is reasonable to expect that common VCs have incentives to reallocate inventors from less promising firms to more promising ones. Theoretically, VCs have an incentive to reallocate resources from less profitable to more profitable startup (Fulghieri and Sevilir 2009). When firms within the same industry are held by the same VC investor, the incentive for this “winner-picking” can be even stronger. By picking the more promising startup, VCs can avoid cost duplication and create market power for the pioneer (X. Li, Liu, and Taylor 2023). Skilled labour, particularly inventors, is a crucial resource for innovative firms. The scarcity of such talent in the external labour market means that hiring inventors can be both challenging and expensive. I expect that by reallocating inventors within their portfolio companies, VCs can significantly reduce these hiring costs.

Moreover, common VC investors are well-positioned to redeploy inventors. On the one hand, through their involvement with portfolio firms, VCs gain deeper insights into inventors’ abilities to add value to specific companies (Amornsiripanitch, Gompers, and Xuan 2019). On the other hand, common VCs are easier to persuade inventors to join other portfolio firms. Unlike real assets, redeploying human capital can be more challenging since human capital is rented, and neither firms nor VCs have full control over it (Zingales 2000). However, startups in the same industry share common knowledge and industry-specific skills, which help inventors quickly familiarize themselves with each other’s technologies, expediting onboarding.

Based on this motivation, I hypothesize that common VC investment facilitate within- portfolio inventor mobility. Specifically, I test the following null hypothesis:

*Hypothesis* 1: Firms receiving common VC investment exhibit higher within-industry inventor mobility to and from existing portfolio firms compared to firms in the same industry that do not receive investments from that VC.

The completed paper will test further two hypotheses using alternate and extended datasets. As these further hypotheses constitute future research at present, they are not stated here. The Conclusion below outlines details of my future, planned research.

## Methodology

#### Data

My study combines data from several sources. I focus on the investments made by US venture capital firms in US entrepreneurial firms that have filed at least one patent with the US Patent and Trademark Office (USPTO). The investment data is sourced from Refinitiv Workspace’s Private Equity database. Given the availability of data on inventors, I focus on startups that received their first VC financing after 2000. I specifically examine first-time investments made by VCs in these startups, excluding those where the startups first entered the VC’s portfolio after 2015. Inventor mobility is observed over a window of five years before and after the investment. The cutoff of 2015 is chosen to mitigate the confounding effects of COVID-19 on inventor mobility and other firm outcomes (e.g., innovation). My work is solely on venture capital investments, excluding investments by individuals (e.g., angel) and later stage investors (e.g., buyout funds).

To construct the common VC investment dataset, I first calculate the holding period for each VC-startup pair, spanning from the year the startup first enters the VC’s portfolio to its exit date. This approach allows me to track the composition of each VC’s portfolio and determine whether a startup shares a particular VC with its competitors. Common VC investment is then identified on a startup-VC-year basis, indicating whether a startup enters the portfolio of a VC that also invests in other startups within the same industry. For industry classification, I utilize Refinitiv Workspace’s TRBC industry classification system, which categorizes industries into five levels of granularity, ranging from the most detailed with 627 industries to the broadest with 13 industries. In my primary analysis, I employ a moderate level of classification, which yields a total of 136 distinct industries.

I construct a patent dataset from several sources, starting with the USPTO Patent Examination Research Dataset (PatEx), which provides comprehensive information on patent applications, such as filing date, patent applicant, application type, and application status. I only focus on utility patent applications filed between 2001 and 2023. The year 2001 is chosen as the starting point because inventor data for both granted and rejected patent applications became available following the enactment of the American Inventors Protection Act (AIPA) in late 2000. Before 2000, only inventors for successful patent applications could be observed, which could bias our inventor sample towards more successful inventors. To identify the firms responsible for filing the patent applications, I use the USPTO patent assignment database and the 2022 PatEx release. Before the America Invents Act (AIA) was implemented on September

16, 2012, patent ownership initially vested in the named inventors, requiring their employers to obtain ownership through patent assignments. However, after the adoption of the AIA, the USPTO permitted assignees to file patents directly, making employee assignments redundant. The 2022 PatEx, for the first time, provides information on non-inventor applicants, allowing researchers to directly identify the firms responsible for patent applications. To match the first organizational assignee/applicant of a patent application with startups that secured venture capital investment, I first use the Stata command “stn\_compname” to standardize company names in both datasets. Then, I employ the “reclink2” command to fuzzy-match these standardized names. I focus on exact match, resulting in 96,522 patent applications for 5,527 VC-backed startups.

My inventor dataset encompasses both the career histories and the patents of inventors. I focus on patents filed by VC-backed startups and identify the associated inventors using PatentsView, an open data platform supported by the USPTO that provides disambiguated information on individual inventors.[1](#_bookmark14) To track the careers of these identified inventors, I follow existing literature by using patent applications, assuming that changes in patent assignee/applicant between two consecutive patent applications reflect changes in employment (e.g., González-Uribe, 2020; Grieser & Liu, 2019; K. Li & Wang, 2023). For example, if an inventor filed a patent at startup A in 2008, and then filed another patent at startup B in 2010, I assume that the inventor moved from startup A to startup B in 2009. To avoid potential misclassification, I exclude cases where inventors return to a previous company within one year (Melero, Palomeras, and Wehrheim 2020). The resulting dataset includes 3,334 unique inventors who moved to a new startup for a total of 4,345 moves during the sample period. Among these moves, 54% are within-industry moves. When aggregated to the firm level, 1,753 firms experienced inventors moving to 1,611 firms, resulting in 4,121 firm-level inventor movement events.

[Table A1](#_bookmark31) (see the appendix) reports the full sample composition. Panel A shows the number of VC investments and the ratio of common VC investments for each year from 2001 to 2015. The ratio of common VC investments increased from 22.7% in 2001 to about 59.21% in 2015, peaking in 2012 with 65.7% of new investments being common VC investments. Although the share dropped slightly between 2012 and 2015, it remained high. Panel B shows the distribution of industries for startups. Most innovative startups are in Technology (56.97%) and Healthcare (27.12%). Panel C shows the state distribution of all the startups.

1 https://patentsview.org

Unsurprisingly, most startups are in California (46.6%), followed by Massachusetts (10.89%) and New York (5.69%).

#### Common VC Investment Likelihood

Despite the growing trend of common VC investments, no studies have examined how these investments are formed. Therefore, I analyse startup characteristics that lead VCs to engage in common VC investments. This examination will help construct a control group for common VC investments and form the logic for selecting control variables.

Following previous research, I first build a group of pseudo deals as a control group (e.g., Bena & Li, 2014; Gu et al., 2022; Ma, 2020). Specifically, for each VC 𝑗𝑗 that conducts common VC investment in year 𝑡𝑡 and industry 𝑠𝑠, I pair VC 𝑗𝑗 with all the startups in industry 𝑠𝑠 that received funding from other VCs in the same year but were never funded by VC 𝑗𝑗. I then estimate the likelihood of common VC investment with the following specification:

𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑠𝑠𝑡𝑡𝐼𝐼𝐼𝐼𝐼𝐼𝑡𝑡𝑖𝑖𝑖𝑖𝑖𝑖 = 𝛼𝛼0 + 𝛽𝛽0 ⋅ *Startup characteristics*𝑖𝑖𝑖𝑖−1 + 𝛼𝛼𝑖𝑖 + 𝛼𝛼𝑖𝑖 + 𝛼𝛼𝑖𝑖 + 𝜀𝜀𝑖𝑖𝑖𝑖𝑖𝑖, (1)

Where subscripts 𝑖𝑖, 𝑗𝑗, and 𝑡𝑡 denote startup, VC, and year, respectively. 𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑠𝑠𝑡𝑡𝐼𝐼𝐼𝐼𝐼𝐼𝑡𝑡𝑖𝑖𝑖𝑖𝑖𝑖 is a dummy variable equal to 1 for the realized deal and 0 for pseudo deal. *Startup characteristics*𝑖𝑖𝑖𝑖−1 includes typical startup characteristics such as age, successful

patent applications filed by a startup before year 𝑡𝑡, the total capital raised by a startup before

year 𝑡𝑡, the number of VC firms has invested in the startup before year 𝑡𝑡. 𝛼𝛼𝑖𝑖 , 𝛼𝛼𝑖𝑖 and 𝛼𝛼𝑖𝑖 are startup fixed effects, VC fixed effect and year fixed effects, respectively. Standard errors are clustered at the startup-VC pair level. A detailed explanation and construction for each variable are provided in [Table A2](#_bookmark32) (see the appendix).

[Table 1](#_bookmark27) reports the results of [Eq. (1)](#_bookmark16), highlighting several key factors influencing common VC investment in startups. Startups with more investors in the previous period are more likely to receive common VC investments in the following period, likely because a larger number of investors signifies the startup’s quality and credibility. Conversely, startups with higher cumulative funding in the prior period are less likely to accept common VC investments later, possibly due to their reduced need for additional funding and the risk of leaking competitive information associated with common VC investment. Younger startups are more likely to receive common VC investments, possibly because VCs use this strategy to mitigate the higher risk associated with young firms. Interestingly, the coefficient on Ln (Patent stock) is not significant, suggesting that the number of patents held is not a crucial criterion for common VC investment decisions.

#### Econometric Specification of Main Analysis

My study first investigates whether startups receiving common VC investment are associated with higher within-portfolio inventor mobility. To compare the difference in inventor mobility for startups receiving and not receiving common VC investment during the same period, I first build a group of pseudo deals as a control group (e.g., Bena & Li, 2014; Gu et al., 2022; Ma, 2020). Specifically, for each VC 𝑗𝑗 that conducts common VC investment in year 𝑡𝑡 and industry 𝑠𝑠, I pair each VC with all the startups in industry 𝑠𝑠 that received funding from other VCs in the same year but were never funded by VC 𝑗𝑗. For each real deal between startup 𝑖𝑖 and VC 𝑗𝑗 (treated group), I match it with five pseudo deals 𝑖𝑖′ − 𝑗𝑗 (control group)*,* where startup 𝑖𝑖′ is from the same industry as startup 𝑖𝑖 and has the closest propensity score estimated using firm age, the total capital raised by a startup before year 𝑡𝑡, the number of VC firms has invested in the startup before year 𝑡𝑡. This approach produced 20,851 pseudo deals paired with 5,242 realized deals.

For each deal (pseudo-deal), I construct a group of treated and control observations in a 11-year window around the year of deal (pseudo-deal) (5 years before and 5 years after). The baseline specification is as follows:

𝑌𝑌𝑖𝑖𝑖𝑖𝑖𝑖𝑖𝑖 = 𝛼𝛼0 + 𝛽𝛽0 ⋅ 𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑠𝑠𝑡𝑡𝐼𝐼𝐼𝐼𝐼𝐼𝑡𝑡𝑖𝑖𝑖𝑖𝑖𝑖 × *Post*𝑖𝑖𝑖𝑖𝑖𝑖 + 𝛽𝛽1 ⋅ *Post*𝑖𝑖𝑖𝑖𝑖𝑖 + *Controls*𝑖𝑖𝑖𝑖 + 𝛼𝛼𝑖𝑖 + 𝛼𝛼𝑖𝑖𝑖𝑖 + 𝛼𝛼𝑖𝑖 +

𝜀𝜀𝑖𝑖𝑖𝑖𝑖𝑖𝑖𝑖, (2)

Where subscripts 𝑖𝑖, 𝑗𝑗, 𝑐𝑐, 𝑎𝑎𝐼𝐼𝑎𝑎 𝑡𝑡 denote startup, VC, year and deal year, respectively. 𝑌𝑌𝑖𝑖𝑖𝑖𝑖𝑖𝑖𝑖 is one of measures of inventor mobility between startup 𝑖𝑖 and portfolio firms of VC 𝑗𝑗 in year 𝑡𝑡 .

𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑠𝑠𝑡𝑡𝐼𝐼𝐼𝐼𝐼𝐼𝑡𝑡𝑖𝑖𝑖𝑖𝑖𝑖 is a dummy variable equal to 1 for the realized common VC investment and 0

for the pseudo common VC investment. *Post*𝑖𝑖𝑖𝑖𝑖𝑖 equals 1 for any of the five years after deal (pseudo-deal) year. 𝛼𝛼𝑖𝑖𝑖𝑖, 𝛼𝛼𝑖𝑖 and 𝛼𝛼𝑖𝑖 are startup-VC pair fixed effects, deal (pseudo-deal) year fixed effect and year fixed effects, respectively. Standard errors are clustered at the startup-VC pair level. *Controls*𝑖𝑖𝑖𝑖 includes VC reputation, VC age, firm age, total capital previously raised by the startup, patent stock, and the number of VC firms that own a stake in startup in the previous year. The explanations for each variable are included in the [Table A2](#_bookmark32) (see the appendix). The variable of interest is 𝛽𝛽0 . If the hypothesis holds, that is, firms receiving common VC investment are associated with higher within-portfolio inventor mobility, then 𝛽𝛽0 should be significantly positive.

#### Identification Strategy

As startups are not randomly assigned to receive common VC investment, endogeneity issue remains. To address this, I exploit the staggered adoption of ATC, which provides angel investors with tax credits for investing in qualified startups, as an instrumental variable for common VC investment.

During the period of 1988-2018, 31 states across the United States enacted ATCs to provide tax credits to accredited angel investors, aiming to stimulate entrepreneurship and technological advancement.[2](#_bookmark20) [Table A3](#_bookmark33) provides an overview of the adoption of ATC across states. Prior research has indicated that there is a substitution effect between angel funding and VC funding (Hellmann, Schure, and Vo 2021). A recent study by Denes et al. (2023) shows that ATCs did not affect aggregate early-stage financing but instead crowded out non-angel investments, typically early-stage VC investments. Hence, it is likely that startups in states implementing ATCs are less likely to receive common VC investment, as those firms tend to avoid the potential risk of competitive information leakage associated with common VC investment when multiple funding sources are available. In other words, the relevance condition holds for this IV.

To ensure the exclusion restriction holds, ATC should be uncorrelated with other unobservable drivers of inventor mobility and startup innovation. There might be omitted variables that are correlated with both common VC investments and the outcomes of interest. For example, ATC might stimulate the regional economy, which could propel inventor mobility and startup innovation. However, this may not be a concern. Research has shown that ATC has no significant effect on local economic activity, including patenting activities, entrepreneurial activities, and employment for new startups (Denes et al., 2023).

Additionally, I conduct a placebo test on a subsample to ensure there is no violation of the exclusion condition. Following the logic of Eldar and Grennan (2023), I create a subsample where ATCs are less likely to influence the incidence of common VC investment. As ATCs are only available to firms in specific high-tech industries, such as bioscience and information technology, the subsample includes startups outside the two broad industries of healthcare and technology. The rationale is that if IV has no effect in the first stage, then any significant effect in the second stage should be attributed to channels other than common VC investment. Conversely, if there is no significant effect in the second stage, we can infer that ATC affects

2 In terms of the eligibility for Angel Investor Tax Credits, states generally require that startups conduct technological activities within their borders. For example, New Jersey specifies eligible technologies such as biotechnology and information technology (https[://www.njeda.gov/angeltaxcredit/).](http://www.njeda.gov/angeltaxcredit/))

outcome variables only through its impact on common VC investment, thereby confirming that the exclusion condition holds for this IV. Thus, I argue that these programs are a plausibly exogenous source of variation.

Following Qian (2008), the first-stage equation for the IV analysis is estimated by following equation:

𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑠𝑠𝑡𝑡𝐼𝐼𝐼𝐼𝐼𝐼𝑡𝑡𝑖𝑖𝑖𝑖𝑖𝑖 × *Post*𝑖𝑖𝑖𝑖𝑖𝑖 = α0 + 𝛽𝛽0 ⋅ 𝐴𝐴𝐴𝐴𝐴𝐴𝑖𝑖𝑖𝑖 × *Post*𝑖𝑖𝑖𝑖𝑖𝑖 + 𝛽𝛽1 ⋅ *Post*𝑖𝑖𝑖𝑖𝑖𝑖 + *Controls*𝑖𝑖𝑖𝑖𝑖𝑖 + 𝛼𝛼𝑖𝑖 +

𝛼𝛼𝑖𝑖 + 𝛼𝛼𝑖𝑖𝑖𝑖 + 𝜀𝜀𝑖𝑖𝑖𝑖𝑖𝑖𝑖𝑖, (3) The second-stage regression is as follows:

𝑌𝑌𝑖𝑖𝑖𝑖𝑖𝑖𝑖𝑖 = 𝛼𝛼0 + 𝛽𝛽0 ⋅ 𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑠𝑠𝑡𝑡𝐼𝐼𝐼𝐼�𝐼𝐼𝑡𝑡𝚤𝚤𝚤𝚤𝑖𝑖 × *Post*𝚤𝚤𝚤𝚤𝑖𝑖 + 𝛽𝛽1 ⋅ *Post*𝑖𝑖𝑖𝑖𝑖𝑖 + *Controls*𝑖𝑖𝑖𝑖𝑖𝑖 + 𝛼𝛼𝑖𝑖 + 𝛼𝛼𝑖𝑖 + 𝛼𝛼𝑖𝑖𝑖𝑖 +

𝜀𝜀𝑖𝑖𝑖𝑖𝑖𝑖𝑖𝑖, (4)

Where the subscripts 𝑖𝑖, 𝑗𝑗, 𝑐𝑐 and 𝑡𝑡 denote startup, VC, deal year and year, respectively. 𝐴𝐴𝐴𝐴𝐴𝐴𝑖𝑖𝑖𝑖 is a dummy variable that equals 1 if the state of startup 𝑖𝑖 introduced ATC in deal (pseudo-deal) year 𝑐𝑐.

## Empirical Results

#### Summary Statistics

[Table 2](#_bookmark28) presents summary statistics for the main variables in the full sample. The full sample includes 20,851 pseudo deals and 5,242 realized deals over a 5-year period before and after the deal (or pseudo-deal). The mean of inventor within-portfolio inflow and outflow is 0.0058 and 0.0052, respectively. These numbers are consistent with the mean of 0.01 for inventor inflow and outflow detected by González-Uribe (2020).

#### Baseline Results

[Table 3](#_bookmark29) presents the main results of my analysis. In column (1) and column (2), I present the ordinary least squares (OLS) estimation of [Eq. (2).](#_bookmark18) Column (1) focuses on the effect of common VC investment on within-portfolio inventor outflow, while column (2) focuses on within-portfolio inventor inflow. In column (1), the coefficient on 𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑠𝑠𝑡𝑡𝐼𝐼𝐼𝐼𝐼𝐼𝑡𝑡𝑖𝑖𝑖𝑖𝑖𝑖 × *Post*𝑖𝑖𝑖𝑖𝑖𝑖 is significantly positive, indicating that firms experience higher inventor mobility to other portfolio firms after receiving common VC investment. The significantly positive coefficient on 𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑠𝑠𝑡𝑡𝐼𝐼𝐼𝐼𝐼𝐼𝑡𝑡𝑖𝑖𝑖𝑖𝑖𝑖 × *Post*𝑖𝑖𝑖𝑖𝑖𝑖 in column (2) suggests that firms experience higher inventor mobility from other portfolio firms after receiving common VC investment, although the magnitude is lower than that of inventor outflow.

In terms of IV approach, column (3) in [Table 3](#_bookmark29) presents the first stage result, where I

preform the regression in [Eq. (3).](#_bookmark21) As expected, there is a negative association between

𝐴𝐴𝐴𝐴𝐴𝐴𝑖𝑖𝑖𝑖 × *Post*𝑖𝑖𝑖𝑖𝑖𝑖 and 𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑠𝑠𝑡𝑡𝐼𝐼𝐼𝐼𝐼𝐼𝑡𝑡𝑖𝑖𝑖𝑖𝑖𝑖 × *Post*𝑖𝑖𝑖𝑖𝑖𝑖 , consistent with the hypothesis that ATC negatively impacts common VC investment. The first stage F-statistic is 34.67, indicating no problem with weak instruments. Column (4) and column (5) show the second stage of the 2SLS regression in [Eq. (4).](#_bookmark22) The positive coefficients are consistent with the OLS results. After common VC investment, the within-portfolio inventor outflow increases by approximately 5.69%, and the inventor inflow increases by approximately 5.62%, compared to the control group, controlling for VC-startup pair, deal (pseudo deal) year, and year fixed effects.

To sum, these results support my prediction that firms receiving common VC investment are associated with higher within-portfolio inventor mobility.

## Conclusion

In this research, I investigate whether common VC investors redeploy skilled human capital among their portfolio firms. Specifically, I focus on inventors and analyse the dynamics of their mobility between startups and existing portfolio firms. I demonstrate that firms receiving common VC investment exhibit higher within-portfolio inventor mobility. While previous research has documented inventor mobility within VC portfolios (González-Uribe 2020), this study uniquely examines the dynamics among competitors within a VC’s portfolio. This context is crucial for investigating inventor mobility since inventors are typically restricted to moving within the same industry (Marx 2011), and such restrictions can negatively impact innovation (Gu et al. 2022). Efficiently reallocating inventors within the same industry through common VC investment can thus enhance societal value by increasing innovation efficiency. Therefore, this research contributes to the VC literature by highlighting an additional role of VCs in the economy.

Currently, the research is in its early stages, and several aspects need refinement. First, dataset refinement. I have collected patent data and matched it with startups, which serves as the primary source for measuring the innovation productivity of both inventors and startups. However, the fuzzy matching between patents and startups needs manual verification. Additionally, I need to collect citation data for each patent to serve as another measure of innovation performance and to track knowledge spillover. The measure of inventor mobility also needs refinement. A more accurate method involves using LinkedIn profiles of inventors (Ge, Huang, and Png 2016). Furthermore, gathering background information from LinkedIn profiles, such as educational history, can help uncover the reasons behind each inventor’s mobility, which may serve as the basis for my second paper. Thus, my next stage plan also includes collecting inventor’s LinkedIn profile.

Second, additional analysis. While this report has identified within-portfolio inventor mobility in common VC’s portfolio, the patterns of this mobility and its associated outcomes (e.g., innovation output) remain unclear. Therefore, I need to conduct additional tests on the mechanisms between common VC investment and inventor mobility and investigate the outcomes associated with this mobility.

**Table 1**

**The likelihood of common VC investment**

|  |  |
| --- | --- |
|  | (1) |
|  | Investment |
| Ln (Investors) | 0.0347\*\*\* |
|  | (0.0011) |
| Ln (Funding) | -0.0083\*\*\* |
|  | (0.0003) |
| Ln (Patent stock) | -0.0005 |
|  | (0.0004) |
| Ln (Firm Age) | -0.0104\*\*\* |
|  | (0.0009) |
| Observations | 648117 |
| Adj R2 | 0.0256 |
| Startup FE | Y |
| VC FE | Y |
| Year FE | Y |
| Table 1 reports regression results related to startup characteristics on the likelihood of common VC investment. Investment is the dependent variable that equals 1 for realized common VC investment, and 0 for pseudo common VC investment. Ln (Investors) is natural logarithm of 1 plus the number of VC firms has invested in the startup before given year. Ln (Funding) is natural logarithm of the total capital raised by a startup before given year. Investment amounts are in millions of dollars and have been inflation-adjusted to 2010. Ln (Patent stock) is natural logarithm of 1 plus the number of successful patent applications filed by a startup before given year. Ln (Firm Age) is natural logarithm of 1 plus firm age. Startup, VC, year fixed effects are included. Robust standard errors clustered at the startup and VC pair level are reported in parentheses. \*, \*\*, and \*\*\* indicate  significance at the 10%, 5%, and 1% levels, respectively. | |

**Table 2**

**Summary Statistics for Main Analysis Sample**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | N | Mean | SD | p25 | Median | p75 | Max |
| Investment | 201670 | 0.1958 | 0.3968 | 0 | 0 | 0 | 1 |
| Inflow | 201670 | 0.0058 | 0.2020 | 0 | 0 | 0 | 24 |
| Outflow | 201670 | 0.0052 | 0.2111 | 0 | 0 | 0 | 35 |
| Firm age | 201670 | 3.9694 | 2.9629 | 2 | 4 | 6 | 13 |
| Investors | 201670 | 2.2623 | 1.7484 | 1 | 2 | 3 | 8 |
| Patent | 201670 | 0.7342 | 1.8129 | 0 | 0 | 1 | 11 |
| Patent stock | 201670 | 1.8923 | 4.5734 | 0 | 0 | 1 | 29 |
| Funding | 201670 | 18.4587 | 28.9572 | 0 | 6.7727 | 23.9484 | 160.5598 |
| Distance | 201670 | 1153.3688 | 1075.3107 | 26.5351 | 745.0391 | 2428.3495 | 2699.3396 |
| VC age | 201670 | 20.4654 | 15.1440 | 9 | 17 | 29 | 96 |
| VC reputation | 201670 | 0.0159 | 0.0223 | 0 | 0.0074 | 0.0231 | 0.1019 |
| This table reports summary statistics of the full sample at the deal (pseudo deal)-year level. The full sample includes 20,851 pseudo deals and 5,242 realized deals over a 5-year period before and after the deal (or pseudo  -deal). Funding is reported in millions of dollars and is inflation-adjusted to 2010 values. Definitions of the variables are provided in [Table A2](#_bookmark32) (see the appendix). | | | | | | | |

**Table 3**

**Common VC investment and within-portfolio inventor mobility**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) | (5) |
|  | OLS | OLS | 1st Stage | 2nd Stage | 2nd Stage |
|  | Ln (Outflow) | Ln (Inflow) | Investment ×  Post | Ln (Outflow) | Ln (Inflow) |
| ATC × Post |  |  | -0.0314\*\*\* |  |  |
|  |  |  | (0.0063) |  |  |
| Investment × Post | 0.0031\*\*\* | 0.0024\*\* |  | 0.0553\*\*\* | 0.0547\*\* |
|  | (0.0008) | (0.0012) |  | (0.0164) | (0.0221) |
| Post | -0.0018\*\*\* | -0.0012\*\* | 0.1837\*\*\* | -0.0110\*\*\* | -0.0105\*\*\* |
|  | (0.0005) | (0.0005) | (0.0030) | (0.0029) | (0.0040) |
| Ln (VC age) | -0.0011 | -0.0017 | 0.0042 | -0.0014 | -0.0019 |
|  | (0.0008) | (0.0013) | (0.0080) | (0.0009) | (0.0014) |
| VC reputation | 0.0159 | -0.0108 | -0.1437\*\* | 0.0233 | -0.0035 |
|  | (0.0136) | (0.0178) | (0.0733) | (0.0143) | (0.0181) |
| Ln (Investors) | -0.0002 | 0.0019\*\*\* | 0.0385\*\*\* | -0.0021\*\*\* | -0.0001 |
|  | (0.0004) | (0.0006) | (0.0027) | (0.0007) | (0.0009) |
| Ln (Funding) | 0.0007\*\*\* | 0.0009\*\*\* | 0.0191\*\*\* | -0.0003 | -0.0002 |
|  | (0.0002) | (0.0002) | (0.0012) | (0.0004) | (0.0004) |
| Ln (Firm age) | 0.0012\*\*\* | -0.0011\*\* | -0.0239\*\*\* | 0.0024\*\*\* | 0.0001 |
|  | (0.0004) | (0.0005) | (0.0042) | (0.0005) | (0.0007) |
| Ln (Patent stock) | 0.0027\*\*\* | -0.0001 | 0.0086\*\*\* | 0.0022\*\*\* | -0.0006 |
|  | (0.0004) | (0.0006) | (0.0020) | (0.0004) | (0.0006) |
| 1st stage F-stat |  |  | 34.67 |  |  |
| Observations | 201667 | 201667 | 201667 | 201667 | 201667 |
| Adj R2 | 0.0671 | 0.0771 |  |  |  |
| Pair FE | Y | Y | Y | Y | Y |
| Year FE | Y | Y | Y | Y | Y |
| Deal Year FE | Y | Y | Y | Y | Y |
| The table reports the coefficients and standard errors (in parentheses) of [Eq. (2),](#_bookmark18) [Eq. (3)](#_bookmark18) and [Eq. (4).](#_bookmark22) Robust standard errors are clustered by startup-VC pair level. The first-stage F -statistic is the Kleibergen-Paap Wald  statistic. Definitions of the variables are provided in [Table A2](#_bookmark32) (see the appendix). ∗p<.1; ∗∗p<.05; ∗∗∗p<.01 | | | | | |

## Appendix

**Table A1**

**Statistics and Trends in Common VC Investment**

|  |  |  |  |
| --- | --- | --- | --- |
| **Panel A: Common VC investment by year** | | | |
| Year | Number of Investments | Number of common VC investment | Percentage of common VC  investment |
| 2001 | 608 | 138 | 22.70% |
| 2002 | 570 | 201 | 35.26% |
| 2003 | 721 | 347 | 48.13% |
| 2004 | 895 | 479 | 53.52% |
| 2005 | 927 | 508 | 54.80% |
| 2006 | 1005 | 546 | 54.33% |
| 2007 | 1044 | 602 | 57.66% |
| 2008 | 893 | 544 | 60.92% |
| 2009 | 607 | 375 | 61.78% |
| 2010 | 689 | 427 | 61.97% |
| 2011 | 895 | 588 | 65.70% |
| 2012 | 745 | 474 | 63.62% |
| 2013 | 847 | 530 | 62.57% |
| 2014 | 1031 | 630 | 61.11% |
| 2015 | 1086 | 643 | 59.21% |
| Full sample | 12563 | 7032 | 55.97% |

|  |  |  |
| --- | --- | --- |
| **Panel B: Industry distribution of startups** | | |
| Industry | Number of startups | Percentage of startups |
| Technology | 2956 | 56.97% |
| Healthcare | 1407 | 27.12% |
| Industrials | 353 | 6.80% |
| Consumer cyclicals | 206 | 3.97% |
| Energy | 84 | 1.62% |
| Basic materials | 81 | 1.56% |
| Consumer non-cyclicals | 55 | 1.06% |
| Other | 47 | 0.91% |
| Total | 5189 | 100.00% |

|  |  |  |
| --- | --- | --- |
| **Panel C: State distribution of startups (Top 10 states)** | | |
| States | Number of startups | Percentage of startups |
| California | 2418 | 46.60% |

|  |  |  |
| --- | --- | --- |
| **Panel C: State distribution of startups (Top 10 states)** | | |
| States | Number of startups | Percentage of startups |
| Massachusetts | 565 | 10.89% |
| New York | 295 | 5.69% |
| Texas | 260 | 5.01% |
| Washington | 214 | 4.12% |
| Pennsylvania | 147 | 2.83% |
| Colorado | 124 | 2.39% |
| Illinois | 100 | 1.93% |
| New Jersey | 98 | 1.89% |
| Maryland | 87 | 1.68% |
| During the period from 2001 to 2015, 5,189 unique startups entered the portfolios of 1,693 unique venture capital firms for the first time, resulting in 12,563 VC investments, 56% of which were common VC investments. Follow-on funding rounds are excluded from the sample. In Panel B, there are 26 startups in the  financial industry, 11 in the utilities industry, 5 in the academic and education services industry, and 5 in the real estate industry. All these startups are categorized under the “Other” industry. | | |

**Table A2**

**Variable Definition and Construction**

|  |  |
| --- | --- |
| ***Variables*** | ***Definition and construction*** |
| ***A. Inventor mobility*** |  |
| ***Ln(Inflow)*** | Natural logarithm of 1 plus the number of inventors who move from portfolio  firms of a given VC. |
| ***Ln(Outflow)*** | Natural logarithm of 1 plus the number of inventors who move to portfolio  firms of a given VC. |
| ***B. Pair*** |  |
| ***Investment*** | A dummy variable that equals 1 for realized common VC investment, and 0  for pseudo common VC investment. |
| ***Post*** | A dummy variable that equals 1 for any of the five years after common VC  investment. |
| ***Ln(Size)*** | Natural logarithm of 1 plus the number of startups in the specific industry held  by the venture capitalist. |
| ***Technological proximity*** | The degree of technological similarity between the focal startup and the existing portfolio firms.  𝑠𝑠𝑖𝑖 𝑠𝑠′  Technological Proximity = 𝑘 𝑘  �𝑠𝑠𝑖𝑖𝑠𝑠′ �𝑠𝑠𝑘𝑘𝑠𝑠′  𝑖𝑖 𝑘𝑘  where the vector 𝑠𝑠 = (𝑠𝑠1, 𝑠𝑠2, . . . 𝑠𝑠𝑁𝑁) captures the distribution of the innovative activities, and each component 𝑠𝑠𝑁𝑁 is the percentage of patents in technological class 𝑘𝑘 in the patent portfolio (Bena and Li 2014; Ma 2020). The vector for  portfolio firms has been aggregated. |
| ***Knowledge overlap*** | The ratio of the number of patents cited by both the focal startup and the portfolio firms to the total number of patents cited by either the focal startup or the portfolio firms.  |𝐴𝐴𝐹 𝐹 ∩ 𝐴𝐴𝑃𝑃|  Knowledge Overlap =  |𝐴𝐴𝐹𝐹 ∪ 𝐴𝐴𝑃𝑃|  Where 𝐴𝐴𝐹𝐹 is the set of patents that receive at least one citation from the focal startup, 𝐴𝐴𝑝𝑝 is the set of patents that receive at least one citation from the portfolio firms (Ma 2020). The patent set for portfolio firms has been  aggregated. |
| ***Ln(Distance)*** | Natural logarithm of 1 plus the distance (miles) between the startup’s ZIP code  and VC’s ZIP code. |
| ***Ln(Amount)*** | The natural logarithm of 1 plus the amount of investment a venture capital firm  invests in a startup. Investment amounts are in millions of dollars and have been inflation-adjusted to 2010 values. |
| ***Local*** | A dummy variable that equals 1 if the startup is in the same state of VC’s  headquarter, and 0 otherwise. |
| ***C.VC*** | |

|  |  |
| --- | --- |
| ***Variables*** | ***Definition and construction*** |
| ***Portfolio state concentration*** | The ratio of portfolio firms that are located in a given state. |
| ***Ln(VC age)*** | Natural logarithm of 1plus the number of years since the VC founding year. To determine the VC founding year, I use the earliest year of the first deal and  founding year. |
| ***Rigid labour market*** | A dummy variable that equals 1 if a startup is located in a state with high non- compete agreement enforcement. The noncompete enforcement index is  sourced from Starr et al. (2018). |
| ***VC stage focus*** | Percentage of deals made by a VC in early stage in the past 3 year. |
| ***VC industry fit*** | Percentage of deals made by a VC in given industry in the past 3 year. |
| ***VC reputation*** | The number of IPOs backed by a given VC as a fraction of IPOs backed by all  VCs in the market in the previous 3 years. |
| ***Lead*** | A dummy variable that equals 1 if the VC is lead investor, and 0 otherwise. |
| ***D. Startup*** |  |
| ***Early stage*** | A dummy variable that equals 1 if firms are those whose first investment by a  VC was secured either at seed or early stage, and 0 otherwise. |
| ***Ln(Firm age)*** | Natural logarithm of 1 plus the number of years since the startup founding year.  To determine the startup founding year, I use the earliest year of the first deal and founding year. |
| ***Ln(Funding)*** | Natural logarithm of the total capital raised by a startup before given year.  Investment amounts are in millions of dollars and have been inflation-adjusted to 2010. |
| ***Ln(Investors)*** | Natural logarithm of 1 plus the number of VC firms has invested in the startup  before given year. |
| ***IPO*** | A dummy variable that equals 1 if the startup goes public, and 0 otherwise. |
| ***Merger*** | A dummy variable that equals 1 if the startup is involved in a merger or  acquisition, and 0 otherwise. |
| ***Ln(Patents)*** | The natural logarithm of 1 plus the number of successful patent applications  filed by a startup in given year. |
| ***Ln(Patent stock)*** | The natural logarithm of 1 plus the number of successful patent applications  filed by a startup before given year. |
| ***Ln(Citations)*** | The natural logarithm of 1 plus the average citations received by the patents  applied by a startup in a given year. |
| ***Innovation deterioration*** | The change of firm innovation performance (patents/citations) over the past 3  years ending in 𝑡𝑡 − 1. |

**Table A3 ATC adoption**

|  |  |  |
| --- | --- | --- |
| State | Adoption Date | Rejection Date |
| Maine | 1988/8/28 |  |
| North Dakota | 1993/1/1 |  |
| Ohio | 1996/11/18 | 2013/9/29 |
| Oklahoma | 1998/1/1 | 2011/12/31 |
| New York | 1999/1/1 |  |
| Virginia | 1999/1/1 |  |
| Hawaii | 1999/7/1 | 2010/12/31 |
| Iowa | 2002/1/1 |  |
| Indiana | 2003/12/31 | 2020/12/31 |
| Wisconsin | 2004/7/1 |  |
| Kansas | 2005/1/1 | 2021/12/31 |
| Louisiana | 2005/1/1 | 2021/7/1 |
| West Virginia | 2005/7/1 | 2008/6/30 |
| Arizona | 2006/7/1 | 2021/6/30 |
| Maryland | 2006/7/1 |  |
| New Mexico | 2007/1/1 | 2024/12/31 |
| Rhode Island | 2007/1/1 | 2016/12/31 |
| Arkansas | 2007/8/28 | 2019/12/31 |
| North Carolina | 2008/1/1 | 2013/12/31 |
| Minnesota | 2008/7/1 |  |
| Colorado | 2010/1/1 | 2010/12/31 |
| Minnesota | 2010/3/29 | 2017/12/31 |
| Connecticut | 2010/7/1 | 2019/6/30 |
| Georgia | 2011/1/1 | 2020/12/31 |
| Illinois | 2011/1/1 | 2021/12/31 |
| Michigan | 2011/1/1 | 2011/12/31 |
| Ohio | 2011/7/1 |  |
| Utah | 2011/7/3 |  |
| Nebraska | 2011/8/10 | 2022/12/31 |
| New Jersey | 2012/1/1 |  |
| South Carolina | 2013/6/14 | 2019/12/31 |
| Maryland | 2014/1/1 | 2018/12/31 |
| Colorado | 2014/7/1 | 2022/12/31 |
| Kentucky | 2014/7/15 |  |
| This table offers an overview of the states that adopted ATC before 2015 (Denes et al. 2023). | | |

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Energy Transition and Electricity Utility Firms’ Loan Contracting (Preliminary)

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Abstract:

Climate change has become a global challenge. Electricity companies are among the largest producers of greenhouse gases, particularly those that rely on fossil fuels for power generation, making them a primary focus of renewable energy policies. In this study, we investigate whether electricity utility firms face increased borrowing costs, following the implementation of RPS. We find a significant increase in interest spreads for electricity utility firms post-RPS implementation. Our findings reveal that lenders incorporate perceived energy transition risks into the interest rates charged to electricity utility companies. Our study contributes to the understanding of how lenders respond to policy-driven shifts toward sustainability and renewable energy. Moreover, our study is crucial for policymakers and the electricity utility sector, as it provides a better understanding of the regulatory risks involved, aiding in the development of effective policies and financial strategies to manage these risks.

1. Introduction

Climate change has become a global challenge. The emission of greenhouse gases, primarily from burning fossil fuels, has led to global warming, resulting in more frequent and severe weather-related disasters, for instance, wildfires, melting glaciers, flooding, etc. The transition to renewable energy sources is seen as a crucial step towards mitigating these severe impacts and achieving a more sustainable future development.

Electricity companies are among the largest producers of greenhouse gases, particularly those that rely on fossil fuels for power generation, making them a primary focus of renewable energy policies. The primary reason for high greenhouse gas emissions in the electricity sector is the combustion of fossil fuels. For example, before renewable energy was widely implemented, the electricity sector relied heavily on coal- fired power plants to generate electricity. These plants produce significantly more CO2 per unit of electricity compared to other types of power plants, causing substantial environmental damage. Therefore, cutting greenhouse gas emissions from electricity generation is crucial for combating climate change.

Renewable Portfolio Standards (RPS) is a renewable energy policy in the United States that mandates electricity providers to produce a certain percentage of electricity from renewable sources. By targeting electricity providers, RPS aims to transition the energy sector from reliance on fossil fuels to cleaner, renewable sources like solar, wind, hydroelectric, and geothermal power. These renewable sources produce electricity without emitting greenhouse gases, making them essential for achieving significant greenhouse gas emission reduction. For instance, solar and wind power use natural energy flows and don't involve burning fuels, thus eliminating direct greenhouse gas emissions.

However, implementing this policy may lead to a significant impact on power companies' borrowing. In this study, we investigate whether lenders perceive energy transition risks and consequently demand higher interest rates from electricity utility firms. Specifically, we examine if the financial risks associated

with asset impairment and cost uncertainty lead lenders to increase the interest rates they charge to electricity utility firms.

On one hand, electricity utility firms face the risk of asset impairment. This means their fossil fuel-based infrastructure, like coal plants, can lose value or become obsolete. As these assets become less profitable or unusable, the financial risk for utility firms increases. Recognizing this risk, lenders may demand higher interest rates to compensate. On the other hand, electricity utility firms also face the risk of cost uncertainty. To comply with RPS requirements, electricity utility firms must invest heavily in renewable energy technologies and infrastructure. If companies cannot meet their states’ RPS goals through their own renewable generation, they must buy additional RECs, incurring extra costs. The uncertainty and potential cost volatility during this shift further concern lenders. As a result, lenders may increase interest rates to account for these risks, making borrowing more expensive for electricity utility firms.

Our findings reveal that lenders incorporate perceived energy transition risks into the interest rates charged to electricity utility companies. Also, our study contributes to the understanding of how lenders respond to policy-driven shifts toward sustainability and renewable energy. Additionally, our study is crucial for policymakers and the electricity utility sector, as it provides a better understanding of the regulatory risks involved, aiding in the development of effective policies and financial strategies to manage these risks

The rest of this paper is structured as follows. Section 2 discusses the background of Renewable Portfolio Standards (RPS), previous literature, and the development of the hypothesis. Section 3 reports the sample and research design. Section 4 presents the main results, and section 5 concludes our study.

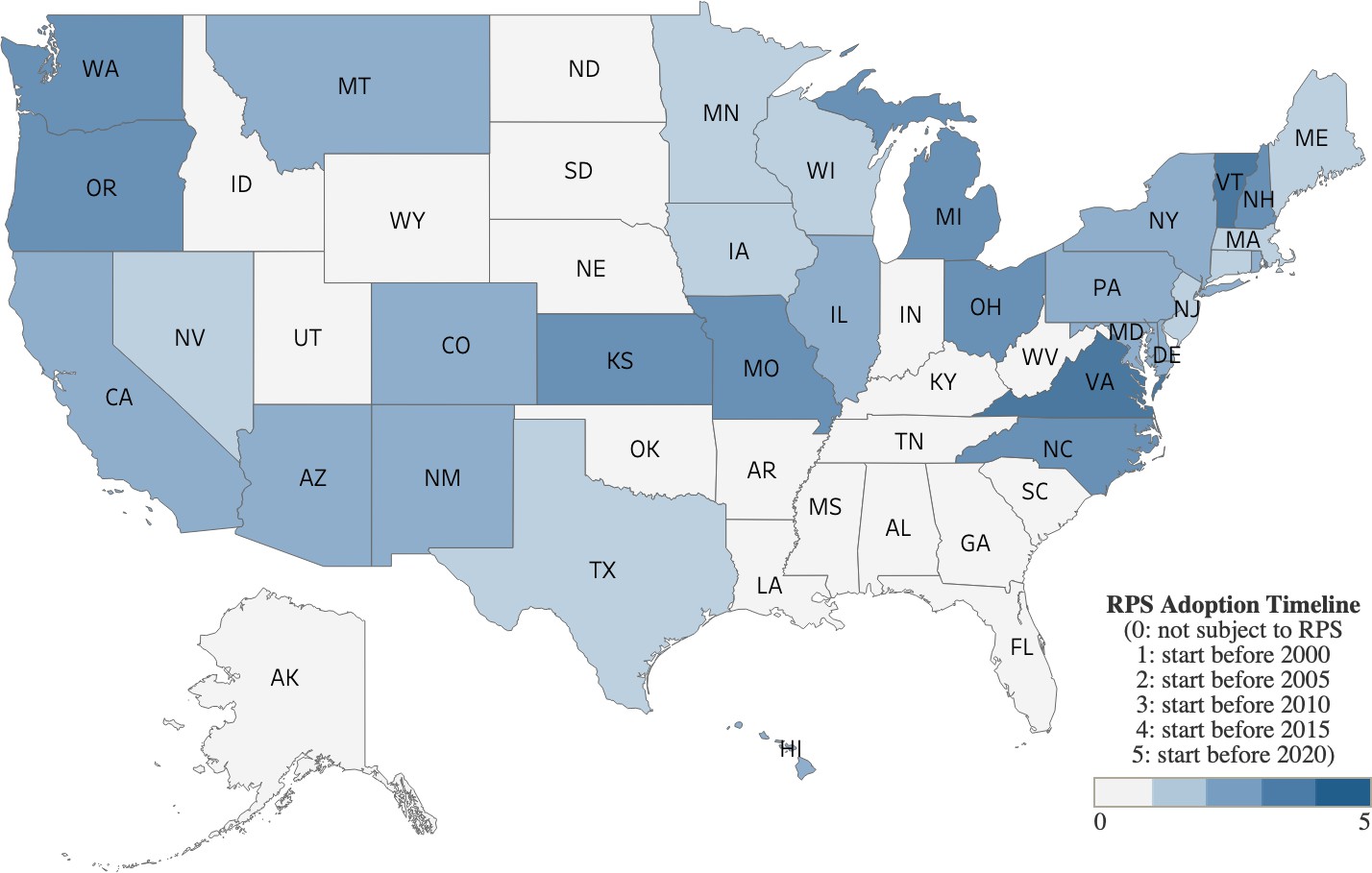
1. Background, Literature Review, and Hypothesis
   1. Background of Renewable Portfolio Standards

Renewable Portfolio Standards (RPS) is a policy that requires electricity providers or electricity utilities to produce a certain percentage of electricity from renewable sources (for example, wind, solar, geothermal, and biomass). These standards aim to increase the use of clean energy, reduce reliance on fossil fuels, and decrease greenhouse gas emissions. Therefore, RPS is not only a renewable energy policy but also plays a crucial role in combating climate change.

The mechanism that allows utility firms to deploy renewable capacity is the Renewable Energy Credits (RECs). RECs serves as proof that one megawatt-hour (MWh) of electricity has been generated from renewable energy sources and delivered to the power grid. RECs allow utility companies to meet RPS targets by purchasing credits from other entities that generate excess renewable energy. This way, even if a utility can't produce enough electricity using renewable energy, it can still comply with RPS by buying these credits, supporting overall renewable energy growth.

Iowa was the first state in the United States to start RPS in 1991 (Greenstone and Nath, 2021). After that, more and more states followed Iowa’s lead and started their own RPS programs. For the states that have implemented the RPS, each state has its own unique RPS program, specifying the percentage of electricity that must be generated from renewable sources by a designated future date. For instance, New York's RPS targets 70% renewable electricity by 2030. These programs are designed differently according to the states because each state has different specific needs and goals. Factors like economic goals, environmental objectives, social and political factors, and the ability to increase renewable energy production all play a role in shaping these policies. Figure 1 shows the RPS adoption timeline for each state in the United States.

Figure 1: RPS Adoption Timeline



*Note*: This map displays the regions affected by RPS implementation. By 2023, 31 U.S. states plus Washington DC have adopted RPS mandatory.

* 1. Literature Review and Hypothesis
     1. Literature Review

The study is associated with a growing body of research on the impact of renewable energy policy. Yin and Powers (2010) find that the implementation of RPS indeed has a positive impact on the development of states’ renewable energy, but allowing trading on RECs impairs this positive impact. This suggests that although RPS policies generally achieve their goal of boosting renewable energy, allowing REC trading might lessen this impact. Instead of producing renewable energy locally, companies could simply buy RECs, which could reduce the policy's effectiveness in each state. Upton and Powers (2010) document

that the electricity price increases for the state with RPS adoption. This could be explained by one hypothesis that utilities transfer the costs of expensive renewable projects to consumers through pricing adjustments (Nogee et al., 1999; Bryce, 2012). However, Fischer (2010) this sharp increase in electricity price is only for the states with high RPS shares (a significant portion of the electricity generated comes from renewable energy sources). For the impact of RPS on the utility industry, Kydes (2007) points out that RPS is expected to raise power generation costs substantially, estimated to increase from approximately $35 billion to $60 billion by 2020. Utilities that rely heavily on coal or other non-renewable sources of energy in deregulated regions must now factor in the cost of Renewable Energy Credits (RECs) into their overall expenses. This suggests that RPS would have a great impact on electric utility firms’ financial operations. Furthermore, Pfeiffer et al. (2016) demonstrate that all new power generation infrastructures should be sustainable to avoid the risk of becoming stranded assets. Hence, after the RPS adoption, fossil fuel-based infrastructure, like coal plants in electricity utility, could left unused or retired early, thus becoming stranded assets.

Besides renewable energy policy, a strand of papers also discusses the impact of climate policy (Veith et al., 2009; Marin et al., 2018; Dang et al., 2023; Laeven and Popov, 2023). For instance, Dang et al. (2023) find that manufacturing companies apply more conservative financial policies to adjust the climate change transition risk following the implementation of Nitrogen Oxides Budget Trading Program (NBP). Veith et al. (2009) and Marin et al. (2018) point out that the electricity utility industry transferred a substantial portion of the compliance costs associated with the NBP to their customers. Laeven and Popov (2023) provide evidence that following the introduction of a domestic carbon tax, banks decrease their lending to coal, oil, and gas firms within their home country while increasing such financing internationally. Those studies suggest that climate policies have a crucial impact on various sectors, influencing corporate financial strategies, compliance costs for industries, and the lending behavior of financial institutions.

Additionally, this study is part of an expanding body of research examining the impact of climate change risk on interest spread. Jung et al. (2018) indicate that lenders consider a firm's carbon-related risks when making lending decisions, which affects the cost of financing for the firm. Moreover, Cogan et al. (2008) point out that most lenders have adopted general environmental and climate change risk assessment policies. These policies often include evaluating whether the borrowing firm has implemented or is developing strategies to reduce carbon emissions. Although lenders prefer companies to engage in carbon emission reduction strategies, electricity utility companies face substantial transition risks associated with carbon-related regulations and market shifts toward renewable energy. Therefore, lenders are likely to consider multiple dimensions when making lending decisions.

* + 1. Hypothesis Development

Previous studies state that the variation of macroeconomic conditions would have a significant impact on firms’ default risks (Fama, 1986; Duffie and Singleton, 2003; Hackbarth, Miao, and Morellec, 2006). Variations in macroeconomic conditions, such as changes in policies, can significantly impact credit risk and firms' financing decisions. Therefore, the implementation of RPS can also induce potential default risks to electricity utility firms.

Specifically, the implementation of RPS can raise asset impairment risk for electricity utility firms, as it can lead to stranded assets. Stranded assets refer to infrastructure, particularly those built around fossil fuels, that face the risk of becoming obsolete prematurely due to the low-carbon transition. (Krause et al., 1989). Environmentally unsustainable assets could suffer significant value reduction after new environmental-related government policy adoption. Due to the implementation of RPS, electricity utility companies are mandated to generate a specific portion of their electricity from clean energy sources. As a result, coal-fired power plants and other fossil fuel-based infrastructure will see reduced utilization and

could become stranded assets (Farfan and Bayer, 2017). As these assets become less profitable or unusable, firms would incur substantial losses, thereby impacting their ability to repay debts (Semieniuk et al., 2021). Moreover, the risk of stranding assets can increase when a sector undergoes significant innovations in policy, technology, and market (Caldecott et al., 2017). Recognizing this risk, lenders may demand higher interest rates to compensate.

Furthermore, the implementation of RPS can raise cost uncertainty risk for electricity utility firms. Utility firms must invest heavily in renewable energy technologies and infrastructure to comply with RPS. For example, wind power plants and solar power plants construction. However, the cost of renewable energy electricity generation can be more uncertain compared to conventional fossil fuel electricity generation. Patrick and Damon (2016) point out that renewable energy sources such as wind and solar are energy flows, not stocks, which leads to inherent variability. Their intermittent nature introduces uncertainty in energy production, contrasting with the stable supply of fossil fuels. This uncertainty means that if companies cannot meet their RPS goals through their own renewable generation, they must buy additional RECs, incurring extra costs. This transition adds uncertainty to electricity utility firms’ future costs. Hence, lenders might perceive this uncertainty, and charge a higher interest rate to the electricity utility firms.

However, before 2010, a lot of banks engaged in financing low-carbon and sustainable projects. For example, Bank of America has committed to financing low-carbon and sustainable business activities through its Environmental Business Initiative since 2007. Despite BoA’s efforts and similar initiatives by other financial institutions, the inherent risks (for example, asset impairment risk and cost uncertainty risk) and market dynamics associated with renewable energy projects can still result in higher interest spreads. Accordingly, based on the arguments, we formulate the following hypothesis, stated in an alternative form:

Hypothesis: the implementation of RPS increases the interest spread in electricity utility firms’ borrowing.

1. Research Design
   1. Sample and Data

The data for this study are from two sources. We obtain US electricity utility company’s loan data from the DealScan Database. The data we use is from 1996 to 2017 because the loan’s information is relatively complete after 1996. For firm characteristics data, we obtained from Compustat, which covers company’s annual fundamental financial information. After merging the dataset and excluding the missing variable that needed to be used in the main regression, our final sample consists of 829 loans issued to 59 US electricity utility companies (SIC Code 4911 and 4931) from 1996 to 2011. We excluded data from 2011 onwards because we employed a stacked difference and differences model. To ensure each group has both a treated and control group, and every company has at least one observation before and after the RPS policy, we removed controls without corresponding treated transactions. Therefore, our analysis spans from 1996 to 2011.

Table 1 presents the sample distribution by industry and year. The table reveals that the total number of loans for electricity utility companies saw a steady increase from 1996 to 2005 but experienced a sharp decline around 2008. This significant drop in loan numbers can likely be attributed to the 2008 financial crisis. During this period, the crisis led to widespread economic instability, causing banks and other lending institutions to tighten their credit policies and reduce the availability of loans.

Table 1: Sample distribution

|  |  |
| --- | --- |
|  | **No. of Loans** |
| Panel A: Sample Distribution by Electricity Utility Industry | |
| SIC49-11 Electric Services | 495 |
| SIC49-31 Electric and Other Services Combined | 334 |
| Panel B: Sample Distribution by Year |  |
| 1996 | 9 |
| 1997 | 12 |

|  |  |
| --- | --- |
| 1998 | 7 |
| 1999 | 26 |
| 2000 | 32 |
| 2001 | 43 |
| 2002 | 63 |
| 2003 | 107 |
| 2004 | 125 |
| 2005 | 126 |
| 2006 | 94 |
| 2007 | 78 |
| 2008 | 39 |
| 2009 | 21 |
| 2010 | 34 |
| 2011 | 13 |

*Note*: This table presents the sample distribution by industry (Panel A), and year (Panel B).

* 1. Methodologies

Our primary goal is to evaluate the impact of RPS implementations on the borrowing of electricity companies. Due to the gradual implementation of RPS in each state, we rely on the staggered timing of RPS adoption across states to examine our hypotheses regarding this impact. This allows us to use a difference-in-differences approach, where we compare how outcomes change in states that implemented the RPS (treated states) versus states that did not (control states) over the same time frame.

Recent studies suggest that traditional difference-in-differences (DID) methods in financial research when applied to staggered treatment timings, do not accurately estimate the average treatment effect on the treated, it causes bias (Athey and Imbens, 2018; Callaway and Sant’Anna, 2021; Sun and Abraham, 2021). For example, in staggered difference-in-differences, pre- and post-window are not consistent. Also, the later-treated group can serve as the control group before the shock happens. To address the heterogeneous

treatment issues, we adopt Cengiz et al (2019) approach to mitigate those biases. More specifically, we apply a “stacked” difference-in-differences approach. We create ten “clean 2×2” cohorts for each RPS implementation year. All of the cohorts have the same time window, which is three years before the RPS implementation and three years after the RPS implementation (including the RPS implementation year). To ensure each cohort has both a treated and control group, and every company has at least one observation before and after the RPS policy, we remove controls without corresponding treated transactions. Finally, we have eight “clean 2×2” cohorts. For each cohort, we assign a unique cohort number to the observations in that cohort. For instance, if the cohort is constructed based on the RPS implementation year 1999, all loans within that cohort would be assigned the cohort number 1999. Then, we stack all of the cohorts together to get our final dataset. Our control group is the states that are never subject to the RPS.

The stacked difference-in-differences regression is as follows, for borrower firm *i*, loan *j*, year *t*, state *s*, loan purpose *p*, and cohort *c*:

𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑖𝑖,𝑗𝑗,𝑐𝑐,𝑡𝑡 = 𝛽𝛽(𝑇𝑇𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑖𝑖,𝑗𝑗,𝑐𝑐,𝑡𝑡 × 𝑃𝑃𝑃𝑃𝑃𝑃𝐼𝐼𝑡𝑡 ) + 𝜃𝜃𝑋𝑋𝑗𝑗,𝑐𝑐,𝑡𝑡−1 + 𝛿𝛿𝑍𝑍𝑖𝑖,𝑗𝑗, 𝑐𝑐,𝑡𝑡 + 𝛾𝛾𝑠𝑠,𝑐𝑐 + 𝜆𝜆𝑡𝑡,𝑐𝑐 + 𝜂𝜂𝑝𝑝,𝑐𝑐 + 𝜀𝜀𝑖𝑖,𝑗𝑗,𝑐𝑐,𝑡𝑡

Where the dependent variable 𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑖𝑖,𝑡𝑡,𝑐𝑐 is the interest spread for loan i issued in year t, 𝑇𝑇𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑖𝑖,𝑡𝑡 is 1 for the firm’s historical headquarter located in RPS implementation states, and 0 otherwise, 𝑃𝑃𝑃𝑃𝑃𝑃𝐼𝐼𝑡𝑡 is 1 for the year after RPS implementation (including RPS implementation year), 𝑋𝑋𝑖𝑖,𝑡𝑡−1,𝑐𝑐 and 𝑍𝑍𝑖𝑖,𝑡𝑡,𝑐𝑐 are a set of the borrower firm’s performance control variables and loan specific control variable, and 𝜀𝜀𝑖𝑖,𝑡𝑡,𝑐𝑐 is the error term. Our regression model also includes state-cohort 𝛾𝛾𝑠𝑠,𝑐𝑐, year-cohort 𝜆𝜆𝑡𝑡,𝑐𝑐, and loan purpose-cohort 𝜂𝜂𝑝𝑝,𝑐𝑐 fixed effects. State-fixed effect absorbs the time-invariant state-level factors that influence interest spread, loan purpose fixed effect control for time-invariant loan-level characteristics, and year fixed effect control for changes in economic conditions. The standard errors are clustered at the state level. The detailed description and measurement of the variables used in our main regression is presented in Appendix 1.

1. Empirical Results
   1. Summary Statistics and Correlation Analysis

Table 2 presents the summary statistics for the variables used in our main regression. We winsorize all of the continuous variables at the 1st and 99th percentiles to exclude the outliers. From the table, we can see that the average interest spread for the treatment group is 30.082 basis points higher than that of the control group.

Table 2: Summary statistics

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment group sample (No. of Loans) N=263 | | | | Control group sample (No. of Loans) N=566 | | |
| Variables | Mean | SD | Median | Mean | SD | Median |
| Loan variables: |  |  |  |  |  |  |
| IntSpread (bps) | 124.819 | 115.612 | 75.000 | 94.737 | 98.521 | 51.750 |
| Maturity (month) | 39.072 | 22.247 | 36.000 | 38.799 | 22.132 | 36.000 |
| Log(Maturity) | 3.435 | 0.749 | 3.584 | 3.407 | 0.798 | 3.584 |
| Loan Size ($ million) | 499.154 | 495.235 | 350.000 | 518.500 | 662.348 | 277.500 |
| Log(Loan Size) | 5.753 | 1.034 | 5.858 | 5.707 | 1.016 | 5.626 |
| Collateral | 0.209 | 0.407 | 0.000 | 0.092 | 0.289 | 0.000 |
| InstLoan | 0.030 | 0.172 | 0.000 | 0.025 | 0.155 | 0.000 |
| LeadRep | 0.833 | 0.374 | 1.000 | 0.875 | 0.332 | 1.000 |
| PreRelation | 0.589 | 0.493 | 1.000 | 0.634 | 0.482 | 1.000 |
| PPP | 0.460 | 0.499 | 0.000 | 0.387 | 0.487 | 0.000 |
| Revovler | 0.852 | 0.356 | 1.000 | 0.890 | 0.313 | 1.000 |
| Borrower variables: |  |  |  |  |  |  |
| Firm Size ($ million) | 14,980.157 | 13,652.020 | 12,520.900 | 12,223.210 | 11,853.075 | 6,722.100 |
| Log(Firm Size) | 9.126 | 1.084 | 9.435 | 8.930 | 0.999 | 8.813 |
| Leverage | 0.317 | 0.080 | 0.311 | 0.307 | 0.084 | 0.302 |
| ROA | 0.030 | 0.016 | 0.030 | 0.035 | 0.019 | 0.036 |
| σ(ROA) | 0.010 | 0.012 | 0.006 | 0.013 | 0.031 | 0.004 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Tangibility | 0.634 | 0.122 | 0.610 | 0.727 | 0.105 | 0.746 |
| Current Ratio | 0.997 | 0.441 | 0.893 | 0.873 | 0.310 | 0.810 |

Note: This table reports the summary statistics for variables used in the main tests. The sample consists of loan and firm-level variables from 1996 to 2011. Our sample contains 829 loan observations. Continuous variables are winsorized at the 1st and 99th percentiles. All the variable definitions and measurements can be found in Appendix 1.

Table 3 presents the Pearson correlation matrix for all the variables in the main regression. The correlation between IntSpread and Treat\_Post is positive and significant at the 1% level, providing preliminary evidence for our hypotheses that the implementation of RPS (clean energy policy) would lead to an increase in the loan interest spread for utility companies.

Table 3: Pearson correlation matrix

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable Names | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| (1) IntSpread(bps) | 1.000 |  |  |  |  |  |  |  |
| (2) Treat\_Post | **0.216** | 1.000 |  |  |  |  |  |  |
| (3) Log(Firm Size) | −**0.105** | 0.036 | 1.000 |  |  |  |  |  |
| (4) Leverage | **0.275** | −0.036 | −**0.171** | 1.000 |  |  |  |  |
| (5) ROA | −**0.267** | −0.015 | −0.007 | −**0.258** | 1.000 |  |  |  |
| (6) σ(ROA) | **0.252** | −0.033 | −**0.145** | **0.122** | −**0.368** | 1.000 |  |  |
| (7) Tangibility | −**0.276** | −**0.201** | −**0.127** | −0.008 | **0.352** | −**0.285** | 1.000 |  |
| (8) Current Ratio | **0.228** | **0.122** | −0.024 | 0.088 | 0.038 | −0.030 | −**0.157** | 1.000 |
| (9) Log (Maturity) | −0.019 | 0.035 | 0.050 | −**0.103** | 0.018 | 0.036 | **0.099** | **0.176** |
| (10) Log(Loan Size) | −**0.319** | 0.013 | **0.522** | −**0.240** | 0.067 | −**0.142** | 0.030 | −**0.093** |
| (11) Collateral | **0.564** | **0.191** | −**0.128** | **0.107** | −**0.308** | **0.325** | −**0.246** | **0.145** |
| (12) InstLoan | **0.386** | 0.049 | −0.067 | 0.056 | −**0.237** | **0.363** | −**0.194** | 0.028 |
| (13) LeadRep | −**0.380** | −0.012 | 0.085 | −0.067 | **0.090** | −**0.178** | 0.057 | −**0.132** |
| (14) PreRelation | −**0.261** | −0.059 | 0.035 | −0.041 | **0.109** | −**0.140** | **0.095** | 0.007 |
| (15) PPP | 0.064 | **0.097** | −**0.109** | **0.094** | −0.061 | −0.019 | −0.013 | 0.076 |
| (16) Revovler | −**0.504** | −**0.105** | 0.060 | −**0.128** | **0.180** | −**0.167** | **0.193** | 0.002 |

Table 3: Pearson correlation matrix (continues)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable Names | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
| (9) Log(Maturity) | 1.000 |  |  |  |  |  |  |  |
| (10) Log(Loan Size) | 0.088 | 1.000 |  |  |  |  |  |  |
| (11) Collateral | **0.090** | **-0.154** | 1.000 |  |  |  |  |  |
| (12) InstLoan | **0.111** | -0.052 | **0.429** | 1.000 |  |  |  |  |
| (13) LeadRep | -0.068 | **0.359** | **-0.303** | **-0.194** | 1.000 |  |  |  |
| (14) PreRelation | 0.015 | **0.218** | **-0.240** | **-0.118** | **0.398** | 1.000 |  |  |
| (15) PPP | 0.010 | 0.029 | 0.074 | **-0.138** | 0.008 | -0.039 | 1.000 |  |
| (16) Revovler | **0.099** | **0.191** | **-0.385** | **-0.443** | **0.309** | **0.286** | 0.071 | 1.000 |

*Note*: This table reports the Pearson correlation coefficients for variables used in the main tests. Please find variable definitions in the Appendix 1. Figures in bold mean significant at 1% Level (Two-tailed).

* 1. Baseline Result

Table 4 presents the baseline result for our main regression. In panel A, the univariate analysis of the difference in interest spread demonstrates the average treatment effect on treated is positive and significant at the 5% level, which further provides support for our hypothesis. Panel B reports the baseline regression of the RPS’s Implementation impact on interest spread. Column (1) and column (2) present the estimation results of the impact of RPS implementation on utility firms’ interest rates. Column (1) reports the estimation results after including borrowers’ financial performance control variables, loan-specific control variables, and state-cohort, year-cohort, and loan purpose-cohort fixed effects. Column (2) reports the estimation results after including borrowers’ financial performance control variables, loan-specific control variables, and firm-cohort, year-cohort, and loan purpose-cohort fixed effects. The estimation results from all models show positive and significant coefficients on Treat\*Post, suggesting that RPS implementation would increase utility firms’ interest rates. For example, in column (1), the coefficient on Treat\*Post suggests that the interest spread increases by 21.266 bps after RPS implementation, compared with the average interest spread (104.281 bps for electricity utility firms), this change represents an increase of

20.393%. This outcome aligns with our hypothesis that implementing RPS increases the interest rates for utility firms in borrowing.

Table 4: Mian Result

Panel A: Univariate Analysis of the Difference in IntSpread – Comparison of the Sample Means

|  |  |  |  |
| --- | --- | --- | --- |
|  | Treated firm (A) | Control firm (B) | Difference *t*-test (A)-(B) |
| Pre-RPS (C) | 92.316 | 83.583 | 8.733 |
| Post-RPS (D) | 155.637 | 108.736 | 46.901\*\*\* |
| Difference *t*-test (D)-(C) | 63.321\*\*\* | 25.153\*\*\* | 38.168\*\* |

Panel B: The RPS’s Implementation and Interest Spread

|  |  |  |
| --- | --- | --- |
| Variables | Dependent Variable: IntSpread(bps) |  |
| (1) | (2) |
| *Treat\*Post* | 21.266\*\* | 16.834\* |
|  | (2.23) | (1.79) |
| Borrower variables: |  |  |
| *Log(Firm Size)* | 4.181 | 47.882\* |
|  | (1.16) | (1.89) |
| *Leverage* | 282.351\*\*\* | 315.484\*\*\* |
|  | (3.60) | (3.17) |
| *ROA* | -178.584 | 257.514 |
|  | (-0.72) | (1.23) |
| *σ(ROA)* | -356.859\* | -366.715 |
|  | (-1.81) | (-1.69) |
| *Tangibility* | -166.920\*\*\* | -100.740 |
|  | (-4.51) | (-1.34) |
| *Current Ratio* | 8.722 | -10.167 |
|  | (0.76) | (-0.74) |
| Loan variables: |  |  |
| *Log(Maturity)* | -5.179 | -3.728 |
|  | (-1.15) | (-0.89) |

|  |  |  |
| --- | --- | --- |
| *Log(Loan Size)* | -13.272\*\*\* | -10.174\*\* |
|  | (-4.31) | (-2.39) |
| *Collateral* | 45.506\* | 44.149 |
|  | (1.73) | (1.25) |
| *InstLoan* | 32.776 | 25.135 |
|  | (0.58) | (0.42) |
| *LeadRep* | -21.641 | -17.389 |
|  | (-1.62) | (-1.35) |
| *PreRelation* | -0.758 | -3.156 |
|  | (-0.13) | (-0.57) |
| *PPP* | 0.413 | -7.160 |
|  | (0.07) | (-0.80) |
| *Revovler* | -41.591 | -45.835\* |
|  | (-1.60) | (-1.75) |
| Fixed effects: |  |  |
| Loan Purpose-Cohort | YES | YES |
| Year-Cohort | YES | YES |
| State-Cohort | YES | ON |
| Firm-Cohort | NO | YES |
| No. of observations | 829 | 829 |
| Adjusted 𝑅𝑅2 | 0.772 | 0.778 |

*Note*: This table presents the regression results of the impact of RPS implementation on electricity utility firms' interest spreads. The dependent variable is loan spread (bps). The variable 𝑇𝑇𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝐼𝑖𝑖,𝑡𝑡 is a dummy variable equal to 1 for the firm’s historical headquarter located in RPS implementation states and 0 otherwise. 𝑃𝑃𝑃𝑃𝑃𝑃𝐼𝐼𝑡𝑡 is a dummy variable equal to 1 for the year after RPS implementation (including RPS implementation year). Standard errors are clustered at the state level and t-statistics can be found in parentheses. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively. Please find variable definitions in Appendix 1.

1. Conclusion

In this study, we examine whether electricity utility firms face increased borrowing costs, following the implementation of Renewable Portfolio Standards (RPS) and we find a significant increase in interest spreads for electricity utility firms post-RPS implementation. The increased borrowing costs reflect

lenders incorporating perceived energy transition risks, including asset impairment risk and cost uncertainty risk, into the interest rates charged to electricity utility companies. Our study contributes to the understanding of how lenders respond to policy-driven shifts toward sustainability and renewable energy. Additionally, in line with prior studies examining the impact of climate change risk on interest spread (e.g., Cogan et al, 2008; Jung et al, 2018), we find that policy responses to climate changes could have a significant impact on loan spread. Moreover, our study is crucial for policymakers and the electricity utility sector, as it provides a better understanding of the regulatory risks involved, aiding in the development of effective policies and financial strategies to manage these risks.

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Appendix 1: Variable definition

|  |  |
| --- | --- |
| **Variables** | **Definition and measurement** |
| Loan variables |  |
| Collateral | A dummy variable equals to one if the loan is secured, and zero otherwise. |
| IntSpread (bps) | Measured by all-in-drawn loan spread over LIBOR. The commitment fee,  annual fee, upfront fee, etc., are all included in the calculation. |
| InstLoan | A dummy variable equals to one for loans classified as term loan B, C, D, E,  F, G, or H (institutional term loans), and zero otherwise. |
| LeadRep | A dummy variable equal to one if deal i is syndicated by one of the top 25  lead arrangers in the US syndicated loan market, and zero otherwise. |
| Log(Loan Size) | Log of the loan amount ($ million). |
| Log(Maturity) | Log of the loan maturity (month). |
| Loan purpose | Loans are categorized into seven groups based on their primary purpose: acquisition financing, leveraged buyouts/management buyouts/shareholder buyouts, takeover funding, debt repayment/recapitalization, corporate  purposes, working capital, and other purposes. |
| PPP | A dummy variable equals to one if the loan agreement includes performance  pricing provisions, and zero otherwise. |
| PreRelation | A dummy variable that equals one if at least one of the lead arrangers of deal i has previously led the borrower firm's deals within the past 5 years, and 0  otherwise. |
| Revovler | A dummy variable equals to one for revolving loans and zero otherwise. |
| Borrower variables |  |
| Current Ratio | The ratio of firm's current assets (ACT) to current liabilities (LCT). |
| Leverage | Measured by long-term debt (DLTT) to total assets (AT). |
| Log(Firm Size) | Log of firm's total assets (AT) |
| ROA | Measured by net income before extraordinary items (IB) divided by firm's  total assets (AT). |
| σ(ROA) | Standard deviation of ROA, measured over 3-5 previous years. |

|  |  |
| --- | --- |
| Tangibility | The ratio of net property, plant, and equipment plus inventory (PPENT +  INVT) to total assets (AT). |

Note: This table presents the variable definition and measurement.

Appendix 2: RPS Adoption Year

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **State Name** | **Abbr.** | **Adoption Year** | **State Name** | **Abbr.** | **Adoption Year** |
| Iowa | IA | 1991 | Pennsylvania | PA | 2004 |
| Connecticut | CT | 1998 | Rhode Island | RI | 2004 |
| Massachusetts | MA | 1997 | Delaware | DE | 2005 |
| Minnesota | MN | 1997 | Illinois | IL | 2005 |
| Nevada | NV | 1997 | Montana | MT | 2005 |
| Maine | ME | 1999 | Washington | WA | 2006 |
| New Jersey | NJ | 1999 | Washington. DC | DC | 2006 |
| Texas | TX | 1999 | New Hampshire | NH | 2007 |
| Wisconsin | WI | 1999 | North Carolina | NC | 2007 |
| Arizona | AZ | 2001 | Oregon | OR | 2007 |
| California | CA | 2002 | Michigan | MI | 2008 |
| Colorado | CO | 2004 | Missouri | MO | 2008 |
| Hawaii | HI | 2004 | Ohio | OH | 2008 |
| Maryland | MD | 2004 | Kansas | KS | 2009 |
| New Mexico | NM | 2004 | Vermont | VT | 2015 |
| New York | NY | 2004 | Virginia | VA | 2020 |

Note: This table reports the RPS adoption year for each state. By 2023, 31 U.S. states plus Washington DC have adopted RPS.

#### Does Corporate Culture Impact on Firms’ Carbon Emissions?

ABSTRACT: We investigate the impact of corporate culture on the carbon emissions of U.S.- listed firms. By utilizing the Competing Values Framework (CVF) and textual analysis of a comprehensive sample of 10-K corporate filings, we classify corporate culture into four types: competition, creation, collaboration, and control. Our findings reveal that firms with a competition-oriented culture consistently exhibit lower Scope 1 carbon intensity, while the effect of other culture types on carbon emissions appears to be weaker. The effect of competition-oriented culture is robust to a difference-in-differences analysis around CEO turnovers, alternative measures of corporate culture, and additional controls of CEO characteristics and the political environment. Additional analysis suggests that the impact of competition-oriented culture on carbon emissions is more pronounced when the firm faces high bankruptcy risk or financial constraints. Conversely, this impact is moderated by high employee turnover and the implementation of climate change regulations, such as the Paris Agreement and State Climate Adaptation Plans (SCAP). This study highlights the significant role of corporate culture in shaping non-financial performance metrics such as carbon emissions.

Keywords: Carbon emissions; Competition-oriented culture; Corporate culture; Corporate governance; Textual analysis.

JEL Classification: G30; M14; M41; Q56

Conflicts of interest: We have no conflict of interests to declare.

INTRODUCTION

*For companies to be successful over a long period of time, you need more than a good idea and a good strategy. You need a culture that fosters that growth.*

*̶ Satya Nadella, Microsoft CEO*

This paper studies the impact of corporate culture on firms’ carbon performance. Climate change poses significant challenges, evidenced by an average 1.1°C rise in global temperatures

since pre-industrial levels and record CO2 emissions of 36.44 billion metric tons in 2019, contributing to widespread environmental and economic disruptions (Global Carbon Project, 2020; Intergovernmental Panel on Climate Change, 2021). These changes have been related to extreme weather events, leading to substantial financial losses globally. In response, governments across various nations have implemented rigorous policies, such as the Paris

Agreement, aiming to cap global warming to below 2°C to mitigate these impacts (United

Nations Framework Convention on Climate Change, 2015). Such measures underscore the urgency for corporations to address ongoing climate challenges by improving their carbon performance and reducing carbon emissions. Motivated by prior literature highlighting the far- reaching influence of corporate culture on various aspects of a firm’s operations (Camerer et al., 1988; Gorton et al., 2022; Grennan, 2019; Posner et al., 1985; Ray, 1986), we argue that corporate culture can be an important determinant of firms’ carbon performance.

A survey study by Graham et al. (2022) indicates that most executives in North America believe that culture in their corporations plays a crucial role in addressing short-termism, investment risk, and ethical decisions, ranking it among the top factors driving organizational value. Existing empirical studies have observed the direct influence of corporate culture on certain aspects of firm performance (Altamuro et al., 2022; Billings et al., 2022). Moreover, as a pivotal contextual factor within organizations, corporate culture can moderate the effects of other firm decision-making on their performance (Billings et al., 2022; Davidson et al., 2015;

Engelen et al., 2012). Nonetheless, the existing literature connecting corporate culture with non-financial metrics remains limited.

To classify corporate culture, we adopt the Competing Values Framework (CVF). Initially proposed by Quinn et al. (1983) and further developed by Cameron et al. (2006), CVF is a widely adopted framework in prior studies[[1](#_bookmark35)], which classifies corporate culture into four types: competition, creation, collaboration, and control. The first two types are externally oriented, while the latter two are internally oriented. Externally oriented cultures promote market growth and adaptability, whereas internally oriented cultures emphasize internal stability, employee well-being, and consistent operational performance (Cameron et al., 2006). Specifically, competition-oriented culture (also known as Market Culture) focuses on competition, results, achieving market dominance, and meeting external stakeholders’ expectations; creation- oriented culture (also known as Adhocracy Culture) fosters innovation, risk-taking, and the ability to adapt swiftly to changing market conditions; collaboration-oriented culture (also known as Clan Culture) aims for a family-like environment with a focus on collaboration, employee involvement, and a supportive atmosphere; and the control-oriented culture (also known as Hierarchy Culture) relies on formal structures, established procedures, and clear lines of authority, with reliability and stability as its key features.

To measure each dimension of corporate culture, we construct culture scores at the firm- year level using textual analysis of 10-K filings of US-listed firms. Based on a sample of 16,564 firm-years from 2002 to 2021, we find that firms with a competition-oriented culture exhibit significantly lower Scope 1 carbon intensity compared to their peers, indicating superior carbon performance. The influence of the other types of corporate culture (collaboration, control, and creation) on carbon emissions is less pronounced and not consistently significant across all specifications. These findings underline the important role of specific types of corporate culture in advancing carbon reduction efforts and achieving sustainability goals.

We employ several empirical methods to address potential endogeneity concerns related to reverse causality as well as omitted variables affecting both corporate culture and carbon performance. Apart from a lead-lag main research model, we also use CEO turnover as a shock to corporate culture (Altamuro et al., 2022; Davidson et al., 2015; Hossain et al., 2022; Li et al., 2024b; Liu, 2016); our difference-in-differences (DiD) analysis shows that firms which enhance their competition-oriented culture following a CEO turnover experience a significantly larger reduction in carbon emissions compared to firms that do not. We also perform a series of other robustness tests, including the addition of firm fixed effects, using one-year instead of three-year averages of culture scores, focusing on the dominant culture within a firm, measuring culture scores based on the MD&A section of the 10-K filings instead of the entire 10-K filings, and including additional controls for CEO characteristics and the political environment. The negative impact of competition-oriented culture on carbon emissions remains robust across all these specifications. Additional cross-sectional tests show that competition-oriented culture has a greater impact on carbon emissions under adverse financial conditions. However, the impact of competition-oriented culture becomes less pronounced in industries with high labor mobility or after the introduction of the Paris Agreement and State-level Climate Action Plan (SCAP).

The remainder of the paper proceeds as follows: Section 2 reviews the relevant literature; Section 3 develops the testable hypotheses; Section 4 describes the variables, model, and sample; Section 5 presents the research findings; and Section 6 concludes the study.

LITERATURE REVIEW

Prior Research on Corporate Culture

Corporate culture is deemed as people’s psychological connections to their organizations, including the sense of job participation, loyalty, and dedication to the organizations' principles (O'Reilly, 2008); it can also be considered as an intangible asset that functions as a social

control mechanism that aligns actions with firm objectives and facilitates employee responses to unforeseen situations through shared values and ideas (Camerer et al., 1988; Guiso et al., 2015; Hermalin, 2000; Kreps, 1990; Schein, 1990; Schein et al., 2017). Furthermore, corporate culture assists in decision-making processes when explicit regulations are insufficient, thereby complementing traditional control systems (Guiso et al., 2015). These shared values and psychological connections embedded in corporate culture can be characterized by their control over staff behaviors and their influence on organizational commitments.

The role of corporate culture in corporations has been explored widely in the literature (e.g., Graham et al., 2022; Hasan, 2022; Jiang et al., 2019; Li et al., 2021a). While it is widely acknowledged that measuring culture can be challenging, the CVF model has been used extensively in the literature to conceptualize corporate culture classifying it into four types: competition, creation, collaboration, and control. Assuming that corporate culture influences how organizations articulate their operational, strategic, and financial decision-making processes in official communications, narratives within 10-K filings offer a window into the firm’s internal values, priorities, and behavioral norms. By analyzing the language and discourse in these documents, researchers infer aspects of corporate culture that are often not captured through other quantitative metrics alone (Chen et al., 2022; Cumming et al., 2024b; Fang et al., 2023; Fiordelisi et al., 2019; Nguyen et al., 2019).

Fiordelisi et al. (2014) find that firms endorsing a competition-oriented culture have the strongest intention to change their CEOs. Bhandari et al. (2022) show that firms with a competition culture are likely to have better financial reporting quality than those with a collaboration culture. Meanwhile, compensation schemes become more bonus-focused in banks with a competition-oriented culture than in those with other types of corporate culture (Barth et al., 2021). Huynh et al. (2024) document a positive effect of competition culture on bank liquidity creation, whereas collaboration and control cultures show a negative effect.

Using a sample of Australian firms, Bose et al. (2024) find that firms with competition culture are more likely to voluntarily disclose high-quality climate-change information. Creation culture can be related to opportunistic behaviors. For example, Hasan et al. (2024) discover that companies with a more creation-oriented culture are more likely to avoid taxes than those with a less creation-oriented culture. However, this type of culture benefits IPO firms’ financial performance (Cumming et al., 2024b) and promotes innovation (Wang et al., 2021). Regarding the collaboration culture, Chen et al. (2022) find that audit firms charge a lower audit fee for firms with a collaboration culture. Luu et al. (2023a) document that under the increased competition brought by the U.S. Interstate Banking and Branching Efficiency Act, banks with a dominant collaboration-oriented culture are less likely to exercise discretion on loan loss provisions. Additionally, banks with a control-oriented culture manifest greater stability (Luu et al., 2023b). During the financial crisis period of 2008 to 2009, firms with a dominant control- oriented culture show more robust performance regarding asset growth, debt assurance, access to credit-line facilities, and redundancy issues (Fang et al., 2023).

Another widely adopted framework for classifying corporate culture is developed by Li et al. (2021b), which identifies firms with a strong corporate culture based on the sum of five culture dimension scores, namely innovation, integrity, quality, respect, and teamwork. Prior research documents that firms with a strong corporate culture have more positive price revisions and higher initial returns in IPOs (Cumming et al., 2024a), superior financial performance during the COVID-19 pandemic (Li et al., 2021a), fewer stakeholder violations (Zaman, 2024), better workplace safety (Haga et al., 2024), and less toxic releases (Li et al., 2024a). Additionally, some research focuses on corporate integrity culture and finds that an integrity culture contributes to better operational and financial compliance in the pharmaceutical industry (Altamuro et al., 2022), stronger financial performance (Guiso et al.,

2015), a reduced likelihood of future stock price crashes (Hossain et al., 2022), and lower investment–cash flow sensitivity (Jiang et al., 2019).

Research on Carbon Performance

Prior literature highlights a significant influence of carbon emissions on various aspects of firm decisions and outcomes, such as capital structure (Nguyen et al., 2020), acquisition (Bose et al., 2021), dividend policy (Balachandran et al., 2018), investment (Phan et al., 2022), firm value (Matsumura et al., 2014), option price (Ilhan et al., 2021), stock return (Bolton et al., 2023b; Bolton et al., 2021; Pástor et al., 2021), and the cost of debt (Ehlers et al., 2022; Jung et al., 2018).

Investigating the determinants of carbon performance is therefore essential. Prior studies highlight several factors that positively influence firm carbon performance, including governmental regulatory pressure (Shen et al., 2020; Wang et al., 2019), institutional investors (Cohen et al., 2023; Safiullah et al., 2022), staggered boards (Tanthanongsakkun et al., 2023), board gender diversity (Haque, 2017; Konadu et al., 2022), and manager incentives (Garel et al., 2022; Qian et al., 2017).

HYPOTHESIS DEVELOPMENT

Competition-oriented Culture

A competition-oriented culture is characterized by a strong focus on outperforming rivals and achieving market dominance (Cameron et al., 2006; Quinn et al., 1983). To gain a competitive edge in the market, firms with a competition culture are likely to adopt cost-saving and resource-efficient technologies, which can lead to a reduced carbon footprint. Moreover, firms with a competition-oriented culture are often keen to understand and satisfy their customers and investors (Bose et al., 2024; Hartnell et al., 2011; Hooijberg et al., 1993). These stakeholders increasingly demand better environmental performance from firms (Bolton et al.,

2021; Ilhan et al., 2023). By showcasing their commitment to sustainability, competition- oriented firms can attract environmentally conscious customers, investors, and partners, thereby enhancing their reputation and market share. Firms endorsing competition also place a strong emphasis on risk management (Cameron et al., 2006; Quinn et al., 1983). Effective carbon management can mitigate risks related to negative publicity, resource scarcity, energy price volatility, and regulatory changes (Bolton et al., 2023b; Karpoff et al., 2005; Subramaniam et al., 2015), thereby maintaining a competitive market position. In addition, competitive firms are driven to innovate to stay ahead of competitors (Baer et al., 2010; Büschgens et al., 2013; Scherer, 1984). This drive for innovation can result in the development and adoption of cleaner technologies and sustainable practices (Ganda, 2019; Töbelmann et al., 2020).

On the other hand, a competition-oriented culture often emphasizes rapid growth and short-term profitability (Cameron et al., 2011; Cameron et al., 2014), potentially leading to increased carbon emissions as firms prioritize these goals over sustainable practices. Specifically, competitive pressures can drive firms to ramp up production and frequently launch new products to meet market demands quickly (Cooper, 2011; Deeds et al., 2000; Harpaz et al., 1982), leading to higher energy consumption and increased carbon emissions from both manufacturing and disposal processes. Additionally, to outpace competitors, firms may prioritize short-term financial gains over long-term sustainability. This can result in the adoption of practices that are less energy-efficient and more carbon-intensive. Firms focused on competition may hesitate to invest in green technologies or sustainable practices if they perceive these investments as costly or not immediately beneficial to their bottom line (Campbell, 2007; Duanmu et al., 2018; Ioannou et al., 2012; Jensen, 2010; Walley et al., 1994).

Creation-oriented Culture

A creation-oriented culture motivates staff to think innovatively and grants them greater freedom and flexibility within the organization. Consequently, firms with this type of culture tend to develop new products and methods to adapt to changing market conditions (Büschgens et al., 2013; Hasan et al., 2024). To address stakeholders’ environmental concerns, these firms are likely to develop technologies and processes that are more energy-efficient and less carbon- intensive.

However, creative endeavors such as designing, testing, and implementing new technologies often require substantial energy, particularly when new facilities or equipment are involved (Simpson et al., 2006; Van de Ven et al., 1999). Without renewable energy sources, this increased consumption can lead to higher carbon emissions. Additionally, not all innovations succeed, and failed projects can result in wasted resources and energy (Boulding et al., 1997). The environmental cost of these failures can be significant if they occur frequently. Furthermore, if the primary focus is on creativity and market differentiation without integrating sustainability, innovations may neglect their environmental impact. Products and processes might be designed for performance and cost-effectiveness rather than for energy efficiency and low emissions (Fernández Fernández et al., 2018; Ganda, 2019).

Collaboration-oriented Culture

A collaboration-oriented corporate culture can significantly reduce carbon emissions by fostering teamwork and loyalty (Duncan et al., 1998; Panayotopoulou et al., 2003; Porcu et al., 2020). Under this culture, the firm’s carbon reduction strategy is likely to gain more support from employees due to their higher involvement in the decision-making process, the collaborative atmosphere, and improved internal communication. Moreover, employees with a strong sense of loyalty are more committed to helping the organization reduce emissions,

thereby avoiding environmental disputes with external parties such as governments and regulatory groups and enhancing the organization’s public image.

In contrast, emphasizing human capital and granting employees a higher degree of freedom can lead to a relatively lax management approach (Bhandari et al., 2022; Denison, 1990). This less constrained approach can hinder the manager’s ability to enforce discipline in implementing low-carbon plans, thus reducing the effectiveness of carbon emission reductions.

Control-oriented Culture

Control-oriented culture, characterized by hierarchical structures and formalized procedures, can influence carbon emissions through various mechanisms. This culture emphasizes efficiency, consistency, and standardized processes (Cameron et al., 2006), which can enhance resource management and reduce carbon emissions. For instance, firms with a strong control- oriented culture are more likely to implement Environmental Management Systems (EMS) such as ISO 14001, which systematically monitor and reduce energy consumption and emissions (Darnall et al., 2008). Furthermore, the focus on compliance and risk management within this culture ensures adherence to environmental regulations, potentially leading to reduced carbon footprints (Delmas et al., 2008).

However, the rigidity and bureaucratic nature of a control-oriented culture may stifle innovation and delay the adoption of new, energy-efficient technologies (Fang et al., 2023; Landau et al., 1979). This resistance to change can result in continued reliance on outdated, carbon-intensive processes, thereby increasing emissions. Additionally, a strong focus on short-term efficiency gains might deprioritize long-term investments in sustainability, further exacerbating carbon emissions (Jensen, 2001). Limited employee engagement in sustainability initiatives due to top-down decision-making can also undermine efforts to reduce emissions, as frontline employees are often critical in identifying and implementing energy-saving measures (Ramus, 2001).

Main Hypothesis

Based on the above discussions, we argue that across the four types of corporate culture conflicting forces may be at work and it is unclear which one dominates. Figure 1 further illustrates this dynamic relationship between competition, creation, collaboration, and control cultures with carbon performance. Therefore, we treat the impact of culture on carbon emissions as an open empirical question and propose the following non-directional hypothesis, stated in its null form:

*Hypothesis:* Corporate culture (whether competition-oriented, creation-oriented, collaboration- oriented, or control-oriented) does not affect a firm’s carbon emissions.

[insert Figure 1 here]

METHODOLOGY

Measure of Carbon Performance

In line with prior research (Bolton et al., 2023a; Hart et al., 1996; Lewandowski, 2017; Patten, 2002; Qian et al., 2017), we utilize Scope 1 carbon emission intensity as our metric for assessing carbon performance. This measure is calculated by dividing a firm's emissions by its sales in thousands of US dollars at year-end, thus reflecting carbon emissions per thousand dollars of revenue. Aswani et al. (2024) distinguish between emission intensity and absolute emission levels, arguing that the emission intensity, which mitigates the impact of firm size, provides a more accurate assessment of a firm’s carbon performance than absolute emissions. Our primary analysis focuses on Scope 1 emissions, which encompass direct emissions from owned or controlled sources, including those from operational activities such as machinery operation and product manufacturing. In contrast, Scope 2 emissions account for indirect emissions from the generation of purchased energy, which encompasses emissions from electricity and energy used for heating and cooling facilities. Scope 3 includes all other indirect

emissions along the company’s value chain, excluding those covered by Scope 2. We focus on Scope 1 because these emissions are directly manageable by the firm, offering a clearer gauge of cultural influence on environmental performance compared to Scopes 2 and 3.

Measure of Corporate Culture

We use textual analysis to measure corporate culture based on the 10-K fillings of US-listed firms. Following the methodology outlined by Fiordelisi et al. (2014), we compute the four cultural dimensions based on the CVF using the following steps. Initially, we download 10-K reports for all publicly listed US firms from the Securities and Exchange Commission (SEC). These reports are then parsed into distinct word vectors. For each cultural dimension, we identify specific keywords and their synonyms, drawing from the foundational research by Cameron et al. (2006), and expand this list using the Harvard IV-4 Psychological Dictionary. These keywords are detailed in Appendix A. For example, terms like ‘adapt’, ‘begin’, and ‘change’ are associated with ‘create’, which can be expected to be related to a creation-oriented culture.

Before counting the words, we clean the data by removing all HTML tags and other non- alphanumeric characters. Subsequently, we calculate the score for each cultural dimension by dividing the count of words related to that dimension by the total number of words in the 10- K report. For instance, a *Creat* score of 0.08 in 2010 indicates that words associated with a creation-oriented culture constitute 8% of the words in that year's report. This metric has been extensively validated in the literature, with several studies confirming its efficacy in capturing corporate culture dimensions that align significantly with specific firm characteristics (Bhandari et al., 2022; Fang et al., 2023; Fiordelisi et al., 2019; Hasan et al., 2024).

Baseline Model

We employ the following model to test our hypothesis:

𝐶𝐶𝐶𝐶1𝑡𝑡 = 𝛼𝛼 + 𝛽𝛽1𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝑡𝑡−3,𝑡𝑡−1 + 𝛽𝛽2𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝑡𝑡−3,𝑡𝑡−1 + 𝛽𝛽3𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝑡𝑡−3,𝑡𝑡−1 + 𝛽𝛽4𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝑡𝑡−3,𝑡𝑡−1 +

𝛽𝛽5 𝐹𝐹𝐹𝐹𝐶𝐶𝐶𝐶\_𝑆𝑆𝐹𝐹𝑆𝑆𝐶𝐶𝑡𝑡−1 + 𝛽𝛽6𝑅𝑅𝑅𝑅𝑅𝑅𝑡𝑡−1 +

𝛽𝛽7𝐿𝐿𝐿𝐿𝐿𝐿𝐿𝐿𝑡𝑡−1+𝛽𝛽8𝐶𝐶𝑅𝑅𝐶𝐶𝐿𝐿𝐶𝐶𝑡𝑡−1+ 𝛽𝛽9𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐼𝐼𝐹𝐹𝐶𝐶𝐶𝐶𝐶𝐶𝑡𝑡−1+ 𝛽𝛽10𝑀𝑀𝑀𝑀𝑡𝑡−1 + 𝛽𝛽11𝑀𝑀𝐶𝐶𝐶𝐶𝐶𝐶𝐵𝐵\_𝑆𝑆𝐹𝐹𝑆𝑆𝐶𝐶𝑡𝑡−1 +

𝛽𝛽12𝑁𝑁𝐿𝐿𝑁𝑁𝑡𝑡−1 + 𝛽𝛽13𝐹𝐹𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝑡𝑡−1 + 𝐶𝐶𝐶𝐶𝐵𝐵𝐼𝐼𝐼𝐼𝐶𝐶𝐶𝐶𝐼𝐼𝐹𝐹𝐿𝐿 + 𝑆𝑆𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐶𝐹𝐹𝐿𝐿 + 𝑌𝑌𝐶𝐶𝐶𝐶𝐶𝐶𝐹𝐹𝐿𝐿 + 𝜖𝜖*.*

The dependent variable, *CI1t*, represents the firm’s Scope 1 carbon intensity for year t. The variables of interest are the four cultural dimensions of the CVF: competition (*Compet*), creation (*Create*), collaboration (*Collab*), and control (*Control*). Given that the impact of corporate culture on carbon emissions may not be immediate, due to the time needed for operational and production changes (e.g., implementing green innovations and deploying energy-efficient equipment) to affect emissions, we calculate the cultural variables as averages from years t-3 to t-1. This approach allows us to account for the time required for such cultural influences to manifest in the firm's carbon emissions.

We control for a range of firm and board characteristics in year t-1, which prior research suggests may influence a firm's carbon emissions (Atif et al., 2021; de Villiers et al., 2011; Griffin et al., 2017; Haque, 2017; Ott et al., 2023; Qian et al., 2017; Russo et al., 2005). These characteristics include firm size (*Firm\_Size*), profitability (*ROA*), leverage (*Leverage*), capital expenditure (*CAPEX*), the proportion of intangible assets (*Intangible*), market-to-book ratio (*MB*), board size (*Board\_Size*), non-executive director ratio (*NED*), and the proportion of female directors (*Female*). We winsorize all continuous variables at the 1st and 99th percentiles to mitigate the influence of outliers. Additionally, we include industry, state, and year-fixed effects in the baseline regression. Detailed definitions and measurements of these variables are provided in Appendix B.

Data and Sample

We collect carbon emission data from S&P Global Trucost, a leading provider of corporate carbon emissions information. Trucost compiles data from publicly available sources and

employs an Environmentally Extended Input-Output (EEIO) model to estimate annual carbon emissions for companies that do not disclose them.[[2](#_bookmark36)] The use of Trucost data extends beyond the business sector; it is referenced by both S&P 500 and MSCI indices and utilized by international bodies such as the United Nations Environment Program (UNEP). Additionally, this dataset is employed in numerous scholarly works (e.g., Azar et al., 2021; Bolton et al., 2021; Cohen et al., 2023; Ehlers et al., 2022; Pedersen et al., 2021; Pope et al., 2023). Cultural variables are constructed using 10-K reports from US-listed firms sourced from the SEC EDGAR database, while financial performance and board characteristics data are retrieved from Compustat and BoardEx, respectively. We exclude financial sector firms (SIC codes 6000-6999) and entries with missing data essential for the baseline regression. Our final sample includes 16,564 firm-year observations from 2002 to 2021. The starting point of the sample is restricted by the availability of the Trucost data. Table I details the sample processing steps and the resultant observation counts.

[insert Table I here]

Table II, Panel A details the distribution of the sample by year, showing a consistent rise in the number of firm-years throughout the sample period. Notably, there is a marked increase starting in 2016, likely attributable to an expansion in data coverage by Trucost. Panel B presents the sample distribution across various industries, showing substantial representation in sectors such as ‘Non-durable Goods Manufacturing’, ‘Durable Goods Manufacturing’, and ‘Other Services’, among others. This panel highlights the broad industrial diversity of our sample.

[insert Table II here]

Summary Statistics and Correlation

Table III provides summary statistics for all variables used in the baseline regression analysis. The Scope 1 carbon intensity (*CI1*) shows a mean of 0.279 and a standard deviation of 0.880, but with a median significantly lower at 0.020, indicating substantial skewness toward lower emission levels. The cultural dimensions—competition (*Compet*), creation (*Creat*), collaboration (*Collab*), and control (*Control*)—report means and medians of 2.503 (2.444), 0.836 (0.834), 0.740 (0.707), and 0.689 (0.672), respectively, suggesting moderate dispersion across these attributes. Regarding firm size, before logarithmic transformation, there is a pronounced difference between the mean (£7,865 million) and median (£2,596 million) of total assets, highlighting that a few large firms disproportionately influence the average. The firms in our sample, on average, are operating at a loss with a mean ROA of -0.016. Other financial metrics such as leverage (*Leverage*), capital expenditures (*CAPEX*), and market-to-book ratio (*MB*) have means (medians) of 0.255 (0.235), 0.047 (0.031), and 1.751 (1.111), respectively. Additionally, on average, 21.7% of total assets are intangibles. The average board size, before logarithmic transformation, is 9 members. Boards consist predominantly of non-executive directors, making up 84.8% of the total, and 15% of board members are female.

[insert Table III here]

Table IV presents the Pearson correlation coefficients among the variables. The cultural dimensions of competition, creation, collaboration, and control each display significantly negative correlations with carbon intensity, suggesting an inverse relationship between these aspects of corporate culture and firms' carbon emissions. These correlations serve as preliminary evidence supporting the potential impact of corporate culture on environmental performance. The table further reveals notable correlations between the different cultural dimensions themselves. For example, the correlation coefficients between competition and

creation, collaboration, and control are 0.286, 0.260, and 0.236, respectively. These positive correlations suggest some interdependence among these cultural traits. Among the control variables, correlations are generally moderate and mostly below 0.5, with the notable exception of the correlation between *Firm\_Size* and *Board\_Size*, which stands at 0.648. This higher correlation underscores a relationship potentially influenced by larger firms having more extensive boards. However, the overall moderate level of correlations between the variables alleviates the concern regarding multicollinearity in our regression analysis.

[insert Table IV here]

RESULTS

Baseline Tests

Table V reports the baseline regression results of the impact of corporate culture on firms’ carbon intensity. Each regression in Columns (1)-(4) includes a distinct cultural dimension. The results show significantly negative coefficients on *Compet* and *Collab* and a significantly positive coefficient on *Creat*. However, the coefficient on *Control* is not statistically significant. When all four cultural dimensions are integrated into a single regression in Column (5), the findings corroborate significantly negative coefficients on *Compet* (Coefficient = -0.100, t- statistics = -3.253) and *Collab* (Coefficient = -0.292, t-statistics = -3.357), alongside a significantly positive coefficient on *Creat* (Coefficient = 0.242, t-statistics = 2.375). The coefficient on *Control* remains statistically insignificant (Coefficient = -0.048, t-statistics = - 0.498). These results suggest that firms with cultures oriented towards competition and collaboration exhibit lower carbon intensity, whereas those emphasizing creativity exhibit higher emissions. The net effect of a control-oriented culture is negligible. Economically, the impact of these cultural variables is substantial. A one-standard-deviation increase in competition- or collaboration-oriented cultures correlates with reductions in carbon intensity by 0.050 and 0.056, respectively. These reductions account for 17.9% and 20.1% of the mean

carbon intensity. In contrast, a similar increase in creativity-oriented culture corresponds to a

0.036 rise in carbon intensity, representing 12.6% of the mean.

Regarding control variables, our analysis aligns with the existing literature (Griffin et al., 2017; Haque, 2017; Luo et al., 2012; Ott et al., 2023) and indicates that larger firms with lower profitability, intangible assets, and market-to-book ratios, as well as higher proportions of non- executive directors on their boards, tend to produce higher carbon emissions.

[insert Table V here]

Robustness Tests

*The impact of changes in corporate culture following CEO turnover on carbon emissions.* Our baseline analysis potentially suffers from endogeneity due to omitted variables that might concurrently influence corporate culture and carbon performance, leading to a spurious correlation. To address this issue, we employ a staggered DiD approach, similar to the methods used in previous studies (Hasan et al., 2024; Hossain et al., 2022; Liu, 2016). This method leverages CEO turnovers, which are well-documented for their disruptive effects on corporate culture (Altamuro et al., 2022; Davidson et al., 2015; Li et al., 2024b). We focus on firms undergoing a single CEO change during our sample period and analyze three years before and three years after the turnover. We define a *Post* dummy variable as one for observations after the CEO turnover and zero otherwise, along with four culture-specific dummies— *Treated\_Compet*, *Treated\_Creat*, *Treated\_Collab*, and *Treated\_Control*—that capture increases in respective cultural dimensions from the year preceding to the year of the CEO turnover. The regression model includes *Post*, the interactions between *Post* and the culture- specific dummies, the same control variables as in the baseline model, and fixed effects for firms and years. Consequently, we examine the impact of cultural shifts around the time of a CEO turnover on carbon emissions.

The results from Column (1) of Table VI show a significantly negative coefficient on *Post*

*× Treated\_Compet* (coefficient = -0.076, t-statistics = -2.179), suggesting that firms with an increased focus on competition-oriented culture post-CEO turnover see a notable reduction in carbon intensity. However, the coefficients on *Post × Treated\_Creat* (coefficient = 0.034, t- statistics = 1.010), *Post × Treated\_Collab* (coefficient = -0.032, t-statistics = -0.899), and *Post*

*× Treated\_Control* (coefficient = 0.034, t-statistics = 0.952) in Columns (2)-(4) are not statistically significant, indicating no substantial change in carbon intensity associated with increases in creation, collaboration, or control-oriented cultures post-CEO turnover. These findings affirm the specific impact of a competition-oriented culture on reducing carbon emissions but do not support a similar conclusion for the other cultural dimensions.[[3](#_bookmark37)]

[insert Table VI here]

*Other robustness tests.*

In Table VII, we conduct a series of other robustness checks to validate our findings. First, we replace industry, state, and year-fixed effects with firm and year-fixed effects. The results, displayed in Column (1), reaffirm the significantly negative impact of a competition-oriented culture on carbon intensity and the significantly positive impact of a creation-oriented culture. However, the influence of a collaboration-oriented culture is no longer significant, and the impact of a control-oriented culture continues to be statistically negligible.

In Columns (2)-(4), we explore alternative measures of corporate culture. Specifically, in Column (2), we utilize one-year lagged culture scores rather than the average of the three-year lagged scores. The results are qualitatively similar to our baseline analysis. We continue to observe a significantly negative impact of competition and collaboration-oriented cultures on carbon emissions, while the influence of a control-oriented culture remains statistically insignificant.

In Column (3), to address concerns that raw percentages of culture-related words in 10-Ks might reflect temporary fluctuations or be influenced by market or industry-specific distortions within a particular year (Nguyen et al., 2019), we replace the culture scores with indicators for dominant cultures. We define dummy variables—*Compet\_Dominant*, *Creat\_Dominant*, *Collab\_Dominant*, and *Control\_Dominant*—as one if the respective values for *Compet*, *Creat*, *Collab*, and *Control* are in the top quartile among all firms in a given year, and zero otherwise. This method aims to more accurately capture the prevailing cultural dimensions of a firm relative to its peers, an approach widely utilized in previous research (e.g., Bhandari et al., 2022; Luu et al., 2023a; Luu et al., 2023b; Nguyen et al., 2019). Using this approach, the impacts of competition and collaboration-oriented cultures continue to be significantly negative, while the effects of creation and control-oriented cultures are statistically insignificant.

In Column (4), we derive culture scores from the textual content of the MD&A section alone instead of the whole 10-K report. Barth et al. (2021) argue that the MD&A section, which contains more subjective expressions than other parts of annual reports, provides richer insights into corporate cultures. This focused approach helps minimize the inclusion of irrelevant information. We observe significantly negative effects of competition and collaboration- oriented cultures and a significantly positive effect of creation-oriented culture in this test, consistent with the baseline analysis.

To further address the potential omitted variable problem, we introduce additional control variables in Columns (5) and (6). In line with Nguyen et al. (2019), Column (5) adds observable CEO characteristics, such as CEO tenure (*CEO\_Tenure*), cash compensation (*CEO\_Compensation*), age (*CEO\_Age*), and risk-taking incentives (*CEO\_VEGA*). The analysis reveals that the significantly negative impact of a competition-oriented culture on carbon emissions persists, even when accounting for CEO characteristics. The impacts of the other three cultural dimensions are statistically insignificant.

In Column (6), we incorporate the political environment of the firm’s headquarters state, using the proportion of Democratic votes in the state in the most recent presidential election (*Blue\_Votes*) as a proxy. Consistent with existing literature (Beland et al., 2015; Bonnet et al., 2024; Pacca et al., 2021; Shrestha, 2024; Wang et al., 2022), we find that firms in Democratic- leaning states exhibit lower carbon emissions. Even after accounting for political ideology, the significantly negative effects of competition and collaboration-oriented cultures, along with the significantly positive effect of a creation-oriented culture, mirror those in our baseline analysis. Collectively, these robustness tests consistently confirm the significant role of competition- oriented culture in reducing carbon emissions. Findings for creation and collaboration-oriented cultures are mixed, showing significant impacts in certain tests but not in others. The influence

of a control-oriented culture remains consistently insignificant across all tests.

[insert Table VII here]

Cross-Sectional Tests

Given our consistent findings on the impact of competition-oriented culture on carbon performance across firms, we further analyze the variability in the relationship. Previous research (Graham et al., 2022; Li et al., 2021a; Li et al., 2021b) suggests that the influence of culture on firm performance is more pronounced in challenging operational environments. To represent such environments, we employ the inverse of the z-score (*Bankruptcy\_Risk*) and the Kaplan-Zingales (KZ) index (*Financial\_Constraint*) as proxies. These measures, along with their interactions with *Compet*, are incorporated into the baseline regression model and reported in Table VIII, Columns (1) and (2). Our findings reveal significantly positive coefficients on *Bankruptcy\_Risk* (coefficient = 0.029, t-statistics = 3.522) and *Financial\_Constraint* (coefficient = 0.004, t-statistics = 2.923), indicating that financial distress correlates with higher carbon emissions—a result aligning with earlier studies (Nguyen et al., 2020; Xu et al., 2021). Notably, the coefficients on the interaction terms *Bankruptcy\_Risk × Compet* (coefficient = -

0.011, t-statistics = -3.565) and *Financial\_Constraint × Compet* (coefficient = -0.002, t- statistics = -2.563) are significantly negative, underscoring that the effect of a competition- oriented culture on carbon reductions is exacerbated in financially challenging conditions.

Prior research indicates that the impact of corporate culture on business operations tends to diminish in firms experiencing high labor mobility. Frequent employee turnover can dilute established cultural norms, disrupt internal networks essential for building shared values among employees, and necessitate constant management adaptation, impeding the sustainable implementation of culture-driven practices (Bidwell, 2011; Groysberg et al., 2018; Sheridan, 1992). Consequently, high labor mobility challenges the continuity and influence of corporate culture on business operations. In our analysis, we incorporate the Donangelo (2014) measure of industry-level labor mobility (*Mobility*) and its interaction with *Compet* into the baseline regression in Column (3). We observe a significantly negative coefficient on *Mobility* (coefficient = -0.626, t-statistics = -3.462), suggesting that firms operating in industries with greater labor mobility face fewer barriers in redeploying employees towards green innovations and transitioning to more carbon-efficient production processes. The significantly positive coefficient on the interaction *Mobility × Compet* (coefficient = 0.221, t-statistics = 3.336) indicates that labor mobility moderates the negative impact of competition-oriented culture on carbon intensity, aligning with previous literature.

The impact of culture on organizational behavior tends to diminish in the presence of stringent government regulations, which establish uniform standards of conduct for all entities. These regulations act as external control mechanisms, limiting the extent to which cultural variations can influence decision-making and operational processes (Hofstede, 1980; Pistor, 2019; Schein, 2010). In our analysis, we explore the influence of two climate-change regulations—the Paris Agreement and the SCAP—on the relationship between competition- oriented culture and carbon performance. We utilize dummy variables *Paris\_Agreement*,

defined as one for years post-2015 and zero otherwise, and *SCAP*, defined as one following its proposal by the firm’s headquarters state and zero otherwise. The results reveal significantly positive coefficients on *Paris\_Agreement × Compet* (coefficient = 0.155, t-statistics = 4.092) and *SCAP × Compet* (coefficient = 0.171, t-statistics = 3.841), indicating that the influence of competition-oriented culture on carbon performance diminishes following the enactment of these regulations. Additionally, *SCAP*'s coefficient is significantly negative (coefficient = - 0.436, t-statistics = -3.675), suggesting a general reduction in carbon intensity subsequent to the adoption of the SCAP by the firm’s headquarters state.[[4](#_bookmark38)]

[insert Table VIII here]

Additional Tests

In Table IX, we replicate the baseline regression using Scope 2 and Scope 3 emissions as dependent variables. The findings indicate a significantly negative impact of a competition- oriented culture on both Scope 2 and Scope 3 emissions, despite firms having relatively limited control over these emission scopes. Furthermore, a collaboration-oriented culture reveals a significantly negative effect on Scope 3 carbon intensity, though its influence on Scope 2 emissions is not significant. Creation and control-oriented cultures do not significantly impact the intensity of either Scope 2 or Scope 3 emissions. These results underscore the potential of specific cultural orientations to influence environmental outcomes, even in areas typically regarded as beyond direct firm control.

[insert Table IX here]

DISCUSSION AND CONCLUSIONS

In this study, we explored the impact of corporate culture on firms' carbon emissions, highlighting the nuanced ways in which different cultural dimensions influence environmental

performance. Our findings substantiate that a competition-oriented culture significantly reduces carbon emissions, suggesting that the drive to outperform competitors aligns with more efficient environmental practices. Conversely, the impacts of other cultural dimensions, such as collaboration, creation, and control, on carbon emissions were less consistent, indicating that the influence of corporate culture on environmental outcomes is complex and multifaceted. Moreover, we find that in environments with high financial distress, the competition-oriented culture's positive impact on carbon performance becomes even more pronounced, whereas high labor mobility and stringent climate regulations tend to diminish its effectiveness.

Theoretical Contributions

This study contributes to the literature by illustrating how corporate culture extends beyond conventional business performance metrics to influence a firm’s environmental footprint. Previous studies have predominantly focused on the impacts of corporate culture on financial activities, performance, and reporting (e.g., Altamuro et al., 2022; Cumming et al., 2024b; Fang et al., 2023; Guiso et al., 2015; Hasan et al., 2024; Jiang et al., 2019; Li et al., 2021a; Liu, 2016). By examining how different types of corporate culture affect carbon emissions, this study provides a novel insight into the environmental dimension of corporate behavior. This shift from purely financial metrics to include environmental outcomes broadens our understanding of the multifaceted impacts of corporate culture.

Previous research has also identified various determinants of carbon emissions, such as regulatory policies and market pressures (e.g., Qian et al., 2017; Shen et al., 2020; Wang et al., 2019). This paper introduces corporate culture as a significant determinant, highlighting that firms with a competition-oriented culture exhibit superior carbon performance. This finding provides a new lens through which to view the drivers of environmental performance, emphasizing the importance of internal organizational factors.

A concurrent paper by Li et al. (2024a) also explores the intersection of corporate culture and environmental performance. Nevertheless, our study differs from theirs in two important aspects. First, the primary focus of Li et al. (2024a) is on the broader category of firm pollution, which includes various types of environmental externalities such as air, water, and soil pollution. It aims to establish a link between corporate culture and general environmental performance metrics. In contrast, our study specifically targets carbon emissions, providing a more focused analysis of how different types of corporate culture influence a firm’s carbon footprint. This focus allows for a deeper exploration of carbon-specific strategies and outcomes. Second, Li et al. (2024a) use the corporate culture measure of Li et al. (2021b), which classifies corporate culture into strong and weak ones whereas our study employs the CVF framework to classify corporate culture into distinct types: competition, creation, collaboration, and control. This detailed classification allows us to examine how each specific type of culture uniquely impacts carbon emissions, offering a nuanced understanding of the relationship.

Another recent study by Bose et al. (2024) also investigates the relationship between corporate culture and environmental practices, with a specific focus on competition culture and its influence on carbon disclosure. Their study differs from ours by emphasizing disclosure behavior and examining whether competition culture shapes a firm's decision to disclose climate-related information while ours focusing on actual carbon performance, providing a comprehensive analysis of how corporate culture affects measurable environmental outcomes.

Practical Implications

Our study provides several practical implications for policymakers, investors, and managers. First, by demonstrating that a competition-oriented culture significantly reduces carbon emissions, our findings can guide policymakers in designing more effective environmental regulations. Policies that encourage competitive behaviors, such as rewards for innovation in sustainability or public recognition for top-performing firms, can amplify the positive impact

of corporate culture on carbon reduction. Second, investors can use insights from our study to better assess the sustainability and transition risks of potential investments. Firms with a strong competition-oriented culture are likely to be more proactive in reducing their carbon footprint, which can mitigate long-term risks associated with climate change and regulatory compliance. Moreover, sustainable investment strategies can be refined by prioritizing firms that exhibit cultural attributes conducive to carbon reduction. This approach aligns investment portfolios with long-term environmental goals and can improve financial returns by reducing exposure to firms with high carbon risks. Finally, our study underscores the importance of fostering a competition-oriented culture to drive carbon reduction efforts. Managers should consider integrating sustainability goals into competitive strategies, such as setting ambitious carbon reduction targets and linking them to performance metrics and rewards.

Limitations and Future Research

While our study offers meaningful insights, it also has certain limitations that present opportunities for future research. First, we do not specifically investigate the reasons behind the lack of consistent significant results for creation, collaboration, and control cultures. There are two potential reasons why the significant effect is not consistently found for these three dimensions of corporate culture. First, the test results reflect the average effect of each culture, and these dimensions may exhibit both positive and negative impacts on carbon performance, which could offset each other in aggregate. Moreover, the relationship may be influenced by country context related to national culture, as prior studies suggest that national culture can modify the effect of organization culture and its impact on corporate outcomes (Hofstede, 1985; Schneider, 1988). Therefore, future studies could examine how differences in national culture moderate the relationship between corporate culture and sustainable performance by utilizing cross-country data. Such research would offer insights into the interplay between

organizational and national cultural contexts and deepen our understanding of the global applicability and variation in this relationship.

Additionally, our study focuses solely on the carbon performance of firms, leaving other important aspects of sustainability performance unexplored. Future research could examine the role of corporate culture in addressing broader dimensions of sustainability, such as social and governance-related outcomes and provide a more comprehensive understanding of its strategic significance in fostering ESG goals.

Overall, our research provides evidence that by integrating cultural assessment into environmental strategy, firms can harness the power of corporate culture to achieve more substantial carbon reductions, aligning economic objectives with environmental sustainability.

NOTES

1. See, for example, (Bhandari et al., 2022; Chen et al., 2022; Fiordelisi et al., 2019; Fiordelisi et al., 2014; Nguyen et al., 2019; Wang et al., 2021)
2. If firms’ voluntary disclosures are deemed insufficient by Trucost, Trucost supplements these with their estimated emissions to provide a more reliable and consistent picture of a firm's environmental impact.
3. This analysis deviates from a typical DID approach as both the treatment and control groups undergo CEO turnovers, which serves as the event of interest. However, what distinguishes treatment firms is an increase in a specific cultural dimension following the turnover, whereas control firms see a decrease. Our identification strategy hinges on the premise that these increases are directly attributable to the influence of the new CEO on the relevant cultural dimension, rather than stemming from other unobserved changes in firm characteristics (Hasan et al., 2024; Hossain et al., 2022; Liu, 2016). While recognizing that CEO turnovers may not be entirely exogenous, this DID approach helps mitigate the omitted variable problem to a significant extent, thereby strengthening our confidence in establishing a link between competition-oriented culture and improved carbon performance.
4. *Paris\_Agreement* is excluded from the regression due to its collinearity with year-fixed effects.

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**Appendix A** Portfolio of Words

|  |  |
| --- | --- |
| **Dimension** | **Words** |
| **Collaboration** | capab\*, certain\*, cohes\*, collab\*, collectiv\*, commit\*, consens\*, cooperat\*, coordin\*, cultur\*, decentr\*, employ\*, empower\*, engag\*, facilitator\*, help\*, hir\*, human\*, interper\*, involv\*, life\*, loyal\*, mentor\*, mutual\*, parent\*, particip\*, partner\*, people\*, relation\*,  retain\*, reten\*, skill\*, social\*, team\*, train\*, workgroup\* |
| **Competition** | achiev\*, acqui\*, aggress\*, agreem\*, attack\*, budget\*, challeng", charg\*, client\*, compet\*, customer\*, deliver\*, direct\*, driv\*, excellen\*, expand\*, fast\*, goal\*, hard\*, invest\*, market\*, mov\*, outsourc\*, performanc\*, position\*, pressur\*, profit\*, rapid\*, reputation\*, result\*, revenue\*, satisfy\*, scan\*, signal\*, speed\*, strong\*, success\*, superior\*, target\*, win\* |
| **Control** | boss\*, bureauc\*, cautio\*, chief\*, conflict\*, conservat\*, control\*, detail\*, document\*, efficien\*, error\*, expectat\*, fail\*, inform\*, logic\*, method\*, monit\*, norm\*, outcom\*,  procedur\*, regular\*, solv\*, standard\*, uniform\* |
| **Create** | adapt\*, begin\*, chang\*, creat\*, discontin\*, dream\*, elabor", entrepre\*, envis\*, experim\*, fantas\*, freedom\*, futur\*, idea\*, init\*, innovate\*, intellect\*, learn\*, new\*, origin\*, pioneer\*, radic\*, risk\*, start\*, thought\*, trend\*, unafra\*, ventur\*, vision\* |

Source: Fiordelisi et al. (2021)

**Appendix B** Variable definition and source

|  |  |  |
| --- | --- | --- |
| **Variable** | **Description** | **Source** |
| **Carbon intensity variables** | | |
| *CI1* | The firm’s Scope 1 carbon emissions divided by total sales in  thousands of US dollars. | Trucost |
| *CI2* | The firm’s Scope 2 carbon emissions divided by total sales in  thousands of US dollars. | Trucost |
| *CI3* | The firm’s Scope 3 carbon emissions divided by total sales in  thousands of US dollars. | Trucost |
| **Culture variables** |  |  |
| *Collab* | The number of collaboration-oriented culture-related words from Harvard IV-4 divided by the total number of words in the overall  10-K filing, multiplied by 100. | 10-K |
| *Collab\_Dominant* | A dummy variable that equals one if a firm’s *Collab* value lies in  the highest quartile of all firms in a year and zero otherwise. | 10-K |
| *Collab\_MDA* | The proportion of collaboration-oriented culture words from Harvard IV-4 in the MD&A of 10-K filings relative to the total  word count in that section, multiplied by 100. | 10-K |
| *Compet* | The number of competition-oriented culture-related words from Harvard IV-4 divided by the total number of words in the overall  10-K filing, multiplied by 100. | 10-K |
| *Compet\_Dominant* | A dummy variable that equals one if a firm’s *Compet* value lies in  the highest quartile of all firms in a year and zero otherwise. | 10-K |
| *Compet\_MDA* | The proportion of competition-oriented culture words from Harvard IV-4 in the MD&A of 10-K filings relative to the total word count  in that section, multiplied by 100. | 10-K |
| *Control* | The number of control-oriented culture-related words from Harvard IV-4 divided by the total number of words in the overall 10-K  filing, multiplied by 100. | 10-K |
| *Control\_Dominant* | A dummy variable that equals one if a firm’s *Control* value lies in  the highest quartile of all firms in a year and zero otherwise. | 10-K |
| *Creat\_MDA* | The proportion of creation-oriented culture words from Harvard IV-  4 in the MD&A of 10-K filings relative to the total word count in that section, multiplied by 100. | 10-K |
| *Creat* | The number of creation-oriented culture-related words from  Harvard IV-4 divided by the total number of words in the overall 10-K filing, multiplied by 100. | 10-K |
| *Creat\_Dominant* | A dummy variable that equals one if a firm’s *Creat* value lies in the  highest quartile of all firms in a year and zero otherwise. | 10-K |
| *Control\_MDA* | The proportion of control-oriented culture words from Harvard IV- 4 in the MD&A of 10-K filings relative to the total word count in  that section, multiplied by 100. | 10-K |
| **Other variables** |  |  |
| *Bankruptcy\_Risk* | The inverse value of the Z-score. A higher value indicates an  increased bankruptcy risk. | Compustat |
| *Blue\_Votes* | The proportion of Democratic votes in the firm’s headquarters state in the last presidential election. | Charles Stewart's Congressional Data Page [https://web.mit.edu](https://web.mit.edu/cstewart/www/data/data_page.html)  [/cstewart/www/dat](https://web.mit.edu/cstewart/www/data/data_page.html) [a/data\_page.html](https://web.mit.edu/cstewart/www/data/data_page.html) |
| *Board\_Size* | The natural logarithm of the number of board members. | BoardEx |
| *CAPEX* | Capital expenditure divided by total assets. | Compustat |
| *CEO\_Age* | The natural logarithm of the CEO's age. | Execucomp |
| *CEO\_Compensation* | The natural logarithm of CEO cash compensation. | Execucomp |
| *CEO\_Tenure* | The natural logarithm of CEO tenure. | Execucomp |
| *CEO\_VEGA* | The measure for CEO risk-taking incentive, defined as the change in the dollar value of the manager's wealth for a 1% change in the  standard deviation of the firm's stock returns. | Execucomp |

|  |  |  |
| --- | --- | --- |
| *Female* | The number of female directors divided by the total number of directors. | BoardEx |
| *Financial\_Constraint* | The firm’s financial constraint measured with the KZ index. | Compustat |
| *Firm\_Size* | The natural logarithm of total assets. | Compustat |
| *Intangible* | Intangible assets divided by total assets. | Compustat |
| *Leverage* | Long-term debt divided by total assets. | Compustat |
| *MB* | The market value of equity divided by the book value of total  assets. | Compustat |
| *Mobility* | Industry labor mobility which measures the flexibility of workers to switch industries for better jobs. | (Donangelo, 2014) |
| *NED* | The number of non-executive directors divided by the total number  of board directors. | BoardEx |
| *Paris\_Agreement* | A dummy variable that equals one for years after 2015 and zero  otherwise. |  |
| *Post* | A dummy variable that equals one if the year is after a CEO change and zero otherwise. | BoardEx |
| *ROA* | Earnings before Interest and Tax (EBIT) divided by total assets. | Compustat |
| *SCAP* | A dummy variable that equals one if the year is after the firm’s headquarters state proposing the State-level Climate Action Plan (SCAP) and zero otherwise. | Georgetown Climate Centre & Centre for Climate  and Energy Solution |
| *Treated\_Collab* | A dummy variable that equals one if there is an increase in the firm’s collaboration culture score (*Collab*) from the year before to  the year of the CEO turnover and zero otherwise. | 10-K |
| *Treated\_Compet* | A dummy variable that equals one if there is an increase in the firm’s competition culture score (*Compet*) from the year before to  the year of the CEO turnover and zero otherwise. | 10-K |
| *Treated\_Control* | A dummy variable that equals one if there is an increase in the firm’s control culture score (*Control*) from the year before to the  year of the CEO turnover and zero otherwise. | 10-K |
| *Treated\_Creat* | A dummy variable that equals one if there is an increase in the firm’s creation culture score (*Creat*) from the year before to the  year of the CEO turnover and zero otherwise. | 10-K |

**Table I** Sample selection

|  |  |  |
| --- | --- | --- |
|  | Number of firm-years | Number of firms |
| Culture data based on the textual analysis of 10-K from 2002 to 2021 | 96,159 | 12,780 |
| After merging with Compustat | 89,554 | 11,979 |
| After merging with BoardEx | 67,414 | 8,479 |
| After merging with Trucost | 27,376 | 4,203 |
| After excluding the financial industry | 20,763 | 3,283 |
| After excluding observations with missing values | 16,564 | 2,383 |

**Table II** Sample distribution

|  |  |
| --- | --- |
| Panel A Sample distribution by year |  |
| Year | Number of firm-years |
| 2002 | 219 |
| 2003 | 334 |
| 2004 | 397 |
| 2005 | 500 |
| 2006 | 502 |
| 2007 | 498 |
| 2008 | 512 |
| 2009 | 527 |
| 2010 | 539 |
| 2011 | 531 |
| 2012 | 539 |
| 2013 | 595 |
| 2014 | 586 |
| 2015 | 590 |
| 2016 | 1,519 |
| 2017 | 1,561 |
| 2018 | 1,611 |
| 2019 | 1,630 |
| 2020 | 1,717 |
| 2021 | 1,657 |
| All years | 16,564 |
| Panel B Sample distribution by industry group |  |
| Industry group (2-digit SIC) | Number of firm-years |
| Agriculture, Forestry and Fishing (01-09) | 32 |
| Mining (10-14) | 1,156 |
| Construction (15-17) | 394 |
| Non-durable goods manufacturing (20-33) | 4,049 |
| Durable goods manufacturing (34-39) | 4,171 |
| Transport and Utilities (40-49) | 2,455 |
| Wholesale Trade (50-51) | 492 |
| Retail Trade (52-59) | 521 |
| Other Services (70-89) | 3,294 |
| All industries | 16,564 |

**Table III** Summary statistics

This table presents descriptive statistics of the variables used in our baseline regression model. See Appendix B for the detailed definitions of all variables. We winsorize all continuous variables at the 1st and 99th percentiles.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variable | N | Mean | SD | p25 | Median | p75 |
| *CI1* | 16,564 | 0.279 | 0.880 | 0.009 | 0.020 | 0.065 |
| *Compet* | 16,564 | 2.503 | 0.498 | 2.149 | 2.444 | 2.797 |
| *Creat* | 16,564 | 0.836 | 0.147 | 0.741 | 0.834 | 0.926 |
| *Collab* | 16,564 | 0.740 | 0.192 | 0.616 | 0.707 | 0.819 |
| *Control* | 16,564 | 0.689 | 0.144 | 0.590 | 0.672 | 0.767 |
| *Firm\_Size* (£ m, unlogged) | 16,564 | 7,865 | 12,679 | 725 | 2,596 | 7,906 |
| *ROA* | 16,564 | -0.016 | 0.246 | -0.011 | 0.036 | 0.076 |
| *Leverage* | 16,564 | 0.255 | 0.212 | 0.092 | 0.235 | 0.364 |
| *CAPEX* | 16,564 | 0.047 | 0.052 | 0.015 | 0.031 | 0.058 |
| *Intangible* | 16,564 | 0.217 | 0.212 | 0.027 | 0.155 | 0.358 |
| *MB* | 16,564 | 1.751 | 2.064 | 0.597 | 1.111 | 2.116 |
| *Board\_Size* (unlogged) | 16,564 | 9.182 | 2.198 | 8.000 | 9.000 | 11.000 |
| *NED* | 16,564 | 0.848 | 0.079 | 0.818 | 0.875 | 0.900 |
| *Female* | 16,564 | 0.150 | 0.108 | 0.091 | 0.143 | 0.222 |

**Table IV** Pearson correlation

This table presents Pearson correlation coefficients between the variables used in our baseline regression model. Bold coefficients are statistically significant at the 1% level or below. See Appendix B for the detailed definitions of all variables. We winsorize all continuous variables at the 1st and 99th percentiles.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* | *(6)* | *(7)* | *(8)* | *(9)* | *(10)* | *(11)* | *(12)* | *(13)* |
| *(1) CI1* |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *(2) Compet* | **-0.235** |  |  |  |  |  |  |  |  |  |  |  |  |
| *(3) Creat* | **-0.068** | **0.286** |  |  |  |  |  |  |  |  |  |  |  |
| *(4) Collab* | **-0.142** | **0.260** | **0.046** |  |  |  |  |  |  |  |  |  |  |
| *(5) Control* | **-0.117** | **0.236** | **0.096** | **0.073** |  |  |  |  |  |  |  |  |  |
| *(6) Firm\_Size* | **0.215** | **-0.160** | **-0.063** | **-0.099** | **-0.185** |  |  |  |  |  |  |  |  |
| *(7) ROA* | **0.035** | **0.044** | **-0.029** | **-0.081** | **0.036** | **0.412** |  |  |  |  |  |  |  |
| *(8) Leverage* | **0.096** | **-0.146** | **-0.037** | **-0.027** | **-0.213** | **0.224** | **-0.060** |  |  |  |  |  |  |
| *(9) CAPEX* | **0.147** | **-0.256** | -0.008 | **-0.148** | **-0.094** | **0.114** | **0.062** | **0.089** |  |  |  |  |  |
| *(10) Intangible* | **-0.216** | **0.305** | 0.009 | **0.049** | **0.093** | **0.162** | **0.143** | **0.129** | **-0.323** |  |  |  |  |
| *(11) MB* | **-0.167** | **0.167** | **0.073** | **0.127** | **0.184** | **-0.326** | **-0.140** | **-0.202** | **-0.099** | **-0.094** |  |  |  |
| *(12) Board-Size* | **0.153** | **-0.137** | **-0.063** | **-0.047** | **-0.104** | **0.648** | **0.234** | **0.133** | 0.016 | **0.111** | **-0.181** |  |  |
| *(13) NED* | **0.114** | **-0.047** | **0.063** | -0.019 | **-0.032** | **0.256** | **0.063** | **0.099** | **-0.040** | **0.071** | **-0.109** | **0.360** |  |
| *(14) Female* | **0.042** | **0.074** | **0.168** | **0.064** | **0.070** | **0.208** | **0.046** | **0.077** | **-0.110** | **0.085** | 0.019 | **0.214** | **0.225** |

**Table V** Baseline tests: The impact of corporate culture on carbon emissions

This table reports the regression results of the impact of corporate culture on carbon emissions. See Appendix B for the detailed definitions of all variables. We winsorize all the continuous variables at the 1st and 99th percentiles. The numbers enclosed in parenthesis are *t*-statistics computed with firm-level clustered standard errors. \*\*\*, \*\*, and \* represent significant levels of 1%, 5%, and 10%, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) | (5) |
|  | *CI1t* | *CI1t* | *CI1t* | *CI1t* | *CI1t* |
| *Compett-3, t-1* | -0.105\*\*\* |  |  |  | -0.100\*\*\* |
|  | (-3.519) |  |  |  | (-3.253) |
| *Creatt-3, t-1* |  | 0.190\* |  |  | 0.242\*\* |
|  |  | (1.885) |  |  | (2.375) |
| *Collabt-3, t-1* |  |  | -0.325\*\*\* |  | -0.292\*\*\* |
|  |  |  | (-3.784) |  | (-3.357) |
| *Controlt-3, t-1* |  |  |  | -0.077 | -0.048 |
|  |  |  |  | (-0.796) | (-0.498) |
| *Firm\_Sizet-1* | 0.041\*\*\* | 0.041\*\*\* | 0.043\*\*\* | 0.041\*\*\* | 0.040\*\*\* |
|  | (3.408) | (3.421) | (3.531) | (3.395) | (3.306) |
| *ROAt-1* | -0.059\*\* | -0.068\*\* | -0.080\*\*\* | -0.065\*\* | -0.068\*\* |
|  | (-2.026) | (-2.338) | (-2.733) | (-2.220) | (-2.328) |
| *Levergaet-1* | 0.030 | 0.054 | 0.053 | 0.043 | 0.036 |
|  | (0.632) | (1.129) | (1.096) | (0.901) | (0.751) |
| *CAPEXt-1* | -0.111 | -0.095 | -0.157 | -0.066 | -0.224 |
|  | (-0.488) | (-0.411) | (-0.689) | (-0.287) | (-0.977) |
| *Intangiblet-1* | -0.330\*\*\* | -0.361\*\*\* | -0.383\*\*\* | -0.363\*\*\* | -0.339\*\*\* |
|  | (-4.958) | (-5.406) | (-5.634) | (-5.416) | (-5.067) |
| *MBt-1* | -0.007\*\* | -0.009\*\*\* | -0.007\*\* | -0.008\*\*\* | -0.007\*\* |
|  | (-2.378) | (-2.782) | (-2.407) | (-2.579) | (-2.128) |
| *Board\_Sizet-1* | -0.050 | -0.046 | -0.039 | -0.043 | -0.044 |
|  | (-0.786) | (-0.715) | (-0.604) | (-0.665) | (-0.690) |
| *NEDt-1* | 0.257\*\* | 0.237\*\* | 0.255\*\* | 0.251\*\* | 0.236\*\* |
|  | (2.139) | (1.973) | (2.129) | (2.075) | (2.009) |
| *Femalet-1* | 0.031 | 0.006 | 0.022 | 0.029 | 0.006 |
|  | (0.206) | (0.042) | (0.143) | (0.189) | (0.040) |
| *Constant* | 0.196 | -0.213 | 0.145 | -0.024 | 0.249 |
|  | (1.226) | (-1.322) | (0.926) | (-0.154) | (1.390) |
| *Industry FE* | Yes | Yes | Yes | Yes | Yes |
| *State FE* | Yes | Yes | Yes | Yes | Yes |
| *Year FE* | Yes | Yes | Yes | Yes | Yes |
| Observations | 16,564 | 16,564 | 16,564 | 16,564 | 16,564 |
| Adjusted R2 | 0.485 | 0.484 | 0.488 | 0.484 | 0.490 |

**Table VI** Robustness tests: The impact of changes in corporate culture following CEO turnover on carbon emissions

This table presents the results from difference-in-differences (DID) regression analyses examining the impact of changes in corporate culture following CEO turnover on carbon emissions. We define *Treated\_Compet/Creat/Collab/Control* as a dummy variable, which equals one if there is an observed increase in competition, creation, collaboration, or control culture from the year before to the year of CEO turnover, and zero otherwise. The *Post* dummy variable indicates whether the observation is from the period after the CEO turnover. See Appendix B for the detailed definitions of all variables. We winsorize all continuous variables at the 1st and 99th percentiles. The numbers enclosed in parenthesis are *t*-statistics computed with firm-level clustered standard errors. \*\*\*, \*\*, and \* represent significant levels of 1%, 5%, and 10%, respectively.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) |
|  | *CI1t* | *CI1t* | *CI1t* | *CI1t* |
| *Postt×Treated\_Compet* | -0.076\*\* |  |  |  |
|  | (-2.179) |  |  |  |
| *Postt×Treated\_Creat* |  | 0.034 |  |  |
|  |  | (1.010) |  |  |
| *Postt×Treated\_Collab* |  |  | -0.032 |  |
|  |  |  | (-0.899) |  |
| *Postt×Treated\_Control* |  |  |  | 0.034 |
|  |  |  |  | (0.952) |
| *Postt* | 0.055\*\* | -0.003 | 0.032 | -0.002 |
|  | (2.581) | (-0.147) | (1.513) | (-0.072) |
| *Firm\_Sizet-1* | -0.010 | -0.010 | -0.007 | -0.008 |
|  | (-0.319) | (-0.323) | (-0.217) | (-0.248) |
| *ROAt-1* | 0.008 | 0.008 | 0.009 | 0.003 |
|  | (0.211) | (0.192) | (0.220) | (0.081) |
| *Levergaet-1* | -0.059 | -0.055 | -0.052 | -0.051 |
|  | (-0.735) | (-0.670) | (-0.633) | (-0.624) |
| *CAPEXt-1* | 0.719 | 0.721 | 0.741 | 0.712 |
|  | (1.471) | (1.457) | (1.481) | (1.407) |
| *Intangiblet-1* | 0.020 | 0.027 | 0.022 | 0.021 |
|  | (0.368) | (0.497) | (0.413) | (0.404) |
| *MBt-1* | -0.004\* | -0.005\* | -0.004 | -0.005\* |
|  | (-1.688) | (-1.689) | (-1.635) | (-1.766) |
| *Board\_Sizet-1* | -0.001 | 0.002 | -0.002 | -0.003 |
|  | (-0.011) | (0.042) | (-0.034) | (-0.043) |
| *NEDt-1* | -0.221 | -0.224 | -0.222 | -0.217 |
|  | (-1.344) | (-1.356) | (-1.329) | (-1.328) |
| *Femalet-1* | 0.278 | 0.287\* | 0.281 | 0.302\* |
|  | (1.610) | (1.648) | (1.608) | (1.715) |
| *Constant* | 0.999\*\* | 1.017\*\* | 1.012\*\* | 1.011\*\* |
|  | (2.476) | (2.525) | (2.503) | (2.477) |
| *Firm FE* | Yes | Yes | Yes | Yes |
| *Year FE* | Yes | Yes | Yes | Yes |
| Observations | 1,723 | 1,723 | 1,723 | 1,723 |
| Adjusted R2 | 0.922 | 0.922 | 0.922 | 0.922 |

**Table VII** Other robustness tests

This table reports the results of other robustness tests. Control variables adopted in the baseline regression are also used in these tests. See Appendix B for the detailed definitions of all variables. We winsorize all the continuous variables at the 1st and 99th percentiles. The numbers enclosed in parenthesis are *t*-statistics computed with firm-level clustered standard errors. \*\*\*, \*\*, and \* represent significant levels of 1%, 5%, and 10%, respectively.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) | (5) | (6) |
|  | *CI1t* | *CI1t* | *CI1t* | *CI1t* | *CI1t* | *CI1t* |
|  | Firm fixed effect | One-year culture score | Dominant culture | MD&A-based culture measures | Additional controls  on CEO characteristics | Additional control  on the political environment |
| *Compett-3, t-1* | -0.072\*\* | -0.097\*\*\* | -0.075\*\*\* | -0.050\*\*\* | -0.086\*\* | -0.112\*\*\* |
|  | (-2.567) | (-3.310) | (-2.899) | (-3.457) | (-2.124) | (-3.708) |
| *Creatt-3, t-1* | 0.193\*\* | 0.226\*\* | 0.001 | 0.105\* | 0.173 | 0.201\* |
|  | (2.401) | (2.414) | (0.057) | (1.928) | (1.232) | (1.846) |
| *Collabt-3, t-1* | -0.007 | -0.285\*\*\* | -0.056\*\* | -0.184\*\*\* | -0.176 | -0.312\*\*\* |
|  | (-0.152) | (-3.476) | (-1.987) | (-2.721) | (-1.331) | (-3.417) |
| *Controlt-3, t-1* | -0.081 | -0.019 | -0.028 | -0.045 | -0.152 | 0.040 |
|  | (-1.198) | (-0.212) | (-1.035) | (-1.220) | (-1.275) | (0.388) |
| *CEO\_Tenuret-1* |  |  |  |  | -0.003 |  |
|  |  |  |  |  | (-0.198) |  |
| *CEO\_Compensationt-1* |  |  |  |  | -0.003 |  |
|  |  |  |  |  | (-0.664) |  |
| *CEO\_Aget-1* |  |  |  |  | 0.010 |  |
|  |  |  |  |  | (0.082) |  |
| *CEO\_VEGAt-1* |  |  |  |  | 0.003 |  |
|  |  |  |  |  | (0.503) |  |
| *Blue\_Votest* |  |  |  |  |  | -0.580\*\* |
|  |  |  |  |  |  | (-2.511) |
| *Constant* | 0.401\*\*\* | 0.225 | -0.033 | 0.062 | 0.314 | 0.445\*\* |
|  | (2.823) | (1.278) | (-0.223) | (0.409) | (0.551) | (2.041) |
| *Control Variables* | Yes | Yes | Yes | Yes | Yes | Yes |
| *Firm FE* | Yes | No | No | No | No | No |
| *Industry FE* | No | Yes | Yes | Yes | Yes | Yes |
| *State FE* | No | Yes | Yes | Yes | Yes | No |
| *Year FE* | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 16,564 | 16,564 | 16,564 | 16,564 | 8,192 | 16,521 |
| Adjusted R2 | 0.922 | 0.490 | 0.486 | 0.488 | 0.530 | 0.471 |

**Table VIII** Cross-sectional tests

This table reports the results of the impact of the bankruptcy risks, financial constraints, labor mobility, Paris Agreement, and State-level Climate Action Plan on the relationship between the competition culture and carbon intensity. *Bankruptcy\_Risk* is the inverse value of the Z-score. *Financial\_Constraint* is the firm’s financial constraint measured with the KZ index. *Mobility* is the industry labor mobility. *Paris\_Agreement* is a dummy variable that equals one for years after 2015 and zero otherwise. *SCAP* is a dummy variable that equals one if the year is after the firm’s headquarters state proposing the State-level Climate Action Plan (SCAP) and zero otherwise. Other corporate culture variables and the control variables adopted in the baseline regression are also used in these cross-sectional tests. See Appendix B for the detailed definitions of all variables. We winsorize all the continuous variables at the 1st and 99th percentiles. The numbers enclosed in parenthesis are *t*-statistics computed with firm- level clustered standard errors. \*\*\*, \*\*, and \* represent significant levels of 1%, 5%, and 10%, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) | (5) |
|  | *CI1t* | *CI1t* | *CI1t* | *CI1t* | *CI1t* |
| *Compett-3, t-1* | -0.158\*\*\* | -0.132\*\*\* | -0.153\*\* | -0.185\*\*\* | -0.139\*\*\* |
|  | (-3.492) | (-3.370) | (-2.180) | (-4.349) | (-4.083) |
| *Bankruptcy\_Riskt-3, t-1×Compett-3, t-1* | -0.011\*\*\* |  |  |  |  |
|  | (-3.565) |  |  |  |  |
| *Bankruptcy\_Riskt-3, t-1* | 0.029\*\*\* |  |  |  |  |
|  | (3.522) |  |  |  |  |
| *Financial\_Constraintt-3, t-1×Compett-3, t-1* |  | -0.002\*\* |  |  |  |
|  |  | (-2.563) |  |  |  |
| *Financial\_Constraintt-3, t-1* |  | 0.004\*\*\* |  |  |  |
|  |  | (2.923) |  |  |  |
| *Mobilityt-3, t-1×Compett-3, t-1* |  |  | 0.221\*\*\* |  |  |
|  |  |  | (3.336) |  |  |
| *Mobilityt-3, t-1* |  |  | -0.626\*\*\* |  |  |
|  |  |  | (-3.462) |  |  |
| *Paris\_Agreementt×Compett-3, t-1* |  |  |  | 0.155\*\*\* |  |
|  |  |  |  | (4.092) |  |
| *SCAPt×Compett-3, t-1* |  |  |  |  | 0.171\*\*\* |
|  |  |  |  |  | (3.841) |
| *SCAPt* |  |  |  |  | -0.436\*\*\* |
|  |  |  |  |  | (-3.675) |
| *Constant* | 0.447\*\* | 0.327 | 0.441 | 0.242 | 0.349\* |
|  | (2.012) | (1.552) | (1.043) | (1.354) | (1.923) |
| *Other Culture Variables* | Yes | Yes | Yes | Yes | Yes |
| *Control Variables* | Yes | Yes | Yes | Yes | Yes |
| *Industry FE* | Yes | Yes | Yes | Yes | Yes |
| *State FE* | Yes | Yes | Yes | Yes | Yes |
| *Year FE* | Yes | Yes | Yes | Yes | Yes |
| Observations | 13,575 | 13,303 | 6,910 | 16,564 | 16,564 |
| Adjusted R2 | 0.495 | 0.494 | 0.553 | 0.491 | 0.491 |

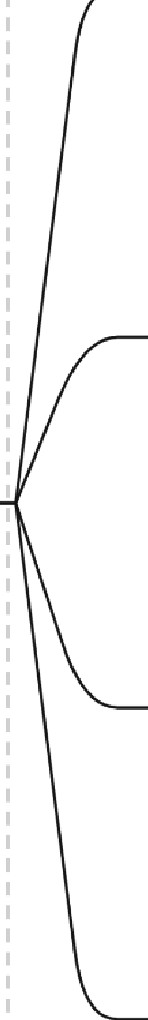
**Table IX** Additional tests: Other scopes of carbon emissions

This table reports the results of the impact of corporate culture on other scopes of carbon emissions. *CI2* and *CI3* represent the intensity of Scope 2 and Scope 3 carbon emissions, respectively. Control variables adopted in the baseline regression are also used in these tests. See Appendix B for the detailed definitions of all variables. We winsorize all the continuous variables at the 1st and 99th percentiles. The numbers enclosed in parenthesis are *t*- statistics computed with firm-level clustered standard errors. \*\*\*, \*\*, and \* represent significant levels of 1%, 5%, and 10%, respectively.

|  |  |  |
| --- | --- | --- |
|  | (1) | (2) |
|  | *CI2t* | *CI3t* |
| *Compett-3, t-1* | -0.008\*\*\* | -0.023\*\*\* |
|  | (-3.385) | (-3.461) |
| *Creatt-3, t-1* | 0.006 | -0.007 |
|  | (1.154) | (-0.431) |
| *Collabt-3, t-1* | -0.004 | -0.070\*\*\* |
|  | (-0.957) | (-6.171) |
| *Controlt-3, t-1* | -0.007 | -0.018 |
|  | (-1.009) | (-1.004) |
| *Constant* | 0.019 | 0.270\*\*\* |
|  | (1.377) | (7.963) |
| *Control Variables* | Yes | Yes |
| *Industry FE* | Yes | Yes |
| *State FE* | Yes | Yes |
| *Year FE* | Yes | Yes |
| Observations | 16,564 | 16,564 |
| Adjusted R2 | 0.387 | 0.590 |

**Figure 1** Mechanisms linking corporate culture to carbon emissions

Research question Culture type Impact Mechanism

Competition culture

Positive

{

Cost-saving and resource-efficient technologies Customer and investor satisfaction

Risk management focus

Innovation and sustainablility

{ . *\_r* Short-term growth prioritization Negative"'---

Profit vs. sustainability trade-offs

The impact of corporate culture on carbon emissions

Creation culture

Positive --- Energy-efficient innovation

High energy consumption in R&D Negative *\_L\_*Resource wasted from failed innovation

� Focus on performance over sustainability

{

Employee support for green strategies

Collaboration culture {

Positive -C

Commitment to improve public image

Negative -- Lax management undermining enforcement

Control culture

Positive

{

N,g,i;v,

Adherence to environmental regulations Resistance to innovation

**Short-t<,m** effid,n,y om ,ost,;n,bmty Limited employee engagement

t

-cStandardized management approach

**Evaluating IAASB’s Claim of Professional Agnosticism in Sustainability Assurance Abstract:**

This paper analyses the interpretive content of comment letters submitted during the consultation process of ISSA 5000, and it applies Andrew Abbott’s theory from The System of the Professions (1988) in this context to explain the broader significance of the finding and see if the IAASB claim of creating a professional agnostic standard is justifiable despite variation in practice among practitioners and its motivation for such a claim. The thematic content analysis reveals the concern of the presence of subjectivity in the application of the new standard to non-accountant assurance practitioners (NAAPs), with the criteria at least as demanding as IESBA and ISQM1, requiring further collaboration of IAASB with relevant parties to enforce the standard on NAAPs. The respondents also express concern about the standard being heavily reliant on existing accounting terms, which may impede neutrality and lead to variability in practice. Thus, stakeholders recommend that the IAASB develop comprehensive guidance alongside the finalisation of the standard to effectively assist NAAPs in the application of ISSA 5000. Given the current drawbacks of the proposed standard highlighted in the comments, it does not stand to be professional neutral to be applied by all practitioners. Suggesting the IAASB prompt approach to expand its jurisdictional claim in the public domain (Abott, 1988) through standard setting in the sustainability assurance market, which is still developing best practices.

1. **Introduction and Research Context:**

Sustainability reporting has become standard practice among corporations, with adoption rates nearing 100% among the world's largest enterprises (KPMG, 2022). Historically voluntary and unregulated, concerns have emerged regarding the reliability and credibility of disclosed information (Boiral et al., 2019a; Sonnerfeldt & Pontoppidan, 2020). To enhance credibility, nearly 69% of the highest-grossing firms now use independent third-party sustainability assurance, a trend likely to grow with impending regulatory reforms (IFAC, 2024a). The political discourse increasingly emphasises financial stability and sustainable development. A webinar on June 16, 2020, hosted by the United Nations Conference on Trade and Development (UNCTAD) and the World Business Council for Sustainable Development (WBCSD), highlighted the importance of enhancing sustainability reporting assurance to build stakeholder trust (Krasodomska et al., 2021). On September 30, 2020, the IFRS Foundation began creating unified global sustainability standards, resulting in the

first two standards, S1 and S2, effective January 2024 (IFRS, n.d.). The EU's Corporate Sustainability Reporting Directive (CSRD), effective January 5, 2023, mandates non- financial reporting for EU businesses. On July 31, 2023, the European Commission (EC) adopted the European Sustainability Reporting Standards (ESRS), aligned with ISSB standards, prompting assurance standard setters to develop fit-for-purpose assurance standards (Venter & Krasodomska, 2024). In response to emerging matters in sustainability assurance, the International Auditing and Assurance Standards Board (IAASB) developed a strategic plan addressing emerging sustainability assurance issue through engagement with major global stakeholders. These consultations underscored the demand for assured information and the necessity of universally recognised sustainability assurance standards (IAASB, 2022). In September 2022, the IAASB approved a project proposal for International Standard on Sustainability Assurance (ISSA) 5000, a new sustainability reporting and assurance standard. An exposure draft (ED) was released in August 2023, with a feedback deadline set for December 1, 2023. The standard is expected to be finalised by 2024, aligning with the International Organisation of Securities Commissions (IOSCO) recommendation for timely approval to familiarise assurance providers and support the upcoming global baseline for sustainability reporting (IAASB, 2024a, n.d.a). As CSRD empowers the European Commission (EC) to adopt assurance standards, it may potentially make the EU the first global jurisdiction to incorporate the IAASB's proposed standards into its regulatory framework upon their release (Ramanauskaite et al., 2023).

The proposed ISSA 5000, titled "General Requirements for Sustainability Assurance Engagements," is designed to be a comprehensive, standalone standard applicable to all types of sustainability assurance engagements. It is relevant for sustainability information reported on any topic and prepared under various frameworks, including the newly introduced IFRS Sustainability Disclosure Standards S1 and S2. Notably, ISSA 5000 is professionally agnostic, facilitating its adoption by assurance practitioners irrespective of their professional backgrounds (IAASB, n.d.b). In contrast to the financial audit market, the absence of enforceable transnational regulations in sustainability assurance has led to a heterogeneous mix of providers. Accounting assurance providers (AAPs), such as public accounting firms, operate alongside non-accounting assurance practitioners (NAAPs), including environmental consultancies, management consultancies, and NGOs (Farooq & De Villiers, 2018; Perego & Kolk, 2012; Venter & Van Eck, 2021). The exposure draft (ED) of ISSA 5000 is characterised as 'profession agnostic,' meaning it is accessible for use by any assurance practitioner provided they adhere to stringent ethical and quality management

requirements. These requirements, as outlined in the ED, are based on two fundamental premises detailed below:

1. Engagement team members and the engagement quality reviewer must comply with the International Ethics Standards Board for Accountants (IESBA's) International Code of Ethics for Professional Accountants (including International Independence Standards) or other professionals,

legal or regulatory requirements that are at least as demanding (IAASB, 2023c).

1. The practitioner must belong to a firm adhering to the International Standard on Quality Management (ISQM) 1 or other professional, legal, or regulatory standards concerning the firm’s quality management system that are at least as demanding as ISQM 1 (IAASB, 2023c).

The concept of "at least as demanding" is not novel, as it has been emphasised in the revisions of ISAE 3000 (revised), the sustainability assurance standard released by IAASB prior to ISSA 5000 (Ge et al., 2024; Sonnerfeldt & Pontoppidan, 2020). The IAASB has noted that both regulators and national standard setters are responsible for defining what qualifies as "at least as demanding" within their jurisdictions (IAASB, 2023c). During the IAASB's consultation, there was debate regarding whether the use of ISAE 3000 should be restricted to professional accountants, as concerns were raised about NAAPs lacking the necessary skills and experience to effectively implement the standard (IAASB, 2011). The absence of a globally accepted standard for sustainability assurance has resulted in confusion due to the proliferation of various privately developed standards. Unlike financial auditing standards, which are often government-initiated, sustainability standards lack a unified normative basis (Carrington, 2019; Rimmel, 2020). Additionally, there is no global standard for audit inspections and enforcement, leading to diverse approaches across jurisdictions. While some regions have minimal external inspections, others rely on peer reviews or regulatory body inspections (Burns & Fogarty, 2010). Despite promoting best practice standards, the IAASB's efforts are constrained by its lack of enforcement authority and the absence of democratic institutions, procedures, and accountability found in national systems, which impedes direct democratic deliberation and decision-making (Ge et al., 2024; Humphrey et al., 2006). This complexity will be further compounded by sustainability assurance, which involves practitioners beyond accounting professionals.

The sustainability assurance market is dominated by the Big Four accounting firms; their strong reputations and networks boost their legitimacy and control, reflecting a shift towards commercial opportunities over traditional professional values (Perego & Kolk, 2012; Perego, 2009; Suddaby et al., 2007; Wallage, 2000). According to the IFAC (2024b) study, audit firms handled about 58% of global assurance engagements in 2022. In 2021, adherence to ISAE 3000 (revised) was reported at 95% among AAPs, compared to just 38% among NAAPs, a disparity that persisted into 2022, with AAP compliance at 92% and NAAP compliance remaining unchanged at 38% (IFAC, 2023, 2024b). Research findings reveal an increased use of ISAE 3000 (revised) post decision by the IAASB to expand its usage to NAAPs, indicating successful promotion by the IAASB. Among NAAPs, ISO standards are most frequently cited, followed by ISAEs and the AA1000 standard. Even though the IAASB's encouragement has broadened the application of ISAEs, no significant change has been observed in the use of ISO or AA1000 standards compared to ISAE 3000 (revised) (Ge et al., 2024). Yet, significant non-compliance with ethics and quality standards persists, posing risks to the assurance profession (IFAC, 2023). The adoption of ISAE 3000 (revised) by NAAPs may aim to enhance perceived quality and may help to enhance their market share, but assessing whether their measures are "at least as demanding as" the IESBA Code and ISQM 1 remains subjective and lacks specific guidance (Ge et al., 2024).

Despite limited acceptance and enforcement by NAAPs, the IAASB's proposed ISSA 5000 outlining the skills and competencies needed for sustainability assurance is similar to ISAE 3000 (revised). It is concerning that ISSA 5000 is being developed without addressing the issuing, which prompted limited adoption of ISAE 3000 (revised), potentially repeating the same challenges. International organisations such as the International Federation of Accountants (IFAC's) IAASB often justify their activities by claiming to work in the public interest to legitimise the actions of professional accounting associations (Humphrey et al., 2006; Matos et al., 2018; Sonnerfeldt, 2013; Willmott, 1990). The standards are not solely issued in the public interest or based purely on technical considerations; they often include a political component influenced by the interests of certain pressure groups (Solomons, 1978; Zeff, 2002). The IAASB's standard-setting process involves extensive stakeholder engagement through exposure drafts (EDs) and public consultation documents. These drafts solicit feedback from a broad range of stakeholders. The final standards are typically published alongside documents that provide the basis for conclusions, detailing the comments received and how they were addressed (Burns & Fogarty, 2010; Matos et al., 2018). Given this context, this research scrutinised the comments received on the ED to examine, from the regulatory perspective, “Is the IAASB's use of the term professionally

agnostic justifiable?” and “Why do IAASB's greater claims encroach beyond its professional remit?”. By drawing on Abbott's (1988) work and content analysis of comment letters from stakeholders submitted to the IAASB during the public consultation phase, a widely used publicly available source in related research (Haapamäki & Mäki, 2023, 2024; Millar & Slack, 2024; Yen et al., 2007).

This study offers several contributions. Firstly, it enriches the comment letter analysis literature by focusing on submissions specific to the latest assurance standard developed by the IAASB, particularly concerning NAAPs. While prior research has largely focused on the types of assurance providers (Martínez‐Ferrero et al., 2018; P. Perego & Kolk, 2012), the processes and preferences involved in developing assurance initiatives by different practitioners from users’ perspectives (Channuntapipat et al., 2019, 2020; O’Dwyer, 2011), and the adoption of ISAEs by non-accounting practitioners (Ge et al., 2024). This study explores the term professionally agnostic and analyses whether the IAASB's standards genuinely accommodate non-accounting practitioners going beyond its professional boundary. These insights can help standard setters improve standards and contribute to broader debates about the enforceability of standards issued by transnational organisations such as the IAASB. The remainder of this paper is organised as follows: relevant literature review, theoretical framework, research methodology, thematic analysis and discussion, and conclusion.

1. **Literature Review:**
   1. Regulatory Structure of the International Auditing and Assurance Standards Board (IAASB):

In a contemporary networked global society, the governance of auditing standards lacks a unified global authority. Instead, it operates through a multifaceted governance architecture involving both private sector entities such as the IFAC and public regulatory agencies, including the US Securities and Exchange Commission (SEC) and the European Commission (EC). This system is further supported by contributions from global organisations such as the World Bank, the International Organisation of Securities Commissions (IOSCO), the Financial Stability Forum (FSF), the International Monetary Fund (IMF), the United Nations (UN), and the World Trade Organisation (WTO). The primary aim

across these bodies is to develop a globally governable auditor framework capable of effectively auditing transnational corporations active in global stock markets (Humphrey et al., 2006; Samsonova-Taddei & Humphrey, 2014). In 2003, a revised standard-setting framework was introduced to transition from self-regulatory professional standards to publicly recognised standards with external oversight, aiming to restore global investor trust and enhance the credibility of financial reporting following the financial crises of 2002–2003. The framework comprises three main components: the IFAC, representing the accounting profession; an oversight body aligned with investor and market interests overseeing the public interest; and international financial institutions, which serve as the ultimate guarantors of the public interest in this domain by exercising a monitoring role (Humphrey et al., 2009; Wymeersh, 2015).

The IFAC, a private entity, comprises national professional accountants' associations from each country. As of June 2023, IFAC included 180 member bodies from 135 countries, representing millions of professional accountants globally (IFAC, 2024c). The IAASB, a component of the IFAC that develops standards for financial statement audits across various sectors, is known as International Standards for Auditing (ISAs) (Humphrey & Loft, 2011). The accounting profession and IFAC provide financial support to the IAASB to facilitate this work (Burns & Fogarty, 2010). In 2002, IFAC transformed the International Auditing Practices Committee (IAPC) into the IAASB to promote standardised global auditing practices, emphasising audited information for decision-making and advocating for "assurance" services to enhance confidence in financial data. This positioned accountants as preferred providers due to their audit-based skills, objectivity, and independence (Sonnerfeldt, 2013; Sonnerfeldt & Pontoppidan, 2020). The membership of the IAASB’s Standard Setting Board (SSB) includes both practicing professional accountants and non-practicing accountants. Nine of the members are non-practicing accountants nominated by member bodies of the IFAC, while the remaining nine consist of the chairperson and at least three public members, all of whom must represent the broader public interest. The remaining members are nominated by the Transnational Auditors Committee (TAC), which serves as the operational body of the Forum of Firms (FoF), a network of international accounting firms conducting transnational audits. The TAC, comprising representatives from transnational audit firms within the FOF, facilitates discussions on standards, regulations, and policies with the IFAC. The FOF, consisting of leading global audit firms, strives for consistency and excellence in auditing practices worldwide. Together, these entities support IFAC's objective to enhance international audit quality and integrity through standard development and regulatory processes (Dewing & Russell, 2014; Humphrey & Loft, 2011; Wymeersh, 2015). The

Consultative Advisory Groups (CAGs) also play a crucial role in the standard-setting process for accountants and auditors. These advisory bodies are composed of individuals or organisations with a direct interest in the accounting profession and its activities. Each Standard Setting Board (SSB) has its own CAG, ensuring that a wide range of stakeholders' opinions are reflected in the standard-setting process (Loft et al., 2006; Wymeersh, 2015).

The second layer features the Public Interest Oversight Board (PIOB), which oversees various phases of the standard-setting process to ensure that standards adequately reflect the public interest. The PIOB is governed by organisational rules that mandate appointments by Monitoring Group (MG) members, limit board membership to ten individuals with terms up to six years, and enforce a strict ethical code barring members from practicing as auditors. The PIOB's independence is safeguarded through the selection of highly reputable members well-versed in international auditing issues and dedicated to the public interest (Wymeersh, 2015).However, members are primarily chosen by financial market regulatory bodies, potentially leading to a narrow focus on financial market stability. There may be concerns about conflicts of interest and whether public interest issues conflicting with financial investors' interests are adequately addressed. The PIOB may not actively engage with civil society groups that seek to influence and shape formal laws and social norms, which could limit the consideration of broader societal interests (Loft et al., 2006). Funded 50% by the IFAC and potentially by MG members, it falls short of effective public oversight in terms of independent funding and comprehensive oversight of all IFAC activities (Humphrey et al., 2006; Wymeersh, 2015). Besides, the PIOB faces significant constraints in its oversight of the IFAC, requiring a two-thirds majority consensus with the IFAC’s leadership and the Monitoring Group to expand its mandate. Although the PIOB can propose agenda items and make non-binding recommendations to Public Interest Activity Committees (PIACs), it lacks the authority to mandate operational changes or initiate projects. It also cannot provide technical input on standards or block the issuance of new ones. Its oversight excludes the FoF and IFAC’s Public Sector Committee, resulting in gaps in audit compliance assurance. The overarching role of the IFAC Council further curtails the PIOB's influence (Humphrey et al., 2006). Thus, the public interest representation within IFAC is characterised by an emphasis on oversight and consultation rather than direct participation, with minimal institutionalisation of external representation due to limited non-practitioner committee membership. IFAC primarily relies on general oversight and consultative groups for committee functions, reflecting a model of accountability to the public interest rather than direct regulatory collaboration with public entities (Humphrey et al., 2006).

The Monitoring Group (MG), representing a crucial third layer of oversight in the global financial regulatory framework, consists of prominent international financial institutions such as IOSCO, the World Bank, the Financial Stability Board, the Basel Committee, the International Association of Insurance Supervisors, the European Commission, and the International Forum of Independent Audit Regulators (IFIAR). Tasked with reforming and overseeing the standard-setting process, the MG ensures a critical dialogue with standard- setting boards (SSBs) to reflect the regulatory needs specific to their sectors and enhance trust in the accounting profession and financial reporting, thereby supporting global financial stability. This group plays a vital role in guiding the PIOB on regulatory, legal, and policy matters, directly influencing SSBs via comments on standards and technical issues, and ensuring its perspectives are integrated within the CAGs. The MG's core mission is to advocate for the development and universal adoption of superior international auditing and assurance standards, contributing to financial stability, innovation, and professional growth worldwide (Humphrey et al., 2011; Humphrey & Loft, 2011; Wymeersh, 2015).

* 1. Recent changes to the IAASB's regulatory oversight:

The MG recommendation paper in July 2020 highlighted critical concerns necessitating an overhaul of the standard-setting process. Key issues included the perceived lack of focus on the public interest and diminished stakeholder confidence due to the accounting profession's significant influence. The report criticised the IFAC role in funding, supporting, and managing the nomination process for SSB, which is predominantly staffed by accounting professionals from audit firms. Furthermore, the standards were deemed not timely or relevant enough to meet the demands of a rapidly changing environment (Heffernan, 2021; Monitoring Group (MG), 2023). Following the recommendation in 2020, the oversight of the IAASB and the IESBA transitioned to the newly established International Foundation for Ethics and Audit (IFEA, or the Foundation) in late 2022 as a new, independent oversight entity, distinct from the IFAC. The Foundation is a US-based nonprofit governed by a Board of Trustees consisting of three members: the Monitoring Group (MG), the Public Interest Oversight Board (PIOB), and the IFAC. The PIOB nominates four trustees, including the Chair, and the IFAC nominates two. An observer is appointed by the MG. The Chairs of the IAASB and the IESBA act as the co-CEOs of the Foundation. This move aims to bolster the independence of ethics, audit, and assurance standards development in the accounting profession. Although the IAASB and IESBA have autonomously set standards since 2003, recent reforms include a new legal structure and a PIOB-led nominating process to further this independence (IFEA, 2023b, 2023a). However, the boards will remain in New York at the

IFAC offices, with IFAC providing administrative support under a service agreement. The relocation of the boards under the foundation will not alter their strategies, work plans, or ongoing projects. Each board will be updated to align with the new structure. In 2024, a unified Stakeholder Advisory Council (SAC) is aimed at replacing the existing CAGs with the PIOB Standard-Setting Board Nominations Committee, which manages nominations through an open process guided by a skills matrix to ensure diverse and expert board composition. SAC will allow the IAASB and IESBA to engage with a diverse range of external stakeholders, leveraging their expertise and experience to inform standard-setting projects. Following a transition period, the IAASB board will consist of 16 members, including a diverse range of stakeholders, with a maximum of five audit practitioners to prevent undue influence while maintaining technical expertise (IFEA, 2023b, 2023a). Overall, reform was made possible through substantial financial contributions from the IFAC and the audit firm networks of the Global Public Policy Committee (GPPC) (IFEA, 2023b; Monitoring Group (MG), 2023). Thus, there is a recognised need to develop a more sustainable funding model for the standard-setting structure to reflect true independence.

* 1. Public consultation in the standard setting process:

International private governance organisations such as IFAC are often criticised for operating outside the scope of democratic oversight, which is traditionally based in national parliamentary systems. These international regulators lack the democratic institutions, procedures, and accountability inherent in national political systems, thereby diminishing nations' abilities to control their own destinies. However, members of the international regulatory elite can support and endorse each other’s standards, contributing to this issue (Humphrey & Loft, 2009; Humphrey et al., 2006; Loft et al., 2006). Furthermore, key institutional actors collaborate to construct a regulatory framework for global finance, establishing themselves as dominant coercive institutions in global financial transactions (Loft et al., 2006). The multi-layered governance arrangements among national, regional, and global bodies complicate the assessment of democratic accountability. The global audit regulatory arena is marked by competing interests and perspectives. Expert governance is often driven by efficiency, under the belief that standard setters and regulators are most effective when removed from political influence (Humphrey et al., 2009; Loft et al., 2006). This poses a challenge for IFAC in balancing its dual roles as an international standard setter serving the public interest and as a promoter of the global accounting profession. At the transnational level, accounting professionals play a crucial role in creating new international standards by developing rule systems that significantly influence market

institutions, thereby consolidating their power and legitimacy as exclusive interpreters of these rules (Covaleski et al., 2003; Suddaby & Viale, 2011).

Private standards may require compliance despite their soft-law status and can become enforceable when incorporated into national laws. Industry association standards often extend beyond members, influencing the market and public sector adoption. Additionally, widespread participation can generate positive externalities. Thus, seeking legitimacy is crucial to establishing itself as a credible, authoritative, and effective standard-setting body in the global accounting landscape (Sanada, 2020). As a result, the IAASB utilises public consultation processes as a tool to gain legitimacy from their constituents, thereby supporting their organisational survival (Durocher et al., 2007; Kenny & Larson, 1993). To achieve this, the IAASB seeks input from various participants in the accounting community during each project phase. Their due process includes issuing Exposure Drafts (EDs) and Consultation Papers (CPs), conducting public consultations, and discussing feedback in technical meetings (Burns & Fogarty, 2010; Matos et al., 2018). IFAC documents and speeches increasingly reference the public interest and emphasise IFAC’s commitments to it, yet detailed explanations of what these commitments entail are rarely provided (Loft et al., 2006). The standards are not solely issued in the public interest or based purely on technical considerations. They often contain a political component, influenced by the interests of certain pressure groups (Hopwood, 1994; Solomons, 1978; Watts & Zimmerman, 1978; Zeff, 2002). Conflicts may arise between independently setting standards and representing the profession, as well as between regulating large international audit firms and their significant financial contributions to IFAC (Loft et al., 2006; Samsonova-Taddei & Humphrey, 2014). The IAASB may face pressure from interest groups, potentially resulting in regulatory capture, where the regulator is influenced by those it is meant to oversee.

Lobbying is integral to the standard-setting process, occurring through formal channels such as submissions to and membership on the standard-setting board and informal channels such as telephone and daily conversations (Tutticci et al., 1994). Among formal methods, submissions on exposure drafts are the most visible and common, providing significant opportunities for influence and persuasion (Reuter & Messner, 2015; Stenka & Taylor, 2010; Tutticci et al., 1994). This process enables interest groups to exert political pressure, potentially leading to standards that prioritise specific group needs over the public interest (Matos et al., 2018). Thus, lobbying by interest groups plays a crucial role in the development and implementation of accounting standards and auditing regulations, making

it an essential component of the rule-setting and policy-making process (Gros & Worret, 2016; Reuter & Messner, 2015). Groups with informational advantages and those most affected by proposed regulations have greater incentives to engage in lobbying (Gros & Worret, 2016; Holder et al., 2013). Stakeholders will submit a comment letter only if the expected benefits, adjusted for the likelihood of influencing the outcome, exceed the costs either individually or collectively (Ryan et al., 2000; Sutton, 1984). Analysing comment letters can offer insights into how interest groups influence the IAASB. Dissatisfied groups often employ detailed arguments and explanations, rather than outright disagreement, to persuade the standard setter to reject or refine proposals. This approach enables them to effectively communicate their concerns and suggest improvements (Giner & Arce, 2012). Due to the accessibility of evidence from formal lobbying, researchers have relied on written comment letters because they are typically the primary source of available data (Tutticci et al., 1994; Weetman et al., 1996). IFAC's global standard-setting process uses the internet for transparency and public participation, enhancing the legitimacy of both the process and the standards. However, private lobbying remains a concern due to differing interests among involved constituencies, despite public comments being available online (Humphrey & Loft, 2009).

* 1. Competitive Context of the Sustainability Assurance Market:

The market for sustainability assurance is bifurcated into two primary segments: AAPs and NAAPs. AAPs primarily consist of the Big Four accounting firms: PwC, E&Y, Deloitte, and KPMG. These firms have traditionally focused on providing financial audit services. However, due to a saturated audit market with low growth potential and higher audit risks, they are now expanding into new assurance markets, such as sustainability assurance (O’Dwyer, 2011; Wallage, 2000). NAAPs constitute a more diverse array of providers than their accounting counterparts, encompassing global engineering consultancies, certification bodies, boutique sustainability consultancies, and a variety of other assurance services. This categorization reflects the broad scope of expertise within the field (Manetti & Toccafondi, 2012; P. Perego & Kolk, 2012; Wong et al., 2016). Assurance providers are required to possess expertise in three distinct areas: (1) assurance and its related procedures; (2) the industry, business, and operations specific to their clients; and (3) the particular subject matter of the engagement, specifically sustainability (Adams & Evans, 2004). The difference stems from their expertise and approach to engagements. For instance, while AAPs are considered to possess specialised expertise in the field of assurance and its procedures acquired through years of conducting financial audits, their advantage is questionable when

it comes to sustainability, the core subject of assurance. In this area, environmentalists, biologists, ethicists, and sociologists who fall into the category of NAAPs are likely to have a superior understanding compared to AAPs (Cohen & Simnett, 2015; Gray, 2000). AAPs are argued to have an advantage over NAAPs due to their knowledge of the reporting entities' industry, business, and operations, especially if they also conduct the financial audits, providing a significant edge (Gillet, 2012). However, it appears that neither AAPs nor NAAPs fully meet all three criteria (Farooq & De Villiers, 2018).

External stakeholders showed a preference for NAAPs over AAPs primarily because of concerns regarding the latter's independence following high-profile scandals and a higher value placed on sustainability expertise rather than procedural knowledge (Wong & Millington, 2014). While internal stakeholders (managers) prefer AAPs largely because they equate sustainability assurance with financial auditing and view financial auditors as already knowledgeable about their operations (Huggins et al., 2011; Jones & Solomon, 2010), the capital market values the credibility of assurance provided by Big 4 accounting firms due to their expertise and perceived trustworthiness, leading to higher market valuations for firms (Clarkson et al., 2019). AAPs, with their financial audit experience, better understand assurance and the need for independence and objectivity compared to NAAPs. As members of a professional accounting body, AAPs adhere to ethical codes that mandate maintaining independence, protecting against threats to objectivity, and enhancing quality (Gray, 2000). However, some clients find NAAPs more relevant due to the high quality of their recommendations (Perego & Kolk, 2012). However, recent corporate accounting scandals have undermined the reputation of accountants as independent and objective assurance providers (Dando & Swift, 2003). Yet, Big Four accounting firms have integrated ESG consulting to address the growing corporate focus on sustainability, emphasising its value in enhancing report credibility and mitigating risks. This strategic move gives them a competitive edge in auditing large multinationals, leveraging their global presence to reduce assurance costs and offer lower fees (Gillet, 2012).

In regard to quality assurance statements, the Big Four accounting firms are considered to have lower quality recommendations and opinions compared to those from NAAPs. NAAPs are recognised for their higher-quality opinions and recommendations, attributed to their technical expertise (Manetti & Toccafondi, 2012; Perego & Kolk, 2012; Perego, 2009). Conversely, AAPs maintain high-quality control and strict procedures, adhering rigorously to standards and providing accurate corporate sustainability reporting (Huggins et al., 2011;

Perego, 2009). However, research also reveals that the type of assurance provider did not impact the quality of reports (Moroney et al., 2012). While reports assured by NAAPs included more qualitative content compared to those assured by AAPs, which were trained to focus on quantitative data, they are less comfortable assuring qualitative information and tend to adopt a more cautious approach to sustainability assurance (Moroney et al., 2012). The approaches of AAPs and NAAPs to sustainability assurance diverge significantly. AAPs adopt a conservative approach rooted in financial audit methodologies, focusing on data accuracy and verification but often overlooking the completeness of the information. In contrast, NAAPs use an evaluative approach, exploring various methods to achieve objectives and aiming to enhance business sustainability by identifying and addressing system weaknesses (Dillard, 2011; O’Dwyer & Owen, 2007, 2005).

The main issue in sustainability report assurance is the lack of a universally recognised standard, resulting in multiple, varied guidelines for practitioners (Wallage, 2000). The numerous standards and guidelines for sustainability assurance stem from its voluntary nature, highlighting the lack of consensus on how such engagements should be conducted (Dando & Swift, 2003). The knowledge bases of the two provider groups vary significantly and are closely tied to their core service areas. These differences manifest in their choice of assurance standards and their strong affiliation with their respective professional backgrounds (Channuntapipat et al., 2020). ISAE 3000, a principle-based assurance standard from the accounting profession, applies to various subjects and is mandatory for accounting assurance providers (Deegan et al., 2006; Manetti & Becatti, 2009). AAPs leverage their accounting expertise and connections, supported by professional bodies, to standardise SA practices. They predominantly use ISAE 3000 to distinguish themselves and attract clients (Channuntapipat et al., 2020). Its adoption has increased since its 2003 launch, especially after the 2013 revision allowing NAAPs to comply with ISAE 3000 (Channuntapipat, 2021; IFAC, 2024b). Despite its widespread use, ISAE 3000 is criticised for not being specifically developed for assurance engagements and for being limited by the principles of financial assurance (Dillard, 2011; Manetti & Becatti, 2009; Sonnerfeldt & Pontoppidan, 2020). While AA1000 was developed by AccountAbility, a global sustainability consultancy based in London, unlike ISAE 3000, AA1000 is a specialised standard designed specifically for sustainability assurance engagements (AccountAbility, 2015; Channuntapipat, 2021; Manetti & Becatti, 2009). The choice of assurance standards affects the scope of SA engagements. AA1000, with its multi-stakeholder approach, allows for an open scope. In contrast, ISAE 3000, linked to financial audit practices, restricts scope to predetermined criteria, supporting NAAPs' claim that their approach better suits sustainability assurance by

avoiding these limitations (Channuntapipat et al., 2020). However, scholars argue that the scope of these two standards varies, suggesting they may be more complementary than rival or substitute standards (Manetti & Toccafondi, 2012). Over the past three years (2019– 2021), ISAE 3000 (Revised) has remained the leading standard in sustainability assurance due to audit firms' market dominance. While NAAPs employ a diverse range of standards for different engagements across various regions, the use of AA1000 and ISO 14064 aligns with jurisdictions where NAAPs dominate the market. In 2021, NAAPs referred to a mix of standards globally, with ISO 14064 (46%) leading for GHG assurance, followed by ISAE 3000 (revised) (38%) and AA1000 (24%) (IFAC, 2023). NAAPs prefer a flexible approach to assurance standards, referring to AA1000 or ISO standards to convince others of the strength and reliability of their knowledge base and expertise, avoiding exclusive commitment to differentiate themselves from the Big 4 and appeal to clients seeking specialised assurance. This flexibility allows them to serve diverse information needs and reflect a dynamic field where they are still developing new assurance methods, unlike AAPs, which typically rely on ISAE 3000 for assurance engagements (Channuntapipat et al., 2020; Ge et al., 2024; Sonnerfeldt & Pontoppidan, 2020).

1. **Theoretical Framework:**

In "The System of Professions: An Essay on the Division of Expert Labour," Abbott (1988) develops a comprehensive theory on the evolution of professions, focusing on why professional groups control and manage expert knowledge and how they acquire and maintain power within their respective fields. Abbott uses the audit profession as an example of narrow professionalisation, characterised by associations, education, licensure, and a state-sanctioned monopoly. However, he argues its true historical impact lies in its evolving jurisdiction, shifting from core accounting services to advisory services (Abbott, 1988, p. 26). Abbott (1988) argues that professional development is driven by interprofessional competition, with conflicts arising from the need to establish control over specific areas of work through specialised abstract knowledge, termed "jurisdiction" (Abbott, 1988, p. 20). He contends that professions enter conflict to establish control, which can be achieved by emphasising either abstract knowledge or practical techniques. Since abstract knowledge is difficult to transfer, it is more valuable for maintaining jurisdiction. In contrast, practical techniques can be delegated to other workers. For instance, AAPs can be viewed as a profession because they possess abstract knowledge and delegate practical techniques to NAAPs.

While litigation and state regulation pressures compel professions to standardise and codify their knowledge, making it less abstract, competition drives them to keep their knowledge abstract (Abbott, 1988, p. 9). While any occupation can establish licensure or a code of ethics, only a profession with abstract knowledge can redefine its problems and tasks, defend against competitors, and expand its territory (Abbott, 1988, p. 9). Abbott also notes that a profession can expand its jurisdiction by asserting its treatments' applicability to problems identified by other groups (Abbott, 1988, p. 100). This approach involves identifying a problem within the professional domain and then creating measurable solutions publicly to validate their professional excellence over their competitors (Gendron & Barrett, 2004; Michelon et al., 2019). This phenomenon can be linked to the current establishment of ISSA-5000 by the IAASB, which claims to be professionally agnostic and provides prescriptions to reduce variability in sustainability assurance reports. Interprofessional competition involves leveraging abstract knowledge to undermine competitors' legitimacy, asserting superior performance (Abbott, 1988, pp. 36). To maintain legitimacy, these claims must be vague enough to deter intruders but clear enough to be understood and accepted by society (Abbott, 1988, p. 45). An intruding profession may initially accept a subordinate jurisdiction, performing routine tasks that underpin the superior profession's work. However, as the subordinate profession integrates, maintaining this role becomes challenging. In response, the superior profession often establishes an "intellectual jurisdiction," controlling the subordinate's knowledge base while allowing relatively unrestricted practice (Abbott, 1988, pp. 69–79).

A profession's jurisdiction includes formal control over key definitions of professional services, the terminology used to describe techniques, the practitioners who perform them, and the actual execution of the work (Abbott, 1988, p. 62). Control over professional language in official documents, conferences, and committees is a crucial resource in jurisdictional competition (Abbott, 1988, p. 139). The manipulation of terminology and definitions in these contexts enables professions to assert their authority and influence over the delivery of professional services. The ability of a group to establish, defend, and expand its jurisdiction is crucial for attaining, maintaining, and enhancing its professional status in society (Abbott, 1988, p. 2). Professionals can redefine their fields by introducing new rules and standards, leveraging their expertise and legitimacy to challenge existing norms and establish innovative regulations. These guidelines reshape the professional landscape,

create new opportunities, and transform industry practices and interactions (Suddaby & Viale, 2011).

This inter-professional competition and legitimization of activities have been analysed across various fields, including auditing, in previous studies (Boiral et al., 2019b; Channuntapipat et al., 2020; Edwards et al., 2007; Walker, 2004). However, prior research has focused on accountants' claims to expertise without delving into the stakeholder's reactions to these claims since stakeholders can ignore, accept, transform, or contest these claims (Gendron & Barrett, 2004). Thus, this study aims to determine whether the IAASB's actions are an attempt to extend the profession's jurisdiction or a genuine effort to establish a neutral standard based on an analysis of stakeholders' comment letters submitted during the standard setting process.

1. **Research Methodology:**

For this study, the research employs an ontology based on a constructionist perspective and an epistemology rooted in an interpretive philosophical viewpoint (Bryman & Bell, 2015). Constructivists regard interview transcripts not as direct reflections of real experiences but as interpretations shaped by interviewees within contexts. These interpretations are considered among many possible ones, with none holding inherent superiority. Adopting an interpretative approach grounded in constructivist philosophy, this study posits that no single objective reality exists; rather, reality is constructed through the diverse interpretations of individuals (Bryman & Bell, 2015). Qualitative research offers deeper insights into human behaviour than quantitative approaches (Creswell & Creswell, 2018). Qualitative methods, which aim to capture the complexity of the studied material, typically link to the interpretive and critical paradigms in accounting (Chua, 1986). In interpretive studies, theory serves as both a starting point and a research outcome, shaped by empirical observations and refined for broader application (Ryan et al., 2002). Many researchers favour an inductive approach, where theory is derived from research by drawing generalizable inferences from observations (Bryman & Bell, 2015). This research adopts an inductive approach, aligning with the interpretive worldview, in the context of ISSA 5000. Thus, this study has addressed the research question using an inductive, qualitative approach.

* 1. Data collection:

A total of 146 comment letters were collected from the IAASB's website for analysis, which served as the primary data source for this research. However, 11 were deemed inadequate as they contained no relevant information or were submitted with largely blank forms. Thus, 135 comment letters were ultimately considered for analysis. The data was derived from the responses to two selected questions (Q1 and Q4), which address the professionally agnostic aspect of the standard. Question 1 inquired, “Do you agree that ED-5000, as an overarching standard, can be applied for each of the items described in paragraph 14 of this EM to provide a global baseline for sustainability assurance engagements? If not, please specify the item(s) from paragraph 14 to which your detailed comments, if any, relate (use a heading for each relevant item).” One of the key topics addressed in paragraph 14 contextualises that ISSA-5000 could be utilised by all practitioners, which was the focus for interpretation from question 1. Question 4 inquired, “Is ED-5000 sufficiently clear about the concept of 'at least as demanding' as the IESBA Code regarding relevant ethical requirements for assurance engagements and ISQM 1 regarding a firm’s responsibility for its system of quality management? If not, what suggestions do you have for additional application material to make it clearer?” (IAASB, 2023b). Qualitative research effectively explores perceptions and subjective logic, but its time-intensive nature typically results in small, purposively selected samples (Wolff et al., 2019). To ensure a comprehensive understanding, the analysis will include comments from all stakeholders (as classified by the IAASB in the question template), irrespective of their type, and use other secondary sources consisting of standard- related documents and information published on relevant websites to reach a conclusion.

|  |  |
| --- | --- |
| Stakeholder Type | No. |
| Member bodies and other professional organisations | 55 |
| Assurance practitioner or firm – accounting profession | 21 |
| Jurisdictional/National Standard Setter | 14 |
| Preparers and users of sustainability information | 14 |
| Regulator or assurance oversight authority | 11 |
| Individuals and others | 8 |
| Academic or academic body | 5 |
| Assurance practitioner or firm – other accounting profession | 5 |
| Public sector organisations | 5 |
| Monitoring Group member | 4 |
| Global standard setter | 2 |

|  |  |
| --- | --- |
| Those charged with governance | 2 |
| Total | 146 |

|  |  |
| --- | --- |
| Region | No. of respondents by region |
| Europe | 40 |
| Global (institutions with offices around the world) | 38 |
| Asia Pacific | 31 |
| North America | 18 |
| Middle East & Africa | 12 |
| South America | 7 |
| Total | 146 |

* 1. Data Analysis:

To analyse the data, a content analysis was conducted. Many previous researchers examining comment letters on standard drafts have utilised content analysis (Haapamäki & Mäki, 2023; Larson, 2008; Millar & Slack, 2024; Yen et al., 2007). Content analysis is a research method that uses systematic procedures to derive valid inferences from text. It organises text into manageable units and can be applied to archived material, making it unobtrusive. However, developing a coding system to ensure reproducibility and reliability demands considerable time and effort (Weber, 1990). There are two general approaches to content analysis: quantitative (form-oriented) analysis, which focuses on word counts and offers more objectivity, and qualitative (meaning-oriented) analysis, which focuses on the meaning behind the words and provides richer insights (Yen et al., 2007). Thus, to extract the meanings from the comment letters, a qualitative thematic content analysis was conducted, focusing on the meaning behind the words. However, a key challenge in qualitative research is the open-ended nature of textual data, which is often more difficult to reduce and identify patterns than numerical data. A theme is a significant construct that links substantial portions of data and relates to the overarching research question (Braun & Clarke, 2006; Saunders et al., 2019). Thematic analysis, a flexible and descriptive method, identifies, analyses, and reports patterns within data (Castleberry & Nolen, 2018). Its robust analytical capabilities make it suitable for a variety of research philosophies. Thematic analysis aids in understanding participants' perspectives, identifying similarities and differences, and generating insights (Braun & Clarke, 2006; Saunders et al., 2019).

Initially, time was devoted to closely reading comment letters and other available public documents available on the IAASB’s website to familiarise oneself with the data prior to thematic coding. Following the approach of Millar and Slack (2024), Larson (2008), Anantharaman (2015), and Yen et al. (2007) in the manual coding process. The first coding identified was binary, assessing whether comment letters expressed support or opposition to the ISSA-5000. However, the focus of this research was not mere agreement or disagreement with the standard, but the opinion expressed regarding the concerns regarding the standard posed to be professionally agnostic. Secondly, the comments in the letters were coded based on the specific arguments detailed within each letter to underscore the concerns between the proposed standards and the feedback from stakeholders (Miller & Slack, 2024; Yen et al., 2007). Krippendorff (2018) warns of the unreliability of self-applied, investigator-developed recording instructions, advising caution. To improve reproducibility and reliability, independent coding during the pilot stage to identify emergent themes is recommended. As a result, researchers employed open coding, meaning codes were not predetermined but developed and refined throughout the coding process. Upon preliminary reading of the comment letters, it was identified that participants addressed the same concerns while answering both questions (1 and 4), as both questions pertain to the professionally agnostic aspect of the standard. Some participants, in response to question 1, also referred to their answer to question 4 for further details in their comment letters. Thus, common themes were identified from the answers to both questions. The themes that were consistent across the sample comment letters, with no new prevalent themes emerging, were further discussed in the analysis section. NVivo version 12 was utilised to support managing large volumes of qualitative data and aiding the manual coding process (Down et al., 2023). Following the consultation period, in March 2024, the IAASB released a staff paper providing insights into their interpretations of the general feedback received for each question. This added another layer to the analysis of the key themes identified, offering triangulation of stakeholder concerns at an aggregated level (Millar & Slack, 2024). Table 1 in the appendix illustrates an example of the process conducted for thematic analysis.

* 1. Ethical Considerations:

When conducting research, ethical considerations are crucial (Bryman & Bell, 2015). These considerations typically focus on the treatment of individual participants. However, this is less relevant for this study as it relies solely on publicly available data, such as reports, comment letters, and meeting minutes, produced with the intent of being public. Thus, an ethical approach that involved thoroughly reading the comment letters to answer the

predetermined question ensured a holistic understanding of the views presented and avoided taking statements out of context.

1. **Analysis and Discussion:**

This section critically examines key themes derived from stakeholder narratives, providing a comprehensive evaluation of the standard's attempts to uphold professional impartiality and professional agnosticism. The analysis reveals four key interconnected issues, highlighting the complexities and challenges of achieving a universally applicable and enforceable standard: 1) subjectivity in the application of IESBA and ISQM1 for NAAPs; 2) the necessity for enhanced collaboration with national and international agencies to ensure convergence and enforcement; 3) reliance on existing accounting terms and standards can hinder application for NAAPs; and 4) the requirement for additional guidance on the enforcement of ISSA-5000 for NAAPs.

* 1. **Subjectivity in the application of IESBA and ISQM1 for NAAPs:**

Respondents have highlighted that the phrase "at least as demanding" lacks a clear operational definition, which can lead to inconsistencies in applying and comparing standards across different professions. This absence of a definitive evaluation framework introduces variability in interpretation and implementation. ISSA 5000 assumes that assurance practitioners are affiliated with firms that adhere to ISQM 1 or equivalent rigorous quality management standards mandated by professional, legal, or regulatory frameworks. However, ISQM 1 primarily targets professional accountants and defines a "firm" as an entity of professional accountants (IAASB, 2020), raising concerns about its suitability for NAAPs. This mismatch could result in a compliance gap under ISSA 5000, as adaptations of ISQM 1 to non-accounting contexts may lack formal recognition by authoritative bodies, failing to meet ED-5000’s stringent requirements. Similarly, the mandate for ethical standards to be "at least as demanding as" the IESBA Code, which is also primarily intended for accountants, complicates compliance for non-accountant practitioners, highlighting a critical limitation in the framework. The comment below further highlights NAAPs preferences to adhere to alternative standards such as IAF and ISO requirements. Previous research indicates that NAAP references to alternative standards instead of ISAEs demonstrate a preference for alternatives deemed equivalent, allowing differentiation from the Big Four and appealing to clients seeking customised solutions (Channuntapipat et al., 2020; Farooq & De Villiers,

2019; Ge et al., 2024; IFAC, 2023). This suggests potential inadequacies in the application of assurance standards made in accordance with traditional accounting standards for NAAPs, highlighting the need for greater flexibility and adaptability to ensure the legitimacy and applicability of professional standards across diverse fields. The comment below also criticises the IAASB's urgency to implement the "at least as demanding" compliance standard, which may compromise long-term sustainability and effectiveness, leading to inadequate regulation and inspection and potentially widening the audit expectation gap. Professionals can leverage their expertise to reshape field logics and boundaries, advancing their own professional agendas by promoting rule systems purportedly designed for the broader social interest, which only they fully comprehend (Suddaby & Viale, 2011).

It is not clear how practitioners currently using other quality management requirements or standards will make the determination of equivalency to ISQM 1 or how they will be held accountable. We recommend an approach where the high-level criteria for quality management assessments are included in ED-ISSA 5000. We note that similar challenges arise with respect to relevant ethical

requirements that are “at least as demanding as” the IESBA Code, all the more considering The ongoing revisions that are being planned to the Code. (IFIAR- Monitoring Group).

The concept of “at least as demanding as” is not clear enough and could be argumentative. It will add more clarity and inclusivity to list paralleled global requirement from TIC industry e.g. IAF and ISO requirement on ethical, quality and personnel management. Or to provide suggestions/guidance for regulators’ decision making. As a non-accounting audit provider, we do not refer to the IESBA code, but we comply with the ‘International Federation of Inspection Agencies

– Compliance Code – Third Edition’ which we consider equivalent to ‘Code

of Ethics for Professional Accountants issued by the International Ethics Standards Board for Accountants’ (TIC Council- Assurance Practitioner or Firm - Other Profession).

Paragraph 5 refers to the IESBA code and highlights that assurance operates within a wider ecosystem to be effective. In financial accounting and auditing there are existing internationally recognised competency requirements. This is not yet the case for sustainability reporting and unless the competency requirements of a particular scope have been identified, it is difficult to see how an assurance provider can meet the requirements of the code or of the paragraphs referenced in paragraph 5. This could be done, however, through the use of and certification against, for example, relevant ISO CASCO standards (Social Value International- Global Standard Setter).

It is unclear how this compliance (“at least as demanding”) will be regulated and inspected, to ensure conformance at a jurisdictional level, given that the standard applies to professional accountants and non-accountant assurance practitioners. The IAASB’s actions in this area in the rush to achieve a short-term objective must not undermine its long-term responsibility around sustainability of the audit profession through standard setting, and managing of the audit expectation gap (Independent Regulatory Board for Auditors (IRBA)- Regulators and Audit Oversight Authorities).

The IAASB also emphasises the requirement that regulators and national standard setters define the criteria for evaluating standard equivalency to meet the "at least as demanding" threshold concerning the ethical requirements of the IESBA Code and the quality management standards in ISQM 1. However, stakeholders in their comments echo that there is no clear benchmark or criteria to determine what constitutes a stringent standard compared to IESBA/ISQM 1, leaving significant room for interpretation and inconsistency during local adaptation. Thus, the level of rigour can vary significantly across different professional bodies, with some standards being more or less stringent than those of IESBA and ISQM1. Practitioners in regions with less developed regulatory frameworks may face challenges in meeting these requirements, potentially leading to a disparity in professional practices across different areas. Additionally, it remains unclear whether compliance necessitates that each individual provision of a standard must meet or surpass the referenced benchmarks or if a holistic, overall assessment suffices. While upholding high standards of ethics and quality management is essential, applying the "at least as demanding" criterion may not effectively establish a universally applicable standard across professions. Thus, without clear ethical requirements set by law, regulation, or nationally recognised standards deemed "at least as demanding" by oversight bodies, significant inconsistencies are likely.

The Committee recognises that the concept of “at least as demanding” is not new and that regulators and national standard setters share responsibility for determining what would be considered as such in practice. For example, does this mean other

standards need to contain all the requirements of the relevant IESBA codes and ISQM1, or only material elements (and if so which) and what actions need to be taken when there are gaps? (Basel Committee on Banking Supervision (BIS)- Monitoring Group).

The notion ‘at least as demanding’, while familiar as a concept, remains challenging in its application. It is unclear to us whether it means that

each and every detailed provision should be at least equal, or whether an overall review is acceptable (Royal Dutch Institute of Chartered Accountant- Member body and other professional organisation).

If the final version of ISSA 5000 does not resolve this point in one way or another, our concern is that widely varying interpretations will arise on what “at least as demanding” means, with the risk that other alternative requirements which might be applied could transpire to be inferior to ISQM and the IESBA Code (PKF International Ltd- Assurance practitioner or firm - accounting profession).

Regarding the ethical and quality requirements, ED of ISSA-5000 also lets that the engagement leader must make sure that all team members understand the relevant ethical obligations related to the engagement's specific nature and context and the firm's corresponding policies or protocols. Additionally, it also acknowledges that the sufficient sustainability competence' required by an engagement leader may vary by context and is subject to professional judgement (IAASB, 2023c). Respondents in the comments below express concern regarding the reliance on individual judgement, which may compromise the standardisation and reliability of assurance quality as interpretations of sufficient expertise and ethical understanding vary among practitioners. This variability could affect the consistency of engagement outcomes. Additionally, placing the responsibility on the engagement leader to inform the team about ethical standards may overlook the advantages of a systematic institutional approach to compliance and training. In response to comment letters, the IAASB released documents referring to the responses of the Standard Advisory Task Force (SATF) of the ISSA 5000 in March 2024. The SATF acknowledges the challenge of prohibiting practitioners from evaluating the equivalence of local standards to ISSA 5000 benchmarks, particularly in cases where local authorities have not conducted such assessments, which may prevent practitioners from complying with the ISSA 5000. However, the SATF recognises the importance of national regulators and standard setters in determining the equivalence of jurisdictional requirements to international standards, as individual practitioners may struggle to make such judgements consistently (IAASB, 2024b). Hence, the IAASB may prioritise adherence to standards without ensuring enforcement, making them more acceptable across diverse professions, similar to ISAE 3000 (revised) (Ge et al., 2024).

My MAIN CONCERN in relation to section 14 of the EM is in relation to

‘Use by all assurance practitioners’. …However, I have grave concerns (already expressed in the ISSA 5000 reference Group) regarding the requirements for sustainability

competence in the current ED, which I believe is insufficiently strong despite it being absolutely critical to the quality of future assurance on sustainability reporting… (APTISA- Assurance Practitioner or Firm - Other Profession).

In relation to ‘Use by all assurance practitioners’, ERM CVS have concern around the strength of reference to sustainability competence throughout the Standard. For example, Para. 32 requires that the engagement leader ..

Without the revision. we have concern around a solo engagement leader, with self-determined professional judgement…provide confidence to a user

where no such confidence is appropriate, resulting in fraud (i.e., greenwashing) (ERM Certification and Verification- Assurance Practitioner or Firm - Other Profession).

A recognised metric for evaluating audit or assurance quality is the change in the number of a provider’s assurance clients or their market share. Enhanced quality improves a practitioner's reputation, leading to an increased client base (DeFond & Zhang, 2014). Assurance reports referencing ISAEs signal quality, consistency, and comparability, as they are the most recognised global standards for non-financial information assurance (Farooq & De Villiers, 2018; Ge et al., 2024; Krasodomska et al., 2021). However, adherence to specific assurance standards may be less indicative of quality than other factors, such as the reputation of Big 4 firms or the employment of specialised professionals (DeFond & Zhang, 2014).Recent trends indicate a rise in ISAE 3000 (revised) adoption among NAAPs (Alsahali & Malagueño, 2022; Ge et al., 2024), suggesting that NAAPs aim to enhance the perceived quality and reliability of their services, thereby boosting their legitimacy and market share (Ge et al., 2024). As of 2021, 53% of NAAPs, compared to 98% of Accountant Assurance Practitioners (AAPs), provided a general statement of performing the engagement in accordance with ISAE 3000 (revised). However, 64% of NAAPs only provided a general statement regarding independence, with 16% referencing the IESBA Code, 12% referencing alternative ethical standards, and 8% providing no disclosure. In contrast, 93% of AAPs included the IESBA Code in their statements. Regarding adherence to ISQM 1, 62% of NAAPs disclosed no information about adherence to any quality standards, and 30% referred to ISQM1 or an equivalent standard, compared to 91% of audit firms adhering to ISQM1 in 2021 (IFAC, 2023). A study by the Centre for Audit Quality (CAQ) 2023 on S&P 500 companies found that about 40% of NAAPs failed to disclose conformity to ISAE 3000 (revised) or other standards in 2021. Given the lack of enforcement improvements, adherence remains questionable to ensure public interest and quality. Consequently, some respondents argued that assurance practitioners should explicitly state the relevant ethical and quality requirements in their reports and that this requirement should be retained in

national versions of ISSA 5000. Its removal, as seen with ISAE 3000, compromises a global- level playing field. However, the IAASB posits that if ISSA 5000 mandates direct adherence to IESBA and ISQM1 standards or adopts a more stringent approach, it could create entry barriers, potentially diminishing NAAPs' use of IAASB standards in the future. This might obstruct ISSA 5000's goal of becoming a global baseline standard for all practitioners. While ED-5000 required the disclosure of quality management requirements, it only mandated the disclosure of the jurisdiction of origin for the applied ethical requirements (IAASB, 2024b). This may result in insufficient transparency, making it difficult for stakeholders to assess the rigour and adequacy of the reports compared to international benchmarks.

‘I strongly support the ethical and quality requirements set out in the ED, as in ISAE3000, and which enable suitably qualified assurance practitioners outside the accounting profession to undertake sustainability report assurance. However, I feel in order to maintain a global level playing field, the IAASB needs to ensure that this

option (using relevant ethical and quality requirements that are at least as demanding’) is not removed from national versions/translations of ED 5000, as I understand has happened in the case of ISAE3000. It is also important to ensure that all future engagements under the new standard may only mention the number and name

of standard if the engagement has been performed ‘in accordance’ with the standard. very effort should be made to prevent misuse of the standard using phrases such as

‘based on’ or ‘with reference to’. (APTISA- Assurance Practitioner or Firm - Other Profession).

‘We also recommend that the IAASB strengthen the application material to indicate that assurance reports cannot refer to ED-5000 if the practitioner has not fully applied the standard, including adhering to ethical and quality management standards,

to help avoid misleading users that the standard has been applied ‘(Centre for Audit Quality- Member Bodies and Other Professional Organizations).

Without this adherence, there may be practitioners who provide their service ‘in alignment with ISSA 5000 (i.e., not meeting independence and ethics requirements) as opposed to ‘in accordance with’ ISSA 5000 which demonstrates adherence to the independence and ethics equivalent to audit engagements. Users are not likely to appreciate the implications of this distinction which could result in Assurance Reports issued as ‘in alignment’ providing false confidence to users (i.e., fraud or greenwashing). We suggest that the Standard make clear that use ‘in accordance’ references are the only acceptable reference for use of ISSA 5000 (ERM Certification and Verification- Assurance Practitioner or Firm - Other Profession).

* 1. **Requires further collaboration with national and international agencies to ensure convergence and enforcement:**

Stakeholders’ comments below echo that ensuring effective implementation of ISSA 5000 for all practitioners requires a more collaborative effort with relevant professional bodies and regulators. Although the IAASB sets these standards, it lacks enforcement authority, which typically resides with regulatory bodies and oversight authorities across various countries (Humphrey et al., 2006, 2009). Accounting associations can closely align IAASB standards with both local and international regulatory frameworks to facilitate their adoption. This alignment ensures that accountants remain compliant with regulatory requirements across various jurisdictions, thereby enhancing the consistency and reliability of accounting practices globally (Ramirez, 2012). However, alignment for NAAPs is more challenging due to the absence of associations and standards specific to their fields, which complicates achieving consistent and reliable practices globally, requiring further collaboration.

The IAASB will likely need to continue to engage with the International Organization of Securities Commissions, the United Kingdom’s Financial Stability Board, the European Commission, the United States Securities and Exchange Commission, and other jurisdictions as to what requirements should be

followed when non-accountant assurance practitioners perform ISSA 5000 engagements, as well as what oversight regime would be in place for those circumstances (American Institute of Certified Public Accountants (AICPA)- Jurisdictional/ National Standard Setter).

We recognise that as this area of assurance is in its nascence, all parties need to work together to rapidly develop an increased capacity among potential assurance providers to meet the impending demand. We therefore recommend the IAASB to

cooperate closely with IOSCO to foster an expansion in the capacity of the market in this area (Corporate Reporting User’s Forum (CRUF)- Preparer and Users of Sustainability Information).

While the application material to the requirements explains in a reasonable level of detail the matters addressed by the IESBA Code and, at a much higher level, for

ISQM 1, the standard cannot set out how a practitioner assesses equivalence.

Similarly, consistent with ISAE 3000 (Revised), the IAASB cannot enforce compliance with this fundamental premise, which is a critical matter that needs to be addressed by jurisdictional regulators. It is, therefore, important that the IAASB engages with global organisations (such as IOSCO and IFIAR) and jurisdictional

regulators…(PWC- Assurance Practitioner or Firm - Accounting Profession).

We believe it is important for the Board to continue to engage with regulators, national standard-setters, and non-accounting sustainability practitioners to support the application of ED-5000 and that includes the enforcement aspects of adherence to the relevant ethical requirements for assurance engagements and the firm's responsibility for its system of quality management to avoid inappropriate or inconsistent statements of compliance, which could have an adverse effect on the quality of the assurance engagements and the public interest (ASEAN Federation of Accountants (AFA)- Member Bodies and Other Professional Organizations).

Despite emphasising the need for further collaboration in the comments, the IAASB has already detailed its extensive collaborative efforts in developing ISSA 5000 within the explanatory memorandum of ED ISSA-5000. The formation of sustainability reference groups, which include both AAPs and NAAPs, aims to guide the development of a comprehensive standard (IAASB, 2023a). The IAASB has engaged in extensive outreach with key stakeholders throughout the project, including the CAG and MG members as well as the EC, the FSB, the IFIAR, and the IOSCO. Additionally, the IAASB has collaborated with international and national regulatory bodies such as the Committee of European Auditing Oversight Bodies (CEAOB), the Japan Financial Services Agency (JFSA), and the United States Securities and Exchange Commission (SEC). Furthermore, the IAASB has engaged with international groups representing stakeholders, such as the International Corporate Governance Network (ICGN), the Forum of Firms (FOF), and the Global Public Policy Committee (GPPC) (IAASB, 2023a). The IAASB's outreach extends to international standard setters for sustainability reporting and assurance, including the International Sustainability Standards Board (ISSB), the Global Reporting Initiative (GRI), and the International Organisation for Standardisation (ISO), as well as jurisdictional and national standard setters (NSS) (IAASB, 2023a). However, standards for sustainability reporting and assurance from organisations such as ISSB, GRI, and ISO are emerging areas distinct from traditional financial auditing standards. Therefore, their integration into the assurance framework is an ongoing development (Channuntapipat et al., 2020; Farooq et al., 2024) to prescribe the best practices.

Entities such as the CAG, MG members, and national regulatory bodies such as the CEAOB, JFSA, the SEC, FOF, and GPPC predominantly comprise members from professions focused on traditional financial auditing and reporting (Ramirez, 2012;

Humphrey et al., 2006; Loft et al., 2006). While the IAASB has engaged with prominent international and national regulatory bodies and standard setters, the focus on aligning with established international bodies might not fully address the unique needs and practices of local regulatory environments. The influence and dynamics within international and national standard-setting bodies may, consciously or unconsciously, support established financial audit networks, potentially overlooking the specific needs and contributions of NAAPs. In jurisdictional contests, occupational groups compete for dominance in a particular field by establishing support networks that bolster their respective claims to expertise (Abbott, 1988; Gendron et al., 2007). Interest groups possessing informational advantages and those significantly affected by proposed regulations have stronger incentives to participate in lobbying activities (Gros & Worret, 2016; Holder et al., 2013). The comment letter submissions for the ED-ISSA 5000 also show the significant participation of the accounting profession, represented by both national associations and auditing firms, overshadowing other stakeholders in the standard setting process. There is also a noticeable lack of letter contributions from NAAPs (only 5 out of 146), even though IAASB formed sustainability reference groups comprising NAAPs and AAPs to guide the formation of the standard, which should have encouraged participation. This underrepresentation is concerning given the standard's objective to serve the wider public interest and uphold professional impartiality. Diverse professional perspectives are essential for developing a professionally agnostic standard and ensuring effective collaboration and enforcement, which may not be fully reflected in the comment letter submission. This may also reflect NAAP's convenience in adopting other standards instead of ISAEs/ISSA 5000, as discussed above.

In March 2024, the IAASB, in response to feedback from comment letters, released documents detailing the Standard Advisory Task Force's (SATF) responses to ISSA 5000. The SATF acknowledges the increased need for engagement with national and global regulators such as IFIAR and IOSCO as an opportunity to underscore the importance of regulatory oversight for quality management standards and ethical requirements that are at least as rigorous as ISQM 1 and the IESBA Code. However, stakeholders also suggest global mapping exercises to assess equivalence through collaborative efforts to prevent variability, but the SATF considers it currently impractical for the IAASB to conduct global mapping exercises despite the existence of alternatives to verify equivalencies given the constraints of project timelines and resources and a lack of collaborative initiatives from other external bodies (IAASB, 2024b). This suggests that the IAASB may not be sufficiently promoting or exploring other standards, which may potentially limit the applicability and acceptance of ISSA 5000 worldwide. Moreover, the IAASB's reluctance to undertake global mapping exercises reveals a deficiency in proactive collaboration. While creating a global

standard, time constraints should be a focus to ensure comprehensiveness and broader engagement. Thus, professionals can make jurisdictional claims by prescribing solutions, but to maintain legitimacy and superiority, these claims can be sufficiently vague to reduce competition (Abbott, 1988). To reinforce these claims and ensure their broad acceptance, it is crucial to form strong partnerships with other regulatory and standard-setting bodies, fostering the development of universally applicable and respected standards.

To avoid inconsistency, it is crucial for regulators and/or standard setters to assess the various options for ethical, independence and quality management standards used by non-accountant practitioners and determine which frameworks are acceptable in

their respective jurisdictions. In Australia, we are encouraging the Auditing and Assurance Standards Board (AUASB) to engage with regulators and other stakeholders to consider how this could be achieved. Ultimately, to achieve global consistency and comparability, the IAASB (with the IESBA) will

need to assist with the global baseline for assessment processes and guidelines (CPA Australia- Member Bodies and Other Professional Organizations).

The IAASB and the IESBA have a crucial role to play to facilitate and assist those not familiar with the ethics and quality management requirements. We encourage the IAASB to work with others, to learn more about the quality management requirements

others apply, and to co-ordinate global mapping exercises. We welcome the collaboration with the International Accreditation Forum (IAF) on Quality Management (New Zealand External

Reporting Board (XRB)-Jurisdictional/National Standard Setter).

In order to assist jurisdictions in determining whether ethical requirements or systems of quality management are ‘at least as demanding’, we recommend that the IAASB work together with IESBA and relevant stakeholders on compiling a list of ethical requirements included in the IESBA Code and requirements for a system of quality management included in ISQM 1 that must be met in order for standards to be

considered ‘at least as demanding’ as the IESBA Code and ISQM 1, respectively. This list could then be used by regulators, standard setters and other stakeholders in each applicable (RSM Int-Assurance Practitioner or Firm - Accounting Profession).

However, on a positive note, IAASB has collaborated with the IESBA, an IFAC subsidiary that develops ethical codes for accountants (IAASB, 2023a; IESBA, n.d.), to create sustainability-related amendments to the International Code of Ethics for Professional Accountants, including International Independence Standards. These amendments will help to apply the code to all sustainability assurance practitioners, including accountants and

other professionals. However, the project is still in the development stage prior to the release of ISSA-5000-ED (IAASB, 2023a). This ongoing development also presents a significant limitation, as expressed in the comments below, given that it remains unclear whether the Code of Ethics will be sufficiently comprehensive for application by non-practitioners. Therefore, the effectiveness of ISSA 5000 is closely linked to the outcomes of the IESBA's initiatives, which may impede ISSA-500 from standing on its own to create a global baseline standard. Abbott (1988) notes that while any occupation can establish licensure or a code of ethics, only a profession with abstract knowledge can redefine its problems and tasks, defend against competitors, and expand its territory. A profession can also broaden its jurisdiction by asserting the applicability of its treatments to problems identified by other groups, identifying relevant issues, and creating measurable solutions to publicly validate their excellence over competitors, which can be associated in this context.

ISSA 5000 should be self-contained and should include all requirements to perform the engagement, including ethical requirements. IAASB should not be constrained by institutional arrangements within the profession if ISSA 5000 is intended to apply outside the

profession as well (Office of the Auditor General of Alberta- public sector organisation).

IESBA has not yet finished its proposals (for consultation) of ethical requirements for sustainability assurance engagements. This is an important caveat, the NBA cannot

commit to proposals that are under development. This is also important because we can at this stage determine whether the Code of Ethics is sufficiently clear for application

by non-practitioners. This is important because the Code of Ethics should contribute to setting the right incentives for practitioners to achieve quality (Royal Dutch Institute of

Chartered Accountants (NBA)- Jurisdictional/ National Standard Setter).

* 1. **Reliance on professional accounting terms and standards to create a neutral standard:**

The IAASB plays a pivotal role in defining and legitimising the accounting profession's formal body of knowledge, enhancing its validity, and fostering environments conducive to its acceptance and application (Ramirez, 2012; Sonnerfeldt, 2013). This foundational knowledge is crucial for the IAASB's efforts to establish jurisdiction and legitimise institutionally accepted knowledge within the profession (Sonnerfeldt, 2013). However, respondents highlighted a key limitation in the feedback on ED-5000: its reliance on technical terms derived from the International Standards on Auditing (ISAs), which may present challenges for NAAPs unfamiliar with the terminology, complicating their ability to

effectively apply the standard. Recognising the need for a standard on non-financial information assurances, the IAASB created ISAE for engagements beyond audits or reviews of historical financial information, targeting accountants. Despite integration challenges, it aimed to harmonise assurance structures with traditional financial audit practices (Sonnerfeldt, 2013; Sonnerfeldt & Pontoppidan, 2020). ISAE 3000's reliance on conventional audit methodologies has raised concerns about terminology inconsistencies and insufficient guidance on scope, materiality, and procedures compared to financial audits. Although it expands assurance services and allows flexibility in defining non-financial assurance principles, it has been criticised for not fully meeting practitioner expectations (Manetti & Becatti, 2009; Sonnerfeldt, 2013). While ISAE 3000 provides guidance to assurance providers, it reflects the IAASB's decision to delegate discretion to national professional associations and practitioners to determine the details of each engagement. Extending the financial audit methodology to non-financial, qualitative, and subjective subject matter without clearly defined criteria led to divergent views within the profession, which were weakly addressed in the construction of ISAE (Sonnerfeldt & Pontoppidan, 2020). Nonetheless, ISAE 3000 serves as a foundational standard for future ISAEs, including ISSA 5000 (Krasodomska et al., 2021). A profession's jurisdiction involves controlling service definitions, terminology, practitioners, and execution of work, making dominance over professional language crucial for competitive advantage (Abbott, 1988). Thus, it is unlikely that the standard could be developed in neutral language, as stated in the comments. Professions establish control by emphasising abstract knowledge, which is crucial for maintaining jurisdiction. To preserve their dominance, they share practical techniques such as the issuance and sharing of standards with subordinate groups while retaining the abstract knowledge that underpins their authority (Abbott, 1988).

The standard has the potential to provide a global baseline for sustainability assurance engagement. However, it will be appropriately scalable and adaptable if it could be developed into neutral language, instead of accounting language…In a word, it needs to jump out the boundary of accounting to a much wider map (TIC Council- Assurance Practitioner or Firm - other Profession).

Although the standard will inevitably be drafted using technical language (as is common in assurance standards), we believe a profession-agnostic assurance standard should provide, or be supplemented by, clear guidance suitable for use by all types of assurance providers, including guidance on key IAASB definitions and terminology (IOSCO- Monitoring Group).

We strongly believe that there should be a single standard that can be used by all assurance practitioners and applaud the efforts of the IAASB in developing a profession agnostic standard. However, as currently drafted, we do not believe that the requirements and application guidance can be easily applied by assurance practitioners who are less familiar with IAASB standards, in particular some of the requirements of the International Standards on Auditing (ISAs)(Mazars Assurance Practitioner or Firm - Accounting Profession).

Non-accountant assurance practitioners at the IAASB’s New York Sustainability Assurance Roundtable on ED-5000 held on September 20, 2023, expressed concern about generally not having an understanding of or experience with applying the ISAs.

Further, they expressed concern about generally not being as familiar with resources beyond the ISAEs, like the Extended External Reporting (EER) Assurance guidance

(Center for Audit Quality (CAQ)- Member Bodies and Other Professional Organizations).

The comments below also highlight concern regarding the potential for inconsistent interpretations and applications by non-accountant assurance practitioners due to the standard's heavy reliance on terminology and concepts familiar to professional accountants. Research reveals that assurance providers, both AAPs and NAAPs, interpret and apply assurance standards differently due to their varied professional backgrounds, competitive dynamics, and client targeting strategies (Channuntapipat et al., 2020; Sonnerfeldt & Pontoppidan, 2020). AAPs focus on traditional accounting materiality, emphasising financial impacts for shareholders and adherence to professional guidance. NAAPs adopt a stakeholder logic, linking materiality to consultancy and environmental management systems, shifting focus towards corporate performance improvement and strategy alignment (Channuntapipat et al., 2019; Edgley et al., 2015). NAAPs adopted the financial audit methodology without fully understanding it, aligning their informal notions of materiality with the formal framework. This methodology provided superficial comfort, helping them navigate ambiguities in materiality determination and rationalise intuitive decisions retrospectively, creating an appearance of competence. This process revealed that the perceived order in the assurance process arose from a blend of tacit and formal knowledge, raising concerns about the depth of their understanding and the authenticity of their assessments (Canning et al., 2019; O’Dwyer, 2011). While there may be a need for principles-based or general guidance for NAAPs, it remains sceptical that prescriptive guidance will significantly advance current practices in sustainability assurance. Practitioners are likely to continue relying heavily on intuition and professional judgement when addressing materiality issues in

sustainability assurance (Canning et al., 2019; Edgley et al., 2015). However, while this diversity in practices introduces innovation, it also creates inconsistencies in how different practitioners understand, assess, and apply assurance engagements. Challenges such as the need for professional scepticism, enhancements in communication skills, and issues related to judgements, evidence gathering, and drawing conclusions can diminish the reliability and credibility of the information provided, undermining public trust (Krasodomska et al., 2021). In professions where abstract knowledge is actively applied, such as accounting, Abbott (1988) anticipates incremental changes rather than significant paradigm shifts. These small changes represent adaptations to new rules, guidelines, or practices rather than fundamental transformations in the profession's core principles. Therefore, without rigorous standardisation efforts and clear guidelines by the IAASB, inconsistencies in practices may persist, potentially compromising the reliability and comparability of sustainability assurance services and impacting the broader public interest.

We support the IAASB’s decision to issue a standard that is profession-agnostic…. It will be critical to overcome threats to performance consistency, which could have far reaching consequences, including, but not limited to: We believe that a key issue which could give rise to consistency threats is that ED 5000 uses terminology that will be well known to auditors (eg, performance materiality) and concepts that are addressed by more

detailed individual auditing standards (eg, accounting estimates in ISA 540 Auditing accounting estimates). These concepts may be difficult to apply without prior experience of the more detailed auditing standards and may lead to different interpretations of the standard by some assurance practitioners. We believe that additional guidance will be necessary to bridge this potential gap in understanding (ICAEW- Member Bodies and Other Professional Organizations).

We heard several concerns about how the entire standard (and more specifically, assurance terms and concepts) would be understood and applied by non-accountant assurance practitioners. ED-5000 includes many references to concepts that are predicated on the assurance practitioner’s understanding of other standards, including the ISAs. Although professional accountants will be familiar with these assurance terms and concepts, non-accountant assurance practitioners may not be as familiar with them. As an example, the standard contains several uses of the term "materiality" – and nonaccountant assurance practitioners may require clarity on their different meanings, application, and

interconnectivity in the assurance engagement (Auditing and Assurance Standards Board Canada (AASB)- Jurisdictional/ National Standard Setter).

While ED-5000 is explicitly intended to be usable by non-accountants and incorporates language changes to ISAE 3000 to broaden its applicability to non- accountants, the language and supporting materials are heavily reliant on the

existing body of assurance knowledge applicable to professional accountants and uses terms of art specific to experience gained by professional accountants... We are concerned that investors may not be aware of these differences in qualifications and ethical standards. In the absence of greater transparency and further research we’re not sure if ED-5000 can be applied by most non-accountant sustainability assurance providers (CFA Institute-User of sustainability information/ external reporting).

* 1. **Need additional guidance for NAAPs:**

The key themes discussed above led to this collective feedback on ED-5000, underscoring the urgent need for supplementary non-authoritative educational resources and clearer application guidance to facilitate a thorough understanding, interpretation, and consistent application of the standard across diverse assurance practitioners. Stakeholders suggest developing a suite of materials, including a beginner's roadmap and detailed comparative guidance aligning with global standards such as those from the IAF and ISO. These resources are intended to support both AAPs and NAAPs, promoting inclusivity and ensuring the standard meets public interest expectations by being profession-agnostic. The enhancement of educational supports and clearer guidelines is critical for enabling consistent, high-quality sustainability assurance practices across all practitioner backgrounds, thereby fostering broader adoption and maintaining rigorous professional standards. However, litigation and state regulatory pressures may compel professions to standardise and codify their knowledge. While formal control grants power, this authority diminishes once a professional field becomes fully codified through rules and programs. Therefore, a profession must continually regenerate its abstract knowledge system to extend its jurisdiction and potentially influence adjacent professions (Abbot, 1988). This complexity will force NAAPs to depend on AAPs for future guidance in adhering to the ISSA 5000, highlighting a reliance that underscores the unequal distribution of expertise and potentially undermines the NAAPs' credibility in the assurance market. Thus, NAAPs may opt for another available standard that better suits their convenience in the absence of enforcement regulation.

IOSCO agrees that the principles-based requirements in the Proposed ISSA5000 are capable of being applied for all sustainability assurance engagements. However, the requirements and application material may need to be expanded and/or clarified

over time to encourage more consistent application and scalability in the conduct

of sustainability assurance engagements. This is particularly important to support assurance engagements by non-accountant assurance practitioners, thereby helping to ensure that equivalent quality and performance standards are expected and upheld (IOSCO- Monitoring Group).

The concept of “at least as demanding as” is not clear enough and could be argumentative. It will add more clarity and inclusivity to list paralleled global requirement from TIC industry e.g. IAF and ISO requirement on ethical, quality and personnel management. Or to provide suggestions/guidance for regulators’ decision making (TIC Council- Assurance practitioner or firm - other profession).

We suggest that non-authoritative educational material be developed in parallel with the finalization of ED-5000 to assist with effective implementation. We believe that these materials should include a “beginner’s roadmap” of where to start, including educational material to help provide a baseline understanding of

key ISAs (to which ED-5000 alludes), as well as ISAE 3000 (Revised), ISAE 3410, Assurance Engagements on Greenhouse Gas Statements, the EER guidance, the IESBA Code, and ISQM 1 to enable consistent, comparable, high-quality assurance engagements in the public interest (Center for Audit Quality (CAQ)-

Member Bodies and Other Professional Organizations).

We believe more application guidance or educational material is needed for ED-5000 to provide a global baseline for consistent and high-quality sustainability assurance (Corporate Reporting User’s Forum (CRUF)- Preparer and Users of Sustainability Information).

1. **Conclusion:**

This paper critically evaluates stakeholder responses to the proposed ISSA 5000 sustainability assurance standard to understand the IAASB’s claim of proposing a professionally agnostic standard, despite the lack of adoption of previous IAASB standards by NAAPs and the availability of alternative standards such as AA1000 and ISOs. Stakeholders highlight several challenges impeding its adoption across varied practitioner groups. A significant concern is the subjectivity in determining how to align with the at least as demanding criterion, which necessitates adherence to the IESBA Code and ISQM 1. The need for tailored compliance strategies to address these discrepancies adds complexity and may deter practitioners, potentially leading them to opt for more familiar alternatives without a lack of enforcement. The IAASB has not been sufficiently thorough or timely in its post-

implementation reviews of previous decisions to evaluate the results of encouraging NAAPs to use ISAEs (Ge et al., 2024). Additionally, the timing of ISSA 5000's development during the IAASB's restructuring phase (IFEA, 2023b) appears premature. Delaying the standard setting process could leverage new reforms aimed at improving stakeholder involvement, ensuring that the IAASB effectively incorporates a wider array of external insights and expertise in their standard-setting processes. This reflects IFAC's model, which indirectly prioritises public interest accountability through general oversight and consultative groups, potentially undermining the benefits of direct collaboration with public entities (Humphrey et al., 2006). Additionally, the introduction of the new standard after the completion of the IESBA project would promote ISSA-5000 to be more neutral and independent than prematurely trying to align with the timeline of sustainability reporting standards (IAASB, 2024a). The rush to finalise ISSA 5000 may reflect a persistent inclination to conform to traditional accounting standards, potentially at the expense of addressing the evolving and diverse needs of other sustainability assurance practitioners. Until its 2013 revision, ISAE 3000 was exclusive to AAPs, with many practitioners considering only audit firms capable of applying it and viewing it as superior and more credible than standards from NAAPs such as AA1000 or ISO standards (Channuntapipat et al., 2020). As per the present status, the ISSA 5000 standard should be exclusively applicable to accountants rather than maintaining its current profession-agnostic status to enhance its effectiveness and relevance globally and broaden its jurisdiction claim in the public domain (Abbott, 1988). In conclusion, for ISSA 5000 to truly serve as an effective and profession-agnostic standard, the highlighted shortcomings need to be addressed together to make the standard operational for all practitioners. It must integrate and respect the distinct ethical and quality management standards of various professions, acknowledging and accommodating their specific challenges through global mapping exercises rather than solely depending on established accounting norms and existing standard setting processes. However, this study exclusively analysed comment letters without examining other lobbying methods, such as formal meetings or informal conversations. This limitation suggests an opportunity for future research to explore these avenues.

1. **Appendix:**

Table 1: Example of thematic coding performed

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Question 1 | Question 1 inquired, “Do you agree that ED-5000, as an overarching standard, can be applied for each of the items described in paragraph 14 of this EM to provide a global baseline for sustainability assurance engagements? If not, please specify the item(s) from paragraph 14 to which your detailed comments, if any, relate (use a heading for each relevant item).” One of the key topic addressed in paragraph 14 contextualises that ISSA-5000 could be utilised by all practitioners(IAASB, 2023b). |  | Question 4 | Question 4 inquired, “Is ED-5000 sufficiently clear about the concept of 'at least as demanding' as the IESBA Code regarding relevant ethical requirements for assurance engagements and ISQM 1 regarding a firm’s responsibility for its system of quality management? If not, what suggestions do you have for additional application material to make it clearer?” (IAASB, 2023b). |
| Theme - 1 | Further, it is unclear how users of assurance reports issued under proposed ISSA 5000 can be confident that non-accountant assurance practitioners are adhering to these high standards without an external monitoring process in place. (See  question 4 for our additional |  | Theme - 1 | The concept of “at least as demanding as” is not clear enough and could be argumentative. It will add more clarity and inclusivity to list paralleled global requirement from TIC industry e.g., IAF and ISO requirement on ethical, quality and personnel management. Or  to provide suggestions/guidance |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | recommendations. **American Institute of Certified Public Accountants (AICPA)- Jurisdictional/ National Standard Setter** |  |  | for regulators’ decision-making. **SGS- Assurance Practitioner or Firm - Other Profession** |
| Theme - 1 | We note the phrase “at least as demanding” relating to possible alternative codes of ethics and quality management requirements for other assurance practitioners. We accept that this is not a new concept for IAASB standards, as the IAASB highlights in the Explanatory Memorandum. However, it might be more helpful for other assurance practitioners if the standard set out required provisions and concepts rather than simply drawing comparisons. We appreciate that this would add to the length of an already long standard, and would also necessitate updating in the future were the IESBA Code or ISQM 1 to undergo revisions. However, such an approach could reduce the scope for confusion in this area and could therefore be more usable and understandable for other  assurance practitioners. Other |  | Theme-1 | Its not possible to hold the practitioners outside a public practice of a professional accountant accountable for the practice of ethics and quality. 4.3 Multiple practitioners>> ‘Sustainablity assurance engagements are being conducted currently by practitioners from different professions’. Section 1-C Explanatory Memo.  For non-accountants performing the engagements it will be difficult to stick to both.  Furthermore, how compliance will be checked. Its not an obligation of the member organizations of the IFAC. **Altaf Noor Ali Chartered Accountants- Assurance Practitioner or Firm**  **- Accounting Profession** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | possible options include: • the IAASB leaving the determination of ‘red lines’ to regulators (although this could give rise to consistency threats -see above); or   * the IAASB and IESBA issuing standalone quality management and ethical provisions reflecting minimum requirements (this would be an effort-intensive option but might be the most usable option)   We are aware of IESBA’s project on the development of new ethics and independence standards for sustainability reporting and assurance.  Application of these standards should be required, unless practitioners are required to comply with ethical requirements prescribed by law, regulation or national standard setters that have been designated by such bodies as “at least as demanding”. Where such bodies do not make that designation, IAASB should provide guidance on how to evaluate whether local codes or requirements meet the “at least as demanding”  threshold. **Institute of** |  |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Chartered Accountants in England and Wales (ICAEW)- Member Bodies and Other Professional**  **Organizations** |  |  |  |
| Theme-1 | We also have concerns regarding the practical application by all practitioners of ethical and quality management standards, which are ‘at least as demanding’ as the International Ethics Standards Board for Accountants’ (IESBA) International Code of Ethics for Professional Accountants (including International Independence Standards (IESBA Code) and International Standard on Quality Management (ISQM) 1, Quality Management for Firms that Perform Audits or Reviews of Financial Statements or Other Assurance or Related Services Engagements (ISQM 1). Our comments in relation to this are set out in our response to question #4.**RSM International-Assurance Practitioner or Firm -**  **Accounting Profession** |  | Theme-1 | While the requirements in their own are sufficiently clear, the reality of many jurisdictions is that there is no single body that regulates all professions who might apply the proposed standard. To that end, outside the accountancy profession in jurisdiction were the IESBA code and ISQMs are adopted or adapted, the effective implementation and monitoring of the concept of “at least as demanding” is questionable.  Additionally the concept “at least as demanding as” can be challenging to be made, monitored and enforced consistently in developing countries’ jurisdictions as mentioned above in question 1. **Pan African Federation of Accountants- Member Bodies and Other Professional Organizations** |
|  |  |  |  |  |

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**Whistleblowing Risk and Corporate Environmental Performance: Evidence From the False Claims Act**

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Whistleblowing Risk and Corporate Environmental Performance: Evidence From the False Claims Act

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**Abstract**

We examine whether and how whistleblowing risk affects corporate environmental performance. Using state-level court rulings associated with the U.S. False Claims Act (FCA) and prior firm-level FCA cases as an identification strategy to capture exogenous variations in whistleblowing risk, we find that firms facing higher whistleblowing risk experience a significant reduction in toxic releases. Further analyses (i) provide evidence that pollution abatement investments serve as a potential channel driving this effect and (ii) reveal that the impact of whistleblowing risk on environmental performance is more pronounced among firms with stronger corporate governance or more active whistleblowers. Overall, our findings imply that whistleblowing risk complements corporate governance in shaping firms’ environmental performance.

Keywords: False Claims Act; Whistleblowing Risk; Toxic Releases; Green Innovations; Whistleblowers

JEL Classification: G32, G38, K20, Q50, Q54, Q5

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“In recent times, it seems that nearly every day has provided us with an opportunity to appreciate the contributions of whistleblowers. Often, they display extraordinary bravery to expose fraud and wrongdoing, and to shine light in some very dark places.”

—Allison Herren Lee, SEC Commissioner, Sept 23, 2020

1. Introduction

Following the notorious accounting frauds of the first few years of this century and the more recent financial crisis in 2008, the U.S. government has implemented various whistleblower provisions, including the False Claims Act (FCA), the Sarbanes-Oxley Act, and the Dodd-Frank Act, to enhance protections for whistleblowers who detect and report fraud as well as incentivising them to help the government to recover losses. From 1987 to 2019, the government recovered $62.1 billion under the False Claims Act, of which more than $44.7 billion or 72% came from qui tam cases brought by whistleblowers (DOJ, 2019).

Consistent with the superior performance of these whistleblowing laws, previous literature has documented the deterrence effects of whistleblowing risk as well as the information discovery role of the whistleblowers. Bowen et al. (2010) find that the information exposed by the whistleblowers urges companies to make more financial restatements; Wilde (2017) shows that the Dodd-Frank whistleblowing program deters companies’ tax aggressiveness; this program has also been documented to have deterrence effects on the probability of financial fraud (Berger and Lee, 2022, Wiedman and Zhu, 2023) or even insider trading (Raleigh et al., 2023). However, to my best knowledge, there is no study focusing on whether these whistleblowing laws would impose any externalities on the environment and public health, which has become a paramount concern in the recent business world following the signing of

the Paris Agreement in 2016. We fill this literature gap by studying the unintended impacts on corporate environmental performance of whistleblowing risk by using state-level court rulings associated with the U.S. False Claims Act and prior firm-level FCA cases as an identification strategy to capture exogenous variations in whistleblowing risk.

The tension in our study arises from two competing hypotheses. On the one hand, whistleblowing laws encourage whistleblowers to disclose valuable information, enhancing firms’ overall information environment and enabling investors and stakeholders to better monitor corporate environmental performance (Dyck et al., 2010; Wilde, 2017). Previous literature finds that investors and other stakeholders actively acquire information to monitor a firm’s environmental performance (Azar et al., 2021; Cohen et al., 2022; Jing et al., 2023). Given that whistleblowing risk can improve a firm’s overall information environment through active whistleblower participation (Dyck et al., 2010; Wilde, 2017), we anticipate that investors and other stakeholders are better able to monitor the environmental performance of firms facing higher whistleblowing risk. Although whistleblowers may not directly expose environmental fraud, enhanced transparency in financial disclosures still supports environmental monitoring. This is because key environmental activities—such as environmental expenditures, investments in green innovations, and environmental provisions—are explicitly reflected, audited, and verified within firms' financial statements. Moreover, whistleblowing risk may also discipline managers by deterring short-term opportunistic behaviour and encouraging investments that improve long-term environmental performance (Berger and Lee, 2022; Hsu et al., 2023).

On the other hand, whistleblowing litigation processes can impose significant direct costs (e.g., fines, legal fees, increased insurance premiums) and indirect costs (e.g., heightened

financial constraints, higher debt costs, reduced operational efficiency, and negative stock returns) on firms (Arena, 2018; Deng et al., 2014; Bowen et al., 2010). These costs resulting from future whistleblower-initiated litigation will hamper the company's day-to-day business activities, which in turn will make it challenging to satisfy investors' return requirements. As for this circumstance, the firm’s response is usually sacrificing the interest of other stakeholders—investing less in emission abatement to secure resources and polluting more (e.g., Liu et al., 2021; Thomas et al., 2022; Xu and Kim, 2022). As whistleblowing risk can shape a firm’s environmental performance in two opposite ways, whether and how this risk affects corporate environmental performance is an empirical question.

To provide plausible causal inferences on how whistleblowing risk affects corporate environmental policies, our study leverages the benefits from state-level court rulings associated with the U.S. False Claims Act and prior firm-level FCA cases as an identification strategy to capture exogenous variations in whistleblowing risk. Exploiting the three shocks and real FCA cases provides us with several benefits: for the three shocks, (i) these shocks are based on four court rulings from the federal-level Courts of Appeals, thereby suffering less from lobbying or political pressure, (ii) compared to the two federal-level provisions: SOX Act section 806 or the Dodd-Frank Act section 922, which makes it very difficult to identify decent treated and control groups, decisions by Courts of Appeals that increase the financial incentives for whistleblowers to file FCA lawsuits provide decent treated and control groups at different points in time and (iii) both the SOX Act and the Dodd-Frank Act contain various corporate governance codes or provisions, therefore it is hard to isolate the effects from one single whistleblowing section; in contrast, these court rulings which rule in favour of the

whistleblowers provide a cleaner and more direct impact on whistleblower’s incentives. For prior FCA cases, (i) these cases capture firm-level exposure to whistleblowing risk (Bowen et al., 2010) and (ii) study shows that previous litigation experience is important in corporate decision-making (e.g., Deng et al., 2014) and these cases directly capture firm’s previous experiences in FCA.

In our baseline results, we find that firms facing higher whistleblowing risk experience a significant reduction in toxic releases. in the toxic release of about 14%-15%, highlighting the positive externality of these court rulings on the environment. This finding is consistent with our hypothesis that whistleblow risk encourage whistleblowers to provide useful information and help investors and other stakeholders to monitor corporate environmental performance more effectively. Also, whistleblowing risk may better discipline managers’ shortsighted behaviours and encourage them to invest more in the firm’s long-term value – environmental performance.

We then tackle the endogeneity concerns and verify the validity of the parallel trends assumption inherent in our stacked DIDID approach by examining the dynamic impact of the whistleblowing risk on corporate environmental performance. Our results alleviate the concerns for pre-treatment effects and reverse causality and suggest that our analysis satisfies the parallel trends assumption to use a stacked triple difference model.

After that, we aim to tackle an additional concern driven by systematic differences in the characteristics between the treatment group and the control group. To achieve this, we apply the propensity score matching (PSM, hereafter) and the entropy balancing (EB, hereafter) as two alternative approaches to identify the control sample. Our results suggest that our baseline

results are robust to the PSM approach with a more similar control group and the EB approach with a covariates-reweighted sample.

We then manage to identify the channel through which whistleblowing risk improves firms' environmental performance by focusing on the firm’s investment in green patents (Cheng et al., 2025; Jing et al., 2023). We provide evidence that green innovation investments serve as a potential channel driving the decrease in firms’ toxic releases. We further examine whether investors perceive improvements in firms' environmental performance following the court rulings. To achieve this, we follow prior studies (e.g., Loughran and McDonald, 2011; Henry and Leone, 2016; Sautner et al., 2023) and conduct sentiment analysis on firms' earnings conference call transcripts to identify environmentally-related questions raised by analysts with positive and/or negative tones. We witness a significant increase in the number of environmental questions with positive tones and negative tones, signalling that analysts are generally more concerned with the firm’s environmental issues after the three court rulings, which is consistent with our hypothesis that whistleblowing risk provides more information for investors to monitor firm’s environmental performance better. We also find the results using both net tone and net tone intensity. We show that analysts' environmental questions are generally more positive, consistent with our baseline findings that investors are optimistic about the firm’s improved environmental performance.

Our study is based on the hypothesis that whistleblowing risk provides stakeholders with useful information, thereby enabling better monitoring of firms' environmental performance; additionally, whistleblowing risk disciplines managers, discouraging short-sighted decisions and promoting investment for long-term value maximization. Central to our argument is the

idea that whistleblowing risk improves existing corporate governance. Therefore, we conduct cross-sectional analyses conditional on corporate governance quality, using proxies from prior studies. The results indicate that the impact of whistleblowing risk on a firm’s toxic releases is more pronounced in firms with better existing corporate governance, in line with our prediction that whistleblowing risk complements a firm’s corporate governance in shaping a firm’s environmental performance.

Finally, whistleblowing risk fundamentally relies on whistleblowers’ active engagement within a country’s legal system. Therefore, we examine cross-sectional heterogeneity based on different types of whistleblowers. Dyck et al. (2010) identify short-sellers, financial analysts, and external auditors as key whistleblowers in capital markets, each with distinct motivations. We find that the effect of whistleblowing risk on corporate toxic releases is more pronounced among firms with greater short-seller coverage, higher analyst coverage, and superior audit quality. These findings suggest that the presence of more active whistleblowers significantly enhances whistleblowing risk, thereby leading to improved environmental performance.

This study’s contribution is twofold. Firstly, this study contributes to the growing body of whistleblowing literature by providing the first evidence of how external whistleblowing risk affects corporate environmental policy. The aforementioned previous research in the field of whistleblowing has concentrated on the effectiveness of whistleblowing in detecting accounting fraud, enhancing the quality of financial reporting or deterring insider trading (Bowen et al., 2010; Dyck et al., 2010; Baloria et al., 2017; Wilde, 2017; Call et al., 2018; Wiedman and Zhu, 2022; Berger and Lee, 2022; Raleigh, 2023). However, these studies have not provided any evidence regarding how whistleblowing laws would impose any externalities on the

environment and public health, which has become a paramount concern in the recent business world following the signing of the Paris Agreement in 2016. Considering the world trend of transferring into a net-zero era, establishing a connection between these laws and decisions related to corporate emissions is important and meaningful. Driven by this motivation, our study fills this gap by indicating the positive environmental externality of whistleblowing risk.

Secondly, this study also contributes to a nascent body of research regarding corporate environmental performance and climate finance. Prior research has explored extensively the factors affecting corporate emissions, including institutional investors (Azar et al., 2021; İlhan et al., 2023), earnings pressure and earnings management (Liu et al., 2021; Thomas et al., 2022), court ruling of limited liability (Akey and Appel, 2021), financial Constraints (Xu and Kim, 2022), the role of analysts (Jing et al., 2023) and Greenwashing through divesting (Duchin et al., 2024). Our paper is the first to study the unintended environmental consequences of the False Claims Act.

The remainder of this paper is organized as follows. Section 2 discusses the institutional background of whistleblower laws and our identification strategy. Section 3 provides the literature review and hypothesis formation. Section 4 discusses the data and empirical model. Section 5 reports our baseline results and various robustness checks. Section 7 reports further analyses. Section 7 concludes the paper.

1. Institutional Background and identification strategy
   1. **Whistleblowing laws and the False Claims Act**

Whistleblowing laws have a history of over 700 years, and the most important provision inherent in the whistleblowing laws is called the qui tam provision. At common law, a writ of

qui tam is a writ by which an individual who assists in a prosecution may obtain for himself or herself all or part of the damages or financial penalties recovered by the government as a result of the prosecution. The first qui tam law can be traced back to medieval times in England when King Edward II shared one-third of the penalties to the whistleblower who had successfully prosecuted a government official for moonlighting as a wine merchant in 1318. In the modern era, the False Claims Act holds the distinction of becoming the first whistleblowing law in the US. It has been passed by Congress in 1867 as a federal law and has been further refined and strengthened in 1986. Since 1987, one year after Congress strengthened the FCA, 18 states have proposed their state-level general False Claims Act to recover the governmental losses at the state level (Berger and Lee, 2022).

After the accounting scandals such as Enron and WorldCom, in 2002 the Sarbanes-Oxley (SOX) Act Section 806 requires the Department of Labor to protect the whistleblowers who provide information or assist in an investigation regarding any conduct that violates sections 1341, 1343, 1344, or 1348, any rule or regulation of the Securities and Exchange Commission (SEC), or any provision of federal law relating to fraud against shareholders. However, there is no qui tam provision in the SOX Act section 806. Finally, as a reaction to the financial crisis in 2008, the government proposed the Dodd-Frank Act to revolute the US’s financial system. This Act requires the SEC to establish the SEC whistleblower program to incentivize whistleblowers to expose any breach of the Security Exchange Act. Similar to the FCA, it also provides monetary benefits to relators who provide information that leads to successful enforcement, and the rewards can be 10%-30% of the collected money from sanctions if the monetary section amount is higher than $1 million.

* 1. **Identification strategy and three shocks by appeals courts**

The US federal court system constitutes three hierarchies: the US district courts, the US courts of appeals, and the Supreme Court of the US. A total of 94 district courts serve the 51 states in the US since one state might possess more than one district court. The 51 states (94 district courts) have been divided into 13 circuits, each of which owns its unique court of appeals and they are responsible for deciding appeals from its federal jurisdiction against the judgments of district courts. Figure 1 This figure plots the geographic boundaries of the US Courts of Appeals (Circuits).

**[Insert Figure 1 Here]**

These appeal courts and the Supreme Court are considered the most influential parts of the US federal court system (US Courts, 2023). Since 1994, three decisions have been made by three different appeal courts in three cases under the False Claims Act, which have increased the financial incentives for whistleblowers. These three decisions were made in 1994 (the 9th Circuit), 2002 (the 8th Circuit), and 2007 (the 7th Circuit), affecting 13 district courts in 9 states, 10 district courts in 7 states, and 7 district courts in 3 states respectively. These state-level staggered decisions create an opportunity for a quasi-natural experiment to examine how financial incentives for whistleblowers moderate their role in affecting corporate environmental performance. We then elaborate on the three shocks we build on the court decisions and explain why they can increase the financial incentives for whistleblowers.

The first shock contains two court decisions [1](#_bookmark40) . The first one is *United States ex rel.*

1 The reason that the first shock contains two court decisions instead of just one is that, after the first decision made by the 9th Circuit which increased the financial incentives for whistleblowers in 1994, it was followed by another decision which decreased the financial incentives for whistleblowers to file lawsuits in this circuit

*Killingsworth v. Northrop Corp. 25 F.3d 715, 722 (9th Cir. 1994)*. In this case, Max Killingsworth brought a qui tam action against the Northrop Corporation, alleging it defrauded the United States by inflating cost estimates used to support MX missile contract proposals. After a series of consultations, Killingsworth and Northrop attempted to settle the case. However, the government (DOJ) then expressed concern with this agreement, since it thought the whistleblower and the defendants had made a collusive settlement. Therefore, the government informed the court that it did not consent to the settlement agreement. Consequently, the court (California district court) entered its order of dismissal of the action with prejudice, stating that the Attorney General's consent to dismissal in the current circumstances was not required. The government then appealed to the Ninth Circuit (appeals court). Nevertheless, contrary to all other appeals courts, the 9th Circuit still rules in favour of the whistleblower’s collusive settlement with the defendant. This decision increased the financial incentives for whistleblowing in two ways (Engstrom, 2013), First, it provides an incentive for whistleblowers and defendants to trade broad releases of liability for larger settlement amounts; and second, it makes it more likely that the DOJ will intervene in cases filed in the Ninth Circuit to monitor collusive settlements. This benefits the whistleblower because DOJ intervention greatly increases the likelihood of settlement.

The second decision is *United States. v. Mackby, 261 F.3d 821 (9th Cir. 2001)*. Here, Peter Mackby, the defendant, appeals to the district court's civil judgment in favour of the United States under the False Claims Act. He argued that the treble damage rewards are

in 2000. Therefore, in our empirical analysis, we end the treatment period for the first shock in 2000 (Dey et al., 2021).

unconstitutionally excessive under the Excessive Fines Clause of the Eighth Amendment. This time, the Court of Appeal ruled in favour of the defendant. This decision made it financially less attractive to file lawsuits in the 9th circuit because the decision raised the possibility that the district courts would assess treble damages as excessive, reducing the overall settlement amount.

The second shock contains one court decision—*United States v. Larry Reed & Sons Partnership, 280 F.3d 1212 (8th Cir. 2002)*. In 2001, Larry Reed Sons (the partnership), an agricultural partnership, and its individual partners were found by a jury to have filed false cotton crop insurance claims eight years earlier. The partnership argued that because the plaintiffs alleged that the partnership's damages were only $49,720, at trial the United States proved only $56,874 in damages as a result of the partnership's false cotton crop insurance claim (the initial complaint). As a result, the jury awarded the partnership nearly $94,000 in damages based on insufficient evidence. The United States Court of Appeals for the Eighth Circuit ruled that the damages were not limited to the amount alleged in the initial complaint. Since the whistleblower's share is based on the total recovery (i.e., the sum of damages and penalties), the award increases the financial incentive for whistleblowing by allowing the whistleblower to modify his or her claim upward throughout the investigation and legal proceedings, thereby increasing the total recovery.

Finally, the third shock also contains one court decision—*U.S. ex rel. Tyson v. Amerigroup Illinois, Inc., 488 F. Supp. 2d 719 (N.D. Ill 2007)*. In this case, the jury returned a verdict that the defendant believed was excessive. The defendant then appealed to the Court of Appeals for the Seventh Circuit in 2007. On appeal, the Court ruled in favour of the plaintiff, ruling that the

penalty was reasonable. This judgement increased the financial incentive for the whistleblower to file a lawsuit in the Seventh Circuit because it ruled that penalties substantially in excess of damages were permissible, thereby increasing the total amount of the recovery.

Exploiting the three shocks stemming from the appeals courts provides us with three benefits: (i) these three shocks are based on four court rulings from the federal-level Courts of Appeals, thereby suffering less from lobbying or political pressure, (ii) compared to the two federal-level provisions: SOX Act section 806 or the Dodd-Frank Act section 922, which makes it difficult to identify decent treated and control groups, decisions by Courts of Appeals that increase the financial incentives for whistleblowers to file FCA lawsuits provide decent treated and control groups at different points in time and (iii) both the SOX Act and the Dodd-Frank Act contain various corporate governance codes or provisions, therefore it is hard to isolate the effects from one single whistleblowing section; in contrast, these court rulings which rule in favour of the whistleblowers provide a cleaner and more direct impact on whistleblower’s incentives.

Apart from employing the court rulings, we also follow previous studies which directly use whistleblowing cases as an identification strategy (Bowen et al., 2010; Kuang et al., 2021; Raleigh, 2023). We follow Dey et al. (2021) and collect firm-level FCA cases[2](#_bookmark41) to capture the firm’s own exposure to the False Claims Act. This approach also provides us with two benefits:

(i) these cases capture firm-level exposure to whistleblowing risk (Bowen et al., 2010) and (ii) study shows that previous litigation experience is important in corporate decision-making (e.g.,

2 Engstrom (2013) files a FOIA request to the Department of Justice for the record of all the FCA lawsuits from 1987-2012. We are grateful to David Freeman Engstrom from Stanford Law School for generously sharing his data on FCA litigations.

Deng et al., 2014) and these cases directly capture firm’s previous experiences in FCA. Overall, we use both state-level court rulings associated with the U.S. False Claims Act (FCA) and prior firm-level FCA cases as an identification strategy to capture exogenous variations in whistleblowing risk.

Specifically, in our following stacked regressions, we define the firms located in states that have been affected by a relative shock which increases the financial incentives for whistleblowers as the treated group, and plants located in states that have never been affected by any of the court rulings as our clean control group to build the stacks. We then interact the DID interaction term with the firm’s prior FCA experiences and estimate a triple interaction term as our variable of interest for whistleblowing risk. Figure 2 plots the timeline of our sample period (1991-2010) and the three shocks stemming from four court decisions.

**[Insert Figure 2 Here]**

1. Literature Review and Hypothesis Formation
   1. **Whistleblowing literature**

Based on the different whistleblowing channels, previous studies on whistleblowing have distinguished two types of whistleblowing[3](#_bookmark42) (e.g., Lee and Xiao, 2018): internal whistleblowing, where whistleblowers blow the whistle within the corporate internal control system—they direct their revelations to top management, the audit committee, or directors; and external

3 To distinguish two types of whistleblowing, please refer to Barnett et al. (1993), Dhamija (2014), Dworkin and Baucus (1998), Lee and Xiao (2018), and Smaili and Arroyo (2019) for a detailed review. In our paper, we focus on the exogenous shocks provided by court rulings on the False Claims Act, which is an external whistleblowing channel, since Dyck et al. (2010) indicate that only 19% of whistleblowing cases are raised by employees. Therefore, the internal whistleblowing system loses the chance to receive valuable whistleblowing information from other stakeholders.

whistleblowing, where whistleblowers report to the external regulatory agencies outside the corporate boundary.

One strand of literature focuses on the consequences of external whistleblowing. They use either whistleblower news or whistleblowing laws as identification strategies to study how external whistleblowing affects the capital market. Dyck et al. (2010) implement a systematic analysis of corporate fraud cases and find that the most crucial source in detecting accounting fraud is the employee, and a monetary incentive is a stronger channel for employee whistleblowing compared to the reputation channel. Bowen et al. (2010) provide evidence that whistleblowing allegations are allocated with lower short-term abnormal returns, more future restatements and lawsuits, and lower future operating performance and stock returns. Wilde (2017) documents that, compared to control samples, firms subject to whistleblowing experience less financial misreporting and tax aggressiveness. Call et al. (2018) highlight the outcome of financial misrepresentation enforcement actions—more monetary penalties and longer prison sentences—after employee whistleblowing. Raleigh et al. (2023) document that this deterrence effect also plays a vital role in corporate governance and capital market— preventing insider trading. Finally, Lee et al. (2024) employ the New York FCA and find that state-level FCA helps reduce state-level tax avoidance. In contrast, some research highlights the dark side of whistleblowing on corporate daily operations. For instance, Kuang et al. (2021) demonstrate the adverse effects of whistleblowing allegations on audit fees, as whistleblowing risk can increase audit risk. Du et al. (2020) find that both FCA and Dodd-Frank whistleblowing laws increase bank loan spread.

Three related studies (Heese and Perez-Cavazos, 2019; Hey et al., 2021; Heese et al., 2021)

explore the whistleblowing cases under the False Claim Act. They find that the government chose to sign more fixed-price contracts rather than cost-plus contracts with accused firms; they also exploit the staggered increase of financial awards for FCA claims in US appeal courts and document that the level-up of financial incentives leads to more lawsuits; they further test the effects of Department of Justice (DOJ) engagement on corporate behaviors and find that the DOJ engagement enhances employee relation, internal control, and board independence. Two recent but related studies document the deterrence effects of the Dodd-Frank whistleblowing provision on corporate financial fraud (Berger and Lee, 2022; Wiedman and Zhu, 2023). Following their studies, Zhou et al. (2023) discover the peer deterrence effect of whistleblowing allegations on corporate aggressive reporting. In the same vein, Huang et al. (2022) find that after the promulgation of the Dodd-Frank whistleblowing program, the firms become more transparent—they disclose more information related to their customers.

Another strand of literature concentrates on the determinations of external whistleblowing. Lee and Fargher (2013) use S&P 200 firms and find that anonymous reporting, organizational support; external directors on the audit committee; and concentrated shareholdings trigger more whistleblowing disclosure. Bereskin et al. (2020) find that prosocial employees and CEOs can increase the likelihood of employee whistleblowing; Heese and Perez-Cavazos (2021) find that the exogenous shock that increases unemployment insurance leads to more employee complaints to OSHA. In contrast, Call et al. (2016) demonstrate that companies strategically grant employees more stock options to prevent them from whistleblowing.

Regarding internal whistleblowing studies, this body of literature is sparse due to the shortage of archival data. Lee and Fargher (2018) use Australian data and find that a high-

quality audit committee can increase the likelihood of internal whistleblowing rather than external. Stubben and Welch (2020) utilize a proprietary dataset and document the first evidence of how a firm’s internal whistleblowing system assists in decreasing government fines and material lawsuits. Lin et al. (2022) explore the effect of internal whistleblowing in a Chinese context and document that internal whistleblowing could reduce stock price crash risk.

* 1. **Literature on corporate environmental performance**

After the signing of the Paris Agreement, we witness a growing trend of literature focusing on climate finance (Hong et al., 2020; Krueger et al., 2020; Stroebel and Wurgler, 2021). Earlier studies concentrate on CO2 emissions and document that institutional investors care about the emissions and take the lead in governing corporate environmental performance (Azar et al., 2021; Shive and Forster, 2020). Recent research has focused on more harmful emissions such as NOx, SOx emissions, and toxic releases, and it has explored various factors that drive corporate emissions policies.

Consistent with Friedman’s (1970) view that “the social responsibility of business is to increase its profits,” firms sacrifice the environment when facing external pressures on profitability or financial constraints, thereby generating negative externalities. Liu et al. (2021) find that firms subject to earning pressure have higher sulfur dioxide emissions; firms even strategically increase their ESG ratings to create a reputational slack for future emissions (Thomas et al., 2022). In addition, Xu and Kim (2022) find that relaxing financial constraints reduces toxic emissions from U.S. public companies. This underscores the significant impact financial constraints have on environmental pollution, a costly negative externality that affects society and public health.

The regional cap-and-trade program also seems not to work since firms will transfer production and emissions to states that have not been regulated (Bartram et al., 2022). The situation was made worse when courts ruled to strengthen parent limited liability protections for certain subsidiaries (Akey and Appel, 2021). Some opportunists have even used divestiture as a tool to greenwash themselves (Duchin et al., 2024). Fortunately, studies do find that financial analysts and socially responsible lenders assist in improving corporate environmental performance (Choy et al., 2024; Jing et al., 2023), and the EPA’s enforcement even shows a spillover effect on reducing toxic releases (Dasgupta et al., 2023).

* 1. **Hypotheses formation**

The tension of our study relies on two competing hypotheses. On the one hand, whistleblowing laws encourage whistleblowers to provide valuable information (Dyck et al., 2010), which improves information disclosure that investors and stakeholders rely on to monitor corporate environmental performance. For example, major institutional shareholders, such as BlackRock, Vanguard, and State Street Global Advisors, directly engage firms with higher CO₂ emissions to influence corporate decisions (Azar et al., 2021). They may also gather climate-related disclosures from the CDP (formerly known as the Carbon Disclosure Project). Similarly, analysts frequently raise environmental-related questions during corporate events, such as earnings conference calls, to obtain relevant insights (Jing et al., 2023). Given that whistleblowing risk can enhance a firm's overall information environment by facilitating whistleblowers’ active participation (Dyck et al., 2010; Wilde, 2017), we anticipate that investors and other stakeholders are better equipped to monitor environmental performance in firms subject to higher whistleblowing risk. Although whistleblowers may not explicitly report

environmental fraud, improvements in a firm’s financial information environment facilitate monitoring environmental performance because critical environmental activities—such as environmental expenditures, investments in green innovations, and environmental provisions— are directly reflected, audited, and verified in firms’ financial statements. In practice, many third-party data providers also base their assessments of corporate environmental performance on precisely such financial disclosures[4](#_bookmark43). Also, whistleblowing laws also pose a deterrence effect on managers’ misconduct (e.g., Berger and Lee, 2022). A key question documented in the corporate finance study is the agency issues of these shortsighted managers (Jensen and Meckling, 1976). As whistleblowing risk can discipline managers and let them focus on the firm’s long-term value maximization, we anticipate firms will increase their investment in environmental performance since pollution reduction is better for their long-term firm value maximization (Hsu et al., 2023).

On the other hand, the whistleblowing process is a time- and resource-consuming process[5](#_bookmark44). These lawsuits can bring firms with direct and indirect costs. Direct costs from a lawsuit include legal fines, attorney fees, and increased insurance premiums. More intuitively, the heightened litigation risk posed by whistleblowing laws can exacerbate financial constraints for companies by raising the cost of debt. Arena (2018) documents that firms facing higher litigation risks

4 For instance, Trucost uses the firm’s financial fundamentals to estimate its emission level (Aswani et al., 2024), and MSCI analyzes capital expenditure on green techs and renewable energies in its ESG rating, see [https://www.msci.com/esg-and-climate-methodologies.](https://www.msci.com/esg-and-climate-methodologies)

5 According to Phillips & Cohen, a leading law firm specializing in whistleblower cases, these cases can be complex and time-consuming. These cases take an average of 3 to 5 years, varying according to the complexity of the fraud, the amount of evidence required, the level of cooperation required, and the extent to which the government investigates and intervenes in the decision.

experience lower credit ratings and must pay higher yields on loans and bonds. Similarly, Deng et al. (2014) find that defendant firms encounter more financial covenants and are more likely to require collateral. Furthermore, the heightened litigation risk posed by whistleblowing laws can exacerbate financial constraints for companies by raising the cost of debt, which is the indirect cost. Other indirect costs include negative future operating performance and stock returns (Bowen et al., 2010). These costs resulting from future whistleblower-initiated litigation will hamper the company's day-to-day business activities, which in turn will make it challenging to satisfy investors' return requirements. As for this circumstance, the firm’s response is usually sacrificing the interest of other stakeholders—investing less in emission abatement to secure resources and polluting more (e.g., Liu et al., 2021; Thomas et al., 2022; Xu and Kim, 2022).

Based on the previous discussion, we propose the following competing hypotheses:

***H1a: Whistleblowing risk is negatively (positively) correlated with toxic releases (environmental performance).***

***H1b: Whistleblowing risk is positively (negatively) correlated with toxic releases (environmental performance).***

1. Data and Empirical model
   1. **Sample selection**

Our FCA case data is from a FOIA requirement directly to the U.S. Department of Justice (Engstrom, 2013). The data provided by the US DOJ includes the whistleblowers’ names, defendants’ names (company names), the time when whistleblowing submitted a case, the attorney firm, and whether the DOJ chose to intervene or not in a case. We search case

documents from the Public Access to Court Electronic Records (PACER) website to supplement the details of these cases. We then manually match these cases using the defendants’ names to COMPUSTAT listed firms. The detailed matching processes are provided in Appendix C.

We draw the plant-level toxic release data from the EPA TRI basic files for the period 1991-2010. To obtain firm-level accounting variables as controls, we then match them to the COMPUSTAT North America annual files using the linking table provided by Hsu et al. (2023). We draw institutional investor’s holding data from the Thomson-Reuters Institutional Holdings (13F) database. Earnings conference call transcripts come from Capital IQ. For cross-sectional analysis, we retrieve firm-level analyst coverage data from I/B/E/S, audit quality data from Audit Analytics, and short-sellers holding data from COMPUSTAT. Consistent with previous literature (Hsu et al., 2023), we exclude financial firms (SIC codes 6000-6999). All continuous variables are winsorized at 1% and 99% percentile.

* 1. **Measuring corporate environmental performance**

We measure corporate environmental performance using the toxic release data provided by the EPA TRI program, which has been widely used by recent studies (e.g., Akey and Appel, 2021; Jing et al., 2023; Xu and Kim, 2022). This program requires all the toxic release inventories to report their emissions if the plant falls within a TRI reportable industry sector, has 10 or more employees, and crosses a certain threshold in manufactured or processed TRI- listed chemicals. Using TRI data provides us with several advantages. First, TRI data are reliable because 18 U.S.C. § 1101 makes it a criminal offense to falsify information provided to the U.S. Government, including knowingly falsifying records for inspection. Secondly, TRI data provides records of establishments’ real emissions levels but not estimated levels. A recent

study (Aswani et al., 2024) documents that vendor-estimated emissions (e.g., Trucost data) differ systematically from company-reported emissions and are highly correlated with financial fundamentals, suggesting that using data on estimated emissions may capture the association between such fundamentals and the variable of interest.

Following previous literature (Hsu et al., 2023), we utilize the value “PROD. WASTE (8.1 THRU 8.7)” to measure corporate environmental performance, that is, the sum of the amounts of all emissions (in pounds) for all chemical categories. Section 8 of the TRI database reports several items, including 8.1 (amount of total releases), 8.2 (energy recovery on-site), 8.3 (energy recovery off-site), 8.4 (recycling on-site), 8.5 (recycling off-site), 8.6 (treatment on-site), 8.7 (treatment off-site), and PROD. WASTE (8.1 THRU 8.7) (the sum of the quantities in items 8.1 through 8.7). We also drop all observations with zero emissions since zero release does not mean a plant emits zero toxic chemicals in the TRI database—TRI inserts zero into a blank field (Akey and Appel, 2021; Thomas et al., 2022; Xu and Kim, 2022).

* 1. **Baseline model**

Following Cengiz et al. (2019), to avoid comparing an afterwards treated sample to previously treated observations which drive biased estimators caused by staggered treatment times, we create a separate dataset (cohort) for each of the three shocks from appeals courts, each excluding observations from states affected by the other two shocks and including observations that never be treated as “clean controls.” For each cohort, we build a 10-year estimation window [-5,+5] around the respective shock and then stack these shock-specific cohorts together to calculate an average treatment effect across the three shocks (Year 0 is dropped). Therefore, we estimate a staggered difference-in-difference-in-difference (DIDID)

baseline specification with two-way fixed effects to test hypotheses 1 and 2:

Log(toxic releases)i,t=𝛽𝛽1Courtsi×Postt×Casei+𝛽𝛽2Courtsi×Postt+**δY**i,t+**θZ**s,t+ϑc,i+μc,t+εi,t (1)

Where i denotes a firm, t denotes a year, s denotes a state, and c denotes a cohort. The dependent variable *Log(toxic releases)* is the Log transformation of TRI toxic release, and the variable of interest is *Courts* ×*Post* ×*Case*. *Courts* takes the value of 1 if the firm is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Post* takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock.

Based on the prior studies regarding corporate emissions (e.g., Azar et al. 2021; Duchin et al., 2024; Choy et al., 2024; Shive and Forster 2020), we use the following firm-level control variables (**Y**i,t) for our regressions: firm size (*Size*), Portability (*ROA*), leverage ratio (*Leverage*), tangibility (*Tangibility*), growth opportunities (M/B), Cash-to-liability-ratio (Cash/liabilities), Altman’s Z score (*AltmanZ*), dividend payout (*Dividend*) and institutional ownership (*Institutional Holding*). We also include state-level control variables(**Z**s,t ): state-level GDP growth (*GDP Growth*) and state-level political balance (*Political Balance*) to control for macroeconomic factors. Finally, we control for cohort-firm and cohort-year fixed effects by interacting these firms and years with different cohorts to build more stringent high dimensional fixed effects as we run stacked regressions. In robustness tests, we also try state-by-year fixed effects or use OLS regressions without stacking our sample and find quantitatively similar results. The details of variable definitions are provided in Appendix A.

1. Empirical results
   1. **Descriptive statistics**

**[Insert Table 1 Here]**

Table 1 presents the summary statistics before building stacks. We report firm-level and state-level variables in different panels. Firm-level variables are from COMPUSTAT annual files, and state-level data are from WRDS. The distribution of our variables is generally comparable with previous literature (e.g., Jing et al., 2023). However, there are discrepancies in several variables stemming from different sample periods.

* 1. **Results for baseline regressions**

**[Insert Table 2 Here]**

Table 2 presents the results for our baseline stacked regressions. We report t-statistics based on heteroskedasticity-robust standard errors clustered at the cohort-firm level. In the first column, we regress the corporate environmental performance measure, *Log(toxic releases)*, on the interaction term of the three shocks from appeals courts, post-court ruling time indicator, and the number of ex-ante FCA cases, *Courts×Post×Case*, without any firm-level or state-level control variables but with cohort-firm and cohort year fixed effects. The result demonstrates that the coefficient on the interaction term is significantly negative at 1% level (t-stat = -3.39). We further control for a set of firm-level and state-level controls that may affect corporate toxic releases with the aforementioned fixed effects in columns (2) and (3). The coefficients remain significant and negative (t-stat = -3.56 and -3.58) on the interaction term for the corporate environmental performance measure. These findings indicate that the three shocks from appeals courts, which increase the financial incentives for whistleblowers, contribute to the reduction of corporate toxic release, which is consistent with *hypothesis 1* that whistleblowing risk

complements corporate governance and helps investors and stakeholders monitor firms’ environmental performance. In columns (4), (5), and (6) of Table 2, we replace the dependent variable to *Log(toxic releases/sales)*. The results continue to be significant (t-stat = -4.58 in column (4), -4.07 in column (5), and -4.10 in column (6)), which corroborates our baseline findings.

Furthermore, in our baseline specifications, the outcome of the three shocks’ impact on corporate environmental performance holds both statistical significance and substantial economic relevance. The coefficient for the interaction term, *Courts×Post×Case*, implies that while keeping other factors constant, one additional ex-ante FCA case causes a decrease in the toxic releases of about 14.1%-15.8% after the three court decisions, highlighting the positive externality of whistleblowing risk.

* 1. **Robustness tests**
     1. **Parallel trend analysis**

Our staggered difference-in-difference-in-difference specification hinges on a key assumption that the treated groups and control groups follow a parallel trend before the three shocks from the US Courts of Appeals (Roth et al., 2022). To tackle the endogeneity concerns and ensure the validity of the parallel trends assumption inherent in our stacked DID approach, we examine the dynamic impact of the court rulings on corporate environmental performance. If concerns regarding reverse causality or pre-treatment effects were real, we would expect to observe ex-ante significant changes in toxic releases. To allay these concerns, we substitute the time indicator, *Postt*, in our baseline tests with a series of distinct dummy variables, namely, *Postt-5*, *Postt-4*, *Postt-3*, *Postt-2*, *Postt-1*, *Postt+1*, *Postt+2*, *Postt+3*, *Postt+4*, *Postt+5*, which allows us

to assess the impact of the court rulings both before and after its announcement. Specifically, *Postt-k* takes the value of 1 if the observation is k years before the relevant court rulings and zero otherwise; *Postt+k* takes the value of 1 if the observation is k years after the relevant court rulings and zero otherwise.

**[Insert Table 3 Here]**

Table 3 presents the results of the dynamic impact. The coefficients on *Courts×Postt- 5×Case, Courts×Postt-4×Case*, *Courts×Postt-3×Case*, *Courts×Postt-2×Case*, and *Courts×Postt- 1×Case* are not significant across the table and the coefficients start to be significantly negative on *Courts×Postt+1×Case*. These results alleviate the concerns for pre-treatment effects and reverse causality and suggest that our analysis satisfies the parallel trends assumption to use a stacked DIDID model.

* + 1. **Endogeneity concern regarding the passages of court rulings**

Another key assumption of our staggered DIDID method is no anticipation (Roth et al., 2022). Fortunately, our identification strategy explores the court rulings from federal-level Courts of Appeals, which suffer less from political pressure or lobbying concerns. However, suppose environmental, whistleblowing, or macroeconomic conditions in one state are less favorable than nationally; in that case, firms in that state may expect the courts to rule in favor of whistleblowers in order to deter misconduct and wrongdoing and improve the business environment. To address these concerns and further validate the assumption of our identification strategy, we follow previous studies (e.g., Acharya et al., 2014) and estimate a Cox proportional hazard model that predicts these court rulings. In our hazard model, a “failure event” is defined as a change in the whistleblower’s financial incentives in a state; we remove

a state from the sample for the years after it affected a relative court ruling. The results are presented in Table 4.

**[Insert Table 4 Here]**

In Table 4 column (1), we include the total toxic release and onetime toxic release (*State Emissions*, *State Onetime Release*, respectively) aggregated to the state level; in column (2), we further include the passage of state-level FCA (State False Claims Acts) as a proxy for the state- level whistleblowing environment; finally, in column (3), we further insert state-level macroeconomic factors including GDP per capita (*GDP per Capita*), GDP growth (*GDP Growth*) and political propensity (*Political Balance*). As illustrated by these columns in Table 4, none of the independent variables are statistically significant, suggesting that these environmental, whistleblowing, or macroeconomic factors do not contribute to the consequences of these court decisions.

* + 1. **Balancing the covariates between treatment and control groups**

At this point, we have successfully mitigated some of the endogeneity issues and strengthened the robustness of my DIDID approach based on the above sections. In this section, we aim to tackle an additional concern driven by systematic differences in the characteristics between the treatment group and the control group. To achieve this, we apply the propensity score matching (PSM, hereafter) and the entropy balancing (EB, hereafter) as two alternative approaches to identify the control sample. Previous accounting and finance studies (Shipman et al., 2017) have widely used the PSM approach to identify an appropriate control group; whereas the EB approach has gained traction in recent accounting and finance studies (e.g., Beck et al., 2022; Dang et al. 2023; McMullin and Schonberger, 2020), it not only preserves all

observations in my sample but also mitigates the potential bias of the iterative matching process employed by PSM (Hainmueller, 2012). Specifically, for the PSM approach, we use a logit model to estimate the propensity score based on firm-level covariates and match a treated firm to a control firm using a caliper of 0.05 without replacement; for the EB method, we balance the covariates at their maximum orders (2nd or 3rd order). After finding a more decent group and rebalancing the covariates, we estimate our baseline specification again based on the propensity score matched sample and EB reweighed sample in Table 5.

**[Insert Table 5 Here]**

In Table 5 Panel A, the coefficients on the triple interaction term continue to be statistically significant, suggesting that our baseline results are robust to the PSM approach with a more similar control group. In Table 5 Panel B, the coefficients on the triple interaction term are statistically significant at 1% level in all columns, indicating that our baseline results are robust to the EB approach with a covariates-reweighted sample.

* + 1. **Additional robustness checks**

In this section, we summarize a series of robustness tests to corroborate the results of our baseline findings. For brevity, we have included these tests in the appendix. Collectively, our baseline results are robust when (1) using a shorter [-3,+3] time window (Appendix B. Table 1 Panel A); (2) using a sample without the period of the global financial crisis (Appendix B. Table 1 Panel B); (3) dropping relocated firms which may cause a spurious identification of our treated and control group (Appendix B. Table 2 Panel A); (4) implementing a falsification test with pseudo-FCA cases (no results, Appendix B. Table 2 Panel B); (5) using another specification with cohort-state-by-year fixed effects to rule out any state-level policies or

unobservable shocks that may drive our results (Appendix B. Table 2 Panel C); (6) adding proxies for internal controls in our baseline specification to control for internal whistleblowing (Appendix B. Table 3); (7) a further identification strategy by splitting firms into high versus low polluting firms (Appendix B. Table 4); (8) using an OLS DID regression without stacking our sample; (9) replacing the ex-ante number of FCA cases (*Cases*) to a dummy variable; (10) using both the ex-ante and ex-post number of FCA cases and therefore replacing *Cases* in the triple interaction term to a firm-year level variable; (11) using geographic weighted toxic releases.

* 1. **Channel tests**

Up to this point, we have provided robust evidence that whistleblowing risk significantly reduces toxic releases among treated firms. The natural subsequent inquiry is identifying the channel through which whistleblowing risk improves firms' environmental performance. Prior literature emphasizes investments in pollution abatement strategies and green patents as essential channels for pollution reduction (Akey and Appel, 2021; Cheng et al., 2025; Jing et al., 2023; Xu and Kim, 2022). Specifically, Cheng et al. (2025) demonstrate that green patents targeting pollution control not only enhance environmental outcomes but also improve financial performance, as pollution represents a direct waste of valuable resources. Building on these insights, we hypothesize that firms decrease their toxic releases through increased investment in green patenting activities. Following previous studies (e.g., Jing et al., 2023), we obtain U.S. patent data from Kogan et al. (2017) and classify green patents according to the Cooperative Patent Classification (CPC) system, specifically identifying CPC classes Y02 and Y04S (Cohen et al. (2022)).

**[Insert Table 6 Here]**

We replace the dependent variable in our baseline specification with the measures of green patents and report our results for channel tests in Table 6. As there is usually a time gap between the time a firm invests in a patent and the time the firm successfully files a patent to the U.S. government (e.g., He and Tian, 2013), we report the results of green patents at t+0, t+1 and t+2 to illustrate a time-trend of firm’s green investing activities. Table 6 shows that firms with prior FCA cases significantly increase their investment in green patents after the court rulings, suggesting that investing in green patents indeed serves as a potential channel for pollution reduction. To ensure the robustness of our channel tests, we also try other specifications using the average number of green patents after the shock or a longer time window (e.g., [-2,+2]) to measure green patents and find quantitatively similar results (Bernstein et al., 2015; Jing et al., 2023).

* 1. **Additional analysis**

We further examine whether investors perceive improvements in firms' environmental performance following the court rulings. To achieve this, we follow prior studies (e.g., Loughran and McDonald, 2011; Henry and Leone, 2016; Sautner et al., 2023) and conduct sentiment analysis on firms' earnings conference call transcripts to identify environmentally- related questions raised by analysts with positive and/or negative tones. Our sentiment analysis consists of two steps. First, we construct a list of environmental keywords based on textual analyses conducted by Jing et al. (2023) and Sautner et al. (2023). We use this list to detect environmentally-focused analyst questions in earnings conference calls. Specifically, our keyword list includes terms such as “environmental,” “environmentally,” “environmental

protection agency,” “protect environment,” “clean air act,” “pollut\*,” “emission,” “climate,” “global warming,” “coal cleaning,” “green energy,” “renewable,” “waste,” “sustainability,” “biologic,” and “water.” Second, we employ the positive and negative word lists developed by Loughran and McDonald (2011) to classify the identified environmental questions into positive or negative tones. Additionally, consistent with Henry and Leone (2016), we calculate a measure of net tone—defined as the difference between the number of positive and negative environmental questions—as a proxy for overall investor optimism during the conference calls. **[Insert Table 7 Here]**

We report our sentiment analysis in Table 7. In both Panel A and B of Table 7, we witness a significant increase in the number of environmental questions with positive tones and negative tones, signalling that analysts are generally more concerned with the firm’s environmental issues after the three court rulings, which is consistent with our hypothesis that whistleblowing risk provides more information for investors to monitor firm’s environmental performance better. In Panel C, we report the results using both net tone and net tone intensity. We show that analysts' environmental questions are generally more positive, consistent with our baseline findings that investors are optimistic about the firm’s improved environmental performance.

1. Cross-sectional analysis
   1. **Corporate governance**

Our study is based on the hypothesis that whistleblowing risk provides stakeholders with useful information, thereby enabling better monitoring of firms' environmental performance; additionally, whistleblowing risk disciplines managers, discouraging short-sighted decisions and promoting investment for long-term value maximization. Central to our argument is the

idea that whistleblowing risk improves existing corporate governance. Specifically, We hypothesize that the observed improvements in environmental outcomes occur because whistleblowing risk complements existing corporate governance mechanisms, either by increasing informational transparency or by strengthening deterrence effects. To empirically test this hypothesis, we conduct cross-sectional analyses conditional on corporate governance quality, using proxies from prior studies. In particular, we employ institutional investor ownership (Azar et al., 2021), product market competition (Hoberg and Phillips, 2016), and industry-level monitoring (Lee et al., 2024) as measures of the existing corporate governance environment.

**[Insert Tables 8 Here]**

We report our cross-sectional analyses in Table 8. The results indicate that in all panels the impact of whistleblowing risk on a firm’s toxic releases is more pronounced in firms with better existing corporate government, in line with our prediction that whistleblowing risk complements a firm’s corporate governance in shaping a firm’s environmental performance.

* 1. **Different types of whistleblowers**

Whistleblowing risk fundamentally relies on whistleblowers’ active engagement within a country’s legal system. Therefore, in this section, we examine cross-sectional heterogeneity based on different types of whistleblowers. Dyck et al. (2010) identify short-sellers, financial analysts, and external auditors as key whistleblowers in capital markets, each with distinct motivations. For instance, short-sellers expose firms’ misconduct to generate trading profits; analysts report corporate fraud to showcase professional expertise; external auditors typically blow the whistle to uphold ethical standards and comply with regulatory obligations. To verify

that our results indeed stem from whistleblowing risk driven by active whistleblower participation, we partition firms into groups based on the median values of short-seller coverage, analyst coverage, and audit quality and then re-estimate our baseline specification.

**[Insert Table 9 Here]**

Table 10 presents the results of our analyses of different types of whistleblowers. We find that the effect of whistleblowing risk on corporate toxic releases is more pronounced among firms with greater short-seller coverage, higher analyst coverage, and superior audit quality. These findings suggest that the presence of more active whistleblowers significantly enhances whistleblowing risk, thereby leading to improved environmental performance.

1. Conclusion

Using state-level court rulings associated with the U.S. False Claims Act (FCA) and prior firm-level FCA cases as an identification strategy to capture exogenous variations in whistleblowing risk, We find that firms with higher whistleblowing risk reduced their toxic releases by approximately 14%–15%, which is consistent with the notion that an enhanced whistleblowing environment enables shareholders to better monitor managers and encourages a stronger focus on long-term value creation. Further analyses (i) provide evidence that pollution abatement investments serve as a potential channel driving this effect and (ii) reveal that the impact of whistleblowing risk on environmental performance is more pronounced among firms with stronger corporate governance or more active whistleblowers.

We contribute to the two strands of literature. Firstly, this study contributes to the growing body of whistleblowing literature by providing the first evidence of how external whistleblowing risk affects corporate environmental policy. The aforementioned previous

research in the field of whistleblowing has concentrated on the effectiveness of whistleblowing in detecting accounting fraud, enhancing the quality of financial reporting or deterring insider trading (Bowen et al., 2010; Dyck et al., 2010; Baloria et al., 2017; Wilde, 2017; Call et al., 2018; Wiedman and Zhu, 2022; Berger and Lee, 2022; Raleigh, 2023). Considering the world trend of transferring into a net-zero era, establishing a connection between these laws and decisions related to corporate emissions is important and meaningful. Driven by this motivation, our study fills this gap by indicating the positive environmental externality of whistleblowing risk. Secondly, this study also contributes to a nascent body of research regarding corporate environmental performance and climate finance. Prior research has explored extensively the factors affecting corporate emissions, including institutional investors (Azar et al., 2021; İlhan et al., 2023), earnings pressure and earnings management (Liu et al., 2021; Thomas et al., 2022), court ruling of limited liability (Akey and Appel, 2021), financial Constraints (Xu and Kim, 2022), the role of analysts (Jing et al., 2023) and Greenwashing through divesting (Duchin et al., 2024). Our paper is the first to study the unintended environmental consequences of the False Claims Act.

Finally, we make policy implications by illustrating the unintended environmental consequence of whistleblowing risk. Therefore, other regions may need to consider the environmental externalities when adopting their False Claims Act or other whistleblower laws. Overall, our findings imply that whistleblowing risk complements corporate governance in shaping firms’ environmental performance.

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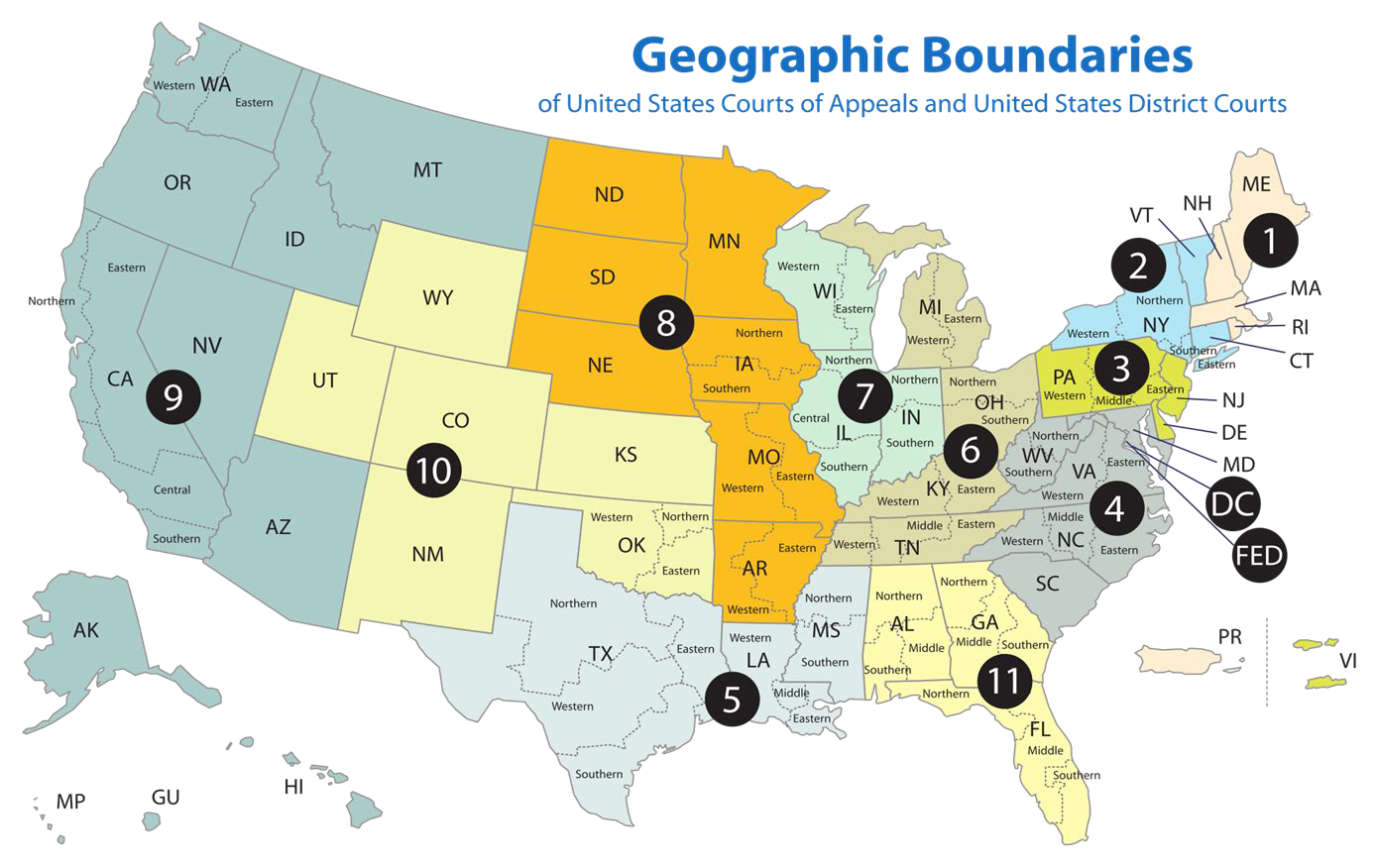
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**Figure 1 The US Court System**

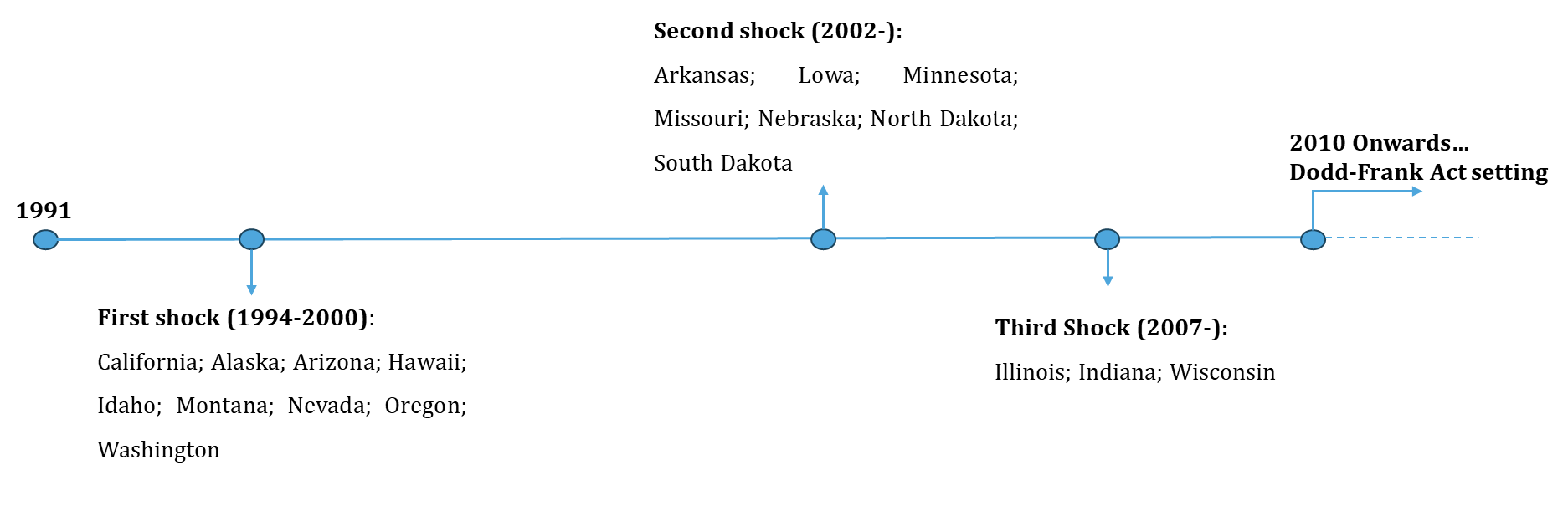
This figure plots the geographic boundaries of the US Courts of Appeals (Circuits). There are a total of 13 Circuits in charge of 94 district courts. (Source: US government)



**Figure 2 Timeline of Three Shocks and Affected States**

This figure plots the timeline of our sample period (1991-2010) and the three shocks stemming from four court decisions.

For each shock, we illustrate the lasting period and the states that have been affected by the shock.



**Table 1 Summary Statistics**

This table presents the summary statistics before building stacks. We report pollution variables, firm variables as well as state variables in different panels. Pollution data are from the EPA TRI program, firm variables are from COMPUSTAT annual files, and state data are from WRDS.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | N | Mean | SD | p25 | Median | p75 | p95 |
| Panel A. Pollution Variables | | | | | | | |
| *Log(toxic releases)* | 10,535 | 12.506 | 3.220 | 10.556 | 12.522 | 14.701 | 17.573 |
| *Log(toxic releases/sale)* | 10,535 | 5.508 | 3.057 | 3.732 | 5.783 | 7.555 | 10.013 |
| Panel B. Firm Variables | | | | | | | |
| *Case* | 10,535 | 0.138 | 0.949 | 0 | 0 | 0 | 1 |
| *Institutional Investor* | 10,535 | 0.369 | 0.333 | 0 | 0.308 | 0.680 | 0.928 |
| *Tangibility* | 10,535 | 0.334 | 0.171 | 0.203 | 0.307 | 0.438 | 0.668 |
| *I/K* | 10,535 | 0.17 | 0.098 | 0.105 | 0.152 | 0.212 | 0.360 |
| *ROA* | 10,535 | 0.092 | 0.073 | 0.054 | 0.089 | 0.132 | 0.214 |
| *Leverage* | 10,535 | 0.281 | 0.182 | 0.152 | 0.267 | 0.386 | 0.611 |
| *Size* | 10,535 | 6.954 | 1.836 | 5.669 | 6.956 | 8.248 | 10.087 |
| *M/B* | 10,535 | 0.512 | 0.873 | 0.289 | 0.481 | 0.738 | 1.562 |
| *Cash/Liability* | 10,535 | 0.158 | 0.285 | 0.019 | 0.058 | 0.161 | 0.663 |
| *Dividend* | 10,535 | 0.592 | 0.491 | 0 | 1 | 1 | 1 |
| *AltmanZ* | 10,535 | 3.511 | 2.591 | 1.979 | 2.940 | 4.320 | 8.211 |
| Panel C. State Variables | | | | | | | |
| *Political Balance* | 10,535 | 0.050 | 0.026 | 0.037 | 0.050 | 0.066 | 0.092 |
| *GDP Growth* | 10,535 | 0.506 | 0.197 | 0.385 | 0.500 | 0.600 | 1 |

**Table 2 Baseline Results**

This table presents the baseline results of whether previous whistleblowing experience affects corporate environmental performance. Our identification strategy relies on the firm’s previous FCA lawsuits with three shocks induced by US appeals courts. We build an estimation window of [-5,+5] for each shock and perform stacked difference-in-difference regressions. The dependent variable *Log(toxic releases)* and *Log(toxic releases/sale)* is the plants’ toxic release and release intensity obtained from EPA TRI datasets, and the independent variable of interest is *Courts×Post×Case*. *Courts* takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Post* takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock. All control variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | | |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts×Post×Case*** | **-0.158\*\*\*** | **-0.155\*\*\*** | **-0.156\*\*\*** |  | **-0.153\*\*\*** | **-0.141\*\*\*** | **-0.141\*\*\*** |
|  | **(-3.39)** | **(-3.56)** | **(-3.58)** |  | **(-4.58)** | **(-4.07)** | **(-4.10)** |
| *Courts×Post* | 0.031 | 0.028 | 0.035 |  | 0.000 | 0.018 | 0.025 |
|  | (0.25) | (0.23) | (0.29) |  | (0.00) | (0.15) | (0.21) |
| *Institutional Holding* |  | -0.008 | -0.008 |  |  | 0.003 | 0.004 |
|  |  | (-0.11) | (-0.10) |  |  | (0.04) | (0.04) |
| *Tangibility* |  | 0.286 | 0.280 |  |  | -0.093 | -0.098 |
|  |  | (0.80) | (0.78) |  |  | (-0.24) | (-0.25) |
| *I/K* |  | -0.040 | -0.036 |  |  | -0.105 | -0.101 |
|  |  | (-0.17) | (-0.15) |  |  | (-0.43) | (-0.41) |
| *ROA* |  | 1.045\*\* | 1.062\*\* |  |  | -0.439 | -0.425 |
|  |  | (2.19) | (2.24) |  |  | (-0.85) | (-0.83) |
| *Leverage* |  | -0.403\* | -0.403\* |  |  | -0.331 | -0.331 |
|  |  | (-1.68) | (-1.68) |  |  | (-1.31) | (-1.30) |
| *Size* |  | 0.311\*\*\* | 0.312\*\*\* |  |  | -0.445\*\*\* | -0.444\*\*\* |
|  |  | (3.98) | (3.99) |  |  | (-5.28) | (-5.26) |
| *M/B* |  | 0.045 | 0.044 |  |  | 0.055 | 0.055 |
|  |  | (1.32) | (1.31) |  |  | (1.61) | (1.60) |
| *Cash/Liability* |  | -0.062 | -0.062 |  |  | 0.136 | 0.136 |
|  |  | (-0.63) | (-0.63) |  |  | (1.31) | (1.31) |
| *Dividend* |  | 0.166\* | 0.165\* |  |  | 0.158\* | 0.157\* |
|  |  | (1.94) | (1.93) |  |  | (1.84) | (1.83) |
| *AltmanZ* |  | 0.001 | 0.001 |  |  | -0.016 | -0.016 |
|  |  | (0.07) | (0.07) |  |  | (-0.78) | (-0.79) |
| *Political Balance* |  |  | 0.046 |  |  |  | 0.094 |
|  |  |  | (0.22) |  |  |  | (0.45) |
| *GDP Growth* |  |  | -1.065 |  |  |  | -1.018 |
|  |  |  | (-1.17) |  |  |  | (-1.09) |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |

**Table 2 Baseline Results (Continued)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| # of Observations | 10,386 | 10,386 | 10,386 | 10,386 | 10,386 | 10,386 |
| Adjusted R2 | 0.883 | 0.884 | 0.884 | 0.869 | 0.871 | 0.871 |

**Table 3 Parallel Trend Analysis**

This table presents the baseline results of whether previous whistleblowing experience affects corporate environmental performance. Our identification strategy relies on the firm’s previous FCA lawsuits with three shocks induced by US appeals courts. We build an estimation window of [-5,+5] for each shock and perform stacked difference-in-difference regressions. The dependent variable *Log(toxic releases)* and *Log(toxic releases/sale)* is the plants’ toxic release and release intensity obtained from EPA TRI datasets, and the independent variable of interest is *Courts×Post×Case*. *Courts* takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock. *Postt-k* takes the value of 1 if the observation is k years before the relevant court rulings and zero otherwise; *Postt+k* takes the value of 1 if the observation is k years after the relevant court rulings and zero otherwise. All control variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | | |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts ×Postt-5×Case*** | 0.145 | 0.138 | 0.140 |  | 0.136 | 0.149 | 0.150 |
|  | (1.34) | (1.31) | (1.31) |  | (1.31) | (1.35) | (1.35) |
| ***Courts ×Postt-4×Case*** | 0.066 | 0.059 | 0.060 |  | 0.057 | 0.069 | 0.071 |
|  | (0.72) | (0.64) | (0.65) |  | (0.61) | (0.71) | (0.72) |
| ***Courts ×Postt-3×Case*** | 0.049 | 0.044 | 0.046 |  | 0.051 | 0.061 | 0.063 |
|  | (1.01) | (0.92) | (0.94) |  | (1.06) | (1.23) | (1.24) |
| ***Courts ×Postt-2×Case*** | 0.049 | 0.047 | 0.048 |  | 0.052 | 0.057 | 0.058 |
|  | (1.08) | (1.03) | (1.03) |  | (1.11) | (1.20) | (1.19) |
| ***Courts ×Postt-1×Case*** | 0.031 | 0.033 | 0.035 |  | 0.044 | 0.053 | 0.055 |
|  | (0.68) | (0.73) | (0.76) |  | (0.95) | (1.14) | (1.16) |
| *Courts ×Postt+1×Case* | -0.084\*\* | -0.080\*\* | -0.080\*\* |  | -0.061\* | -0.057\* | -0.058\* |
|  | (-2.55) | (-2.50) | (-2.52) |  | (-1.85) | (-1.96) | (-1.94) |
| *Courts ×Postt+2×Case* | -0.096 | -0.103\* | -0.101\* |  | -0.101\* | -0.078 | -0.076 |
|  | (-1.62) | (-1.72) | (-1.66) |  | (-1.77) | (-1.51) | (-1.43) |
| *Courts ×Postt+3×Case* | -0.092\*\*\* | -0.098\*\*\* | -0.098\*\*\* |  | -0.108\*\*\* | -0.088\*\*\* | -0.088\*\*\* |
|  | (-2.60) | (-2.65) | (-2.60) |  | (-3.42) | (-2.88) | (-2.76) |
| *Courts ×Postt+4×Case* | -0.131\*\*\* | -0.134\*\*\* | -0.129\*\*\* |  | -0.131\*\* | -0.115\* | -0.110\* |
|  | (-3.50) | (-3.56) | (-3.58) |  | (-2.37) | (-1.93) | (-1.93) |
| *Courts ×Postt+5×Case* | -0.153\*\*\* | -0.155\*\*\* | -0.149\*\*\* |  | -0.146\*\*\* | -0.141\*\*\* | -0.135\*\*\* |
|  | (-6.72) | (-5.60) | (-5.26) |  | (-5.03) | (-4.16) | (-4.02) |
| *Courts ×Post* | 0.019 | 0.014 | 0.020 |  | -0.016 | 0.001 | 0.008 |
|  | (0.17) | (0.13) | (0.19) |  | (-0.15) | (0.01) | (0.07) |
| Firm-level Controls | No | Yes | Yes |  | No | Yes | Yes |
| State-level Controls | No | No | Yes |  | No | No | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| # of Observations | 10,688 | 10,688 | 10,688 |  | 10,688 | 10,688 | 10,688 |
| Adjusted R2 | 0.891 | 0.892 | 0.892 |  | 0.879 | 0.880 | 0.880 |

**Table 4 Hazard Model of Changes in Whistleblower’s Incentives**

This table presents the results from a Cox proportional hazard model. Following previous literature (e.g., Acharya et al., 2014), we define the change in whistleblower’s incentives in a state as a “failure event.” The observation of a state is excluded from the sample when a state is subject to a relative court ruling which increases the financial incentives for whistleblowers. All independent variables are of interest and are measured as of year t-1. All the variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the state level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | (1) | (2) | (3) |
| *State Emissions* | -0.224 | -0.246 | -0.305 |
|  | (-1.19) | (-1.30) | (-1.46) |
| *State Onetime Release* | 0.006 | 0.007 | 0.033 |
|  | (0.08) | (0.10) | (0.43) |
| *State False Claims Acts* |  | 0.695 | 0.863 |
|  |  | (1.18) | (1.30) |
| *GDP per Capita* |  |  | -24.146 |
|  |  |  | (-0.70) |
| *GDP Growth* |  |  | 5.214 |
|  |  |  | (0.65) |
| *Political Balance* |  |  | 0.621 |
|  |  |  | (0.79) |
| # of observations | 791 | 791 | 791 |
| Year FE | Yes | Yes | Yes |

**Table 5 Balancing the Covariates**

This table presents the robustness test of the baseline results in Table 2 using propensity score matching (Panel A) and Entropy Balancing (Panel B). For the PSM method, we use a logit model to estimate the probability of being a treated observation and matched the treated observation to a control observation using a caliber of 0.05 without replacement; for the EB method, we balance the covariates at their maximum orders (2nd or 3rd order). Our identification strategy relies on the firm’s previous FCA lawsuits with three shocks induced by US appeals courts. We build an estimation window of [-5,+5] for each shock and perform stacked difference-in-difference regressions. The dependent variable *Log(toxic releases)* and *Log(toxic releases/sale)* is the plants’ toxic release and release intensity obtained from EPA TRI datasets, and the independent variable of interest is *Courts×Post×Case*. *Courts* takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Post* takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock. All control variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Panel A. Propensity Score Matching** | | | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | | |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts×Post×Case*** | **-0.310\*\*\*** | **-0.333\*\*\*** | **-0.327\*\*\*** |  | **-0.229\*** | **-0.205\*\*** | **-0.199\*** |
|  | **(-3.29)** | **(-3.36)** | **(-3.27)** |  | **(-1.87)** | **(-2.04)** | **(-1.95)** |
| *Courts×Post* | -0.038 | -0.060 | -0.043 |  | -0.106 | -0.068 | -0.051 |
|  | (-0.27) | (-0.42) | (-0.30) |  | (-0.76) | (-0.48) | (-0.36) |
| Firm-level Controls | No | Yes | Yes |  | No | Yes | Yes |
| State-level Controls | No | No | Yes |  | No | No | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| # of Observations | 4,632 | 4,632 | 4,632 |  | 4,632 | 4,632 | 4,632 |
| Adjusted R2 | 0.876 | 0.878 | 0.878 |  | 0.869 | 0.871 | 0.871 |
| **Panel B. Entropy Balancing** | | | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | | |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts×Post×Case*** | **-0.249\*\*\*** | **-0.230\*\*\*** | **-0.220\*\*\*** |  | **-0.209\*\*\*** | **-0.203\*\*\*** | **-0.193\*\*\*** |
|  | **(-3.43)** | **(-3.19)** | **(-3.14)** |  | **(-3.15)** | **(-2.97)** | **(-2.78)** |
| *Courts×Post* | -0.046 | -0.055 | -0.043 |  | -0.063 | -0.057 | -0.045 |
|  | (-0.32) | (-0.39) | (-0.31) |  | (-0.46) | (-0.41) | (-0.32) |
| Firm-level Controls | No | Yes | Yes |  | No | Yes | Yes |
| State-level Controls | No | No | Yes |  | No | No | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| # of Observations | 8,263 | 8,263 | 8,263 |  | 8,263 | 8,263 | 8,263 |
| Adjusted R2 | 0.878 | 0.880 | 0.880 |  | 0.871 | 0.872 | 0.872 |

**Table 6 Channel Tests**

This table presents the channel tests for baseline results. We test whether firms with previous FCA lawsuits invest in green patents after the shocks (Panel A) and whether the decrease in toxic releases is indeed caused by increasing in green patents (Panel B). Our identification strategy relies on the firm’s previous FCA lawsuits with three shocks induced by US appeals courts. We build an estimation window of [-5,+5] for each shock and perform stacked difference-in-difference regressions. The dependent variable *Green Patents* is the number of green patents a company successfully filed to USPTO. The independent variable of interest is *Courts×Post×Case*. *Courts* takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Post* takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock. All control variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |
| --- | --- | --- | --- |
| **Panel A. Investment in Green Patents** | | | |
| Dependent Variable | ***Green Patentst+0*** | ***Green Patentst+1*** | ***Green Patentst+2*** |
| Variables | (1) | (2) | (3) |
| ***Courts×Post×Case*** | **0.997\*\*** | **0.679\*** | **0.271\*\*** |
|  | **(2.40)** | **(1.80)** | **(2.13)** |
| *Courts×Post* | 0.266 | 0.313 | 0.362 |
|  | (1.14) | (1.21) | (1.29) |
| Firm-level Controls | Yes | Yes | Yes |
| State-level Controls | Yes | Yes | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |
| # of Observations | 10,318 | 10,318 | 10,318 |
| Adjusted R2 | 0.835 | 0.838 | 0.50 |

**Table 7 Additional analysis**

This table presents the additional analysis for baseline results. The dependent variables *Pos\_Q (D\_Pos\_Q)* and *Neg\_Q (D\_Neg\_Q)* are the number of environmental questions (dummy variables of have or not have environmental questions) with a positive tone or negative tone. *Net\_Q* and *Net\_Q\_intensity* are two net tone measures to capture the overall optimism of analyst’s questions. The independent variable of interest is *Courts×Post×Case*. *Courts* takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Post* takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock. All control variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Panel A. Positive Tone** | | | | |
| Dependent Variable | ***Pos\_Q*** |  | ***D\_Pos\_Q*** |  |
| Variables | (1) | (2) | (4) | (5) |
| ***Courts×Post×Case*** | **0.277\*\*\*** | **0.276\*\*\*** | **0.277\*\*\*** | **0.276\*\*\*** |
|  | **(8.18)** | **(9.55)** | **(8.18)** | **(9.55)** |
| ***Courts×Post*** | 0.283 | 0.279 | 0.283 | 0.279 |
|  | (1.33) | (1.33) | (1.33) | (1.33) |
| Firm/State Controls | Yes | Yes | Yes | Yes |
| Cohort-Firm/Year FE | Yes | Yes | Yes | Yes |
| # of Observations | 2,931 | 2,931 | 2,931 | 2,931 |
| Adjusted R2 | 0.387 | 0.403 | 0.387 | 0.403 |
| **Panel B. Negative Tone** | | | | |
| Dependent Variable | ***Neg\_Q*** |  | ***D\_Pos\_Q*** |  |
| Variables | (1) | (2) | (3) | (4) |
| ***Courts×Post×Case*** | **0.051\*\*\*** | **0.052\*\*\*** | **0.051\*\*\*** | **0.052\*\*\*** |
|  | **(6.96)** | **(5.95)** | **(6.96)** | **(5.95)** |
| ***Courts×Post*** | 0.033 | 0.031 | 0.033 | 0.031 |
|  | (0.65) | (0.62) | (0.65) | (0.62) |
| Firm/State Controls | Yes | Yes | Yes | Yes |
| Cohort-Firm/Year FE | Yes | Yes | Yes | Yes |
| # of Observations | 2,931 | 2,931 | 2,931 | 2,931 |
| Adjusted R2 | 0.453 | 0.465 | 0.453 | 0.465 |
| **Panel C. Net Tone** | | | | |
| Dependent Variable | ***Net\_Q*** |  | ***Net\_Q\_intensity*** |  |
| Variables | (1) | (2) | (3) | (4) |
| ***Courts×Post×Case*** | **0.018\*** | **0.016\*** |  |  |
|  | **(1.96)** | **(1.72)** |  |  |
| ***Courts×Post*** | -0.103 | -0.126 | **0.699\*\*\*** | **0.734\*\*\*** |
|  | (-1.16) | (-1.43) | **(4.74)** | **(5.11)** |
| Firm/State Controls | Yes | Yes | Yes | Yes |
| Cohort-Firm/Year FE | Yes | Yes | Yes | Yes |
| # of Observations | 2,931 | 2,931 | 536 | 536 |
| Adjusted R2 | 0.387 | 0.403 | 0.387 | 0.403 |

**Table 8 Role of Monitoring**

This table presents the results of the role of monitoring. We split the observations into two groups based on the median of different monitoring proxies by each year. Our identification strategy relies on the firm’s previous FCA lawsuits with three shocks induced by US appeals courts. We build an estimation window of [-5,+5] for each shock and perform stacked difference- in-difference regressions. The dependent variable *Log(toxic releases)* and *Log(toxic releases/sale)* is the plants’ toxic release and release intensity obtained from EPA TRI datasets, and the independent variable of interest is *Courts×Post×Case*. *Courts* takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Post* takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock. *Institutional Holding* is the percentage of shares held by institutional investors. *HHI* and *TSIMM* are the product similarity proxies for market competition. All variables are defined in Appendix A. *Indus\_FCA* is the dummy variable of whether an industry is more exposed to FCA monitoring (Lee et al., 2024). The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Panel A. Institutional Investors (*Institutional Holding*)** | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  | ***Log(toxic releases/sale)*** | |
| Variables | (1) | (2) |  | (4) | (5) |
|  | High monitoring | Low monitoring |  | High monitoring | Low monitoring |
| ***Courts×Post×Case*** | **-0.176\*\*\*** | **-0.102\*\*\*** |  | **-0.126\*\*\*** | **-0.102\*\*\*** |
|  | **(-3.79)** | **(-5.04)** |  | **(-2.66)** | **(-4.98)** |
| *Courts×Post* | 0.012 | 0.087 |  | -0.004 | 0.043 |
|  | (0.08) | (0.49) |  | (-0.03) | (0.24) |
| Firm/State Controls | Yes | Yes |  | Yes | Yes |
| Cohort-Firm/Year FE | Yes | Yes |  | Yes | Yes |
| **[P-Value Test Differences]** | **<0.01** | |  | **<0.01** |  |
| # of Observations | 5,079 | 5,016 |  | 5,079 | 5,016 |
| Adjusted R2 | 0.902 | 0.885 |  | 0.891 | 0.871 |
| **Panel B. Market Competition (*HHI*)** | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  | ***Log(toxic releases/sale)*** | |
| Variables | (1) | (2) |  | (3) | (4) |
|  | High monitoring | Low monitoring |  | High monitoring | Low monitoring |
| ***Courts×Post×Case*** | **-0.158\*\*\*** | **-0.055** |  | **-0.154\*\*\*** | **0.041** |
|  | **(-3.02)** | **(-0.26)** |  | **(-3.25)** | **(0.19)** |
| *Courts×Post* | -0.018 | 0.083 |  | 0.016 | 0.041 |
|  | (-0.09) | (0.47) |  | (0.08) | (0.23) |
| Firm/State Controls | Yes | Yes |  | Yes | Yes |
| Cohort-Firm/Year FE | Yes | Yes |  | Yes | Yes |
| **[P-Value Test Differences]** | **<0.01** | |  | **<0.01** |  |
| # of Observations | 4,776 | 4,848 |  | 4,776 | 4,848 |
| Adjusted R2 | 0.907 | 0.869 |  | 0.894 | 0.861 |

**Table 8 Continued**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Panel C. Market Competition (*TSIMM*)** | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  | ***Log(toxic releases/sale)*** | |
| Variables | (1) | (2) |  | (4) | (5) |
|  | High monitoring | Low monitoring |  | High monitoring | Low monitoring |
| ***Courts×Post×Case*** | **-0.144\*\*\*** | **-0.097** |  | **-0.142\*\*\*** | **0.054** |
|  | **(-3.06)** | **(-0.47)** |  | **(-3.39)** | **(0.30)** |
| *Courts×Post* | -0.032 | 0.056 |  | 0.010 | -0.000 |
|  | (-0.14) | (0.34) |  | (0.04) | (-0.00) |
| Firm/State Controls | Yes | Yes |  | Yes | Yes |
| Cohort-Firm/Year FE | Yes | Yes |  | Yes | Yes |
| **[P-Value Test Differences]** | **<0.01** | |  | **<0.01** |  |
| # of Observations | 4,766 | 4,764 |  | 4,766 | 4,764 |
| Adjusted R2 | 0.905 | 0.864 |  | 0.893 | 0.857 |
| **Panel D. Industry monitoring (*Indus\_FCA*)** | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  | ***Log(toxic releases/sale)*** | |
| Variables | (1) | (2) |  | (3) | (4) |
|  | High monitoring | Low monitoring |  | High monitoring | Low monitoring |
| ***Courts×Post×Case*** | **-0.661\*\*\*** | **-0.130\*\*\*** |  | **-0.584\*\*\*** | **-0.116\*\*\*** |
|  | **(-5.02)** | **(-4.86)** |  | **(-4.59)** | **(-6.09)** |
| *Courts×Post* | 0.172 | 0.031 |  | 0.128 | 0.020 |
|  | (0.74) | (0.22) |  | (0.55) | (0.14) |
| Firm/State Controls | Yes | Yes |  | Yes | Yes |
| Cohort-Firm/Year FE | Yes | Yes |  | Yes | Yes |
| **[P-Value Test Differences]** | **<0.01** | |  | **<0.01** |  |
| # of Observations | 1,470 | 8,847 |  | 1,470 | 8,847 |
| Adjusted R2 | 0.887 | 0.882 |  | 0.852 | 0.872 |

**Table 9 Cross-sectional analysis of different types of whistleblowers**

This table presents the results of the cross-sectional heterogeneities for different types of whistleblowers. We split the observations into two groups based on the median of different whistleblower proxies by each year. Our identification strategy relies on the firm’s previous FCA lawsuits with three shocks induced by US appeals courts. We build an estimation window of [-5,+5] for each shock and perform stacked difference-in-difference regressions. *Short-seller Coverage* is the proportion of stocks held in the short position. *Analyst Coverage* is the number of financial analysts following the firm. *Audit Quality* is the number of audit fees divided by the total fees charged by the audit firm. All variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively. We include firm/state-level controls, and cohort-firm/year fixed effects in all the specifications.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Panel A. Short Sellers (*Short-seller Coverage*)** | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  | ***Log(toxic releases/sale)*** | |
| Variables | (1) | (2) |  | (4) | (5) |
|  | High coverage | Low coverage |  | High coverage | Low coverage |
| ***Courts×Post×Case*** | **-0.215\*\*\*** | **-0.124\*\*\*** |  | **-0.162\*\*\*** | **-0.123\*\*\*** |
|  | **(-4.21)** | **(-3.53)** |  | **(-3.11)** | **(-3.57)** |
| ***Courts×Post*** | 0.097 | 0.018 |  | 0.101 | -0.040 |
|  | (0.63) | (0.10) |  | (0.67) | (-0.24) |
| **[P-Value Test Differences]** | **<0.01** |  |  | **<0.01** |  |
| # of Observations | 5,048 | 4,957 |  | 5,048 | 4,957 |
| Adjusted R2 | 0.912 | 0.870 |  | 0.904 | 0.857 |
| **Panel B. Financial analysts (*Analyst Coverage*)** | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  | ***Log(toxic releases/sale)*** | |
| Variables | (1) | (2) |  | (3) | (4) |
|  | High coverage | Low coverage |  | High coverage | Low coverage |
| ***Courts×Post×Case*** | **-0.151\*\*\*** | **-0.151** |  | **-0.138\*\*\*** | **0.074** |
|  | **(-3.09)** | **(-0.60)** |  | **(-3.47)** | **(0.28)** |
| ***Courts×Post*** | -0.070 | 0.047 |  | -0.092 | 0.057 |
|  | (-0.36) | (0.22) |  | (-0.49) | (0.27) |
| **[P-Value Test Differences]** | **<0.01** |  |  | **<0.01** |  |
| # of Observations | 3,182 | 3,348 |  | 3,182 | 3,348 |
| Adjusted R2 | 0.906 | 0.872 |  | 0.906 | 0.860 |
| **Panel C. Auditors (*Audit Quality*)** | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  | ***Log(toxic releases/sale)*** | |
| Variables | (1) | (2) |  | (3) | (4) |
|  | High quality | Low quality |  | High quality | Low quality |
| ***Courts×Post×Case*** | **-0.150\*\*\*** | **0.117** |  | **-0.151\*\*\*** | **0.204** |
|  | **(-2.77)** | **(0.43)** |  | **(-2.97)** | **(0.75)** |
| ***Courts×Post*** | -0.026 | 0.082 |  | -0.055 | 0.102 |
|  | (-0.13) | (0.41) |  | (-0.28) | (0.51) |
| **[P-Value Test Differences]** | **<0.01** |  |  | **<0.01** |  |
| # of Observations | 2,430 | 2,440 |  | 2,430 | 2,440 |
| Adjusted R2 | 0.924 | 0.914 |  | 0.910 | 0.908 |

**Appendix A. Variable Definition**

**Variable Definition (Compustat data in parentheses) Source**

***Pollution variables***

*Log(toxic releases)* ***The log transformation*** of firm-level total toxic releases

following Hsu et al. (2023)

*Log((toxic releases/sale)* ***The log transformation*** of firm-level total toxic releases divided

by total sales (sale)

*EPA TRI EPA TRI*

*State Emissions* ***The log transformation*** of state-level total toxic releases *EPA TRI State Onetime Release* ***The log transformation*** of state-level one-time releases *EPA TRI* ***False Claims Act Variables***

*Case* ***The number*** of previous FCA lawsuits before each shock *US DOJ*

*Case\_pseudo* ***The number*** of randomly generated pseudo FCA lawsuits before

each shock (same statistical distribution as real lawsuits)

*Courts* ***An indicator*** takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise.

*Post* ***An indicator*** takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise

*Postt+k* ***An indicator*** takes the value of 1 if the observation is k years after the relevant court rulings and zero otherwise

*Postt-k* ***An indicator*** takes the value of 1 if the observation is k years before the relevant court rulings and zero otherwise

*Own calculation Own calculation*

*Own calculation Own calculation Own calculation*

***Firm Characteristics***

*Institutional Holding* Percentage of shares held by institutional investors *13F Tangibility* Tangible assets (ppent) divided by total assets (at) *COMPUSTAT I/K* Capital expenditures (capx) divided by tangible assets (ppent) *COMPUSTAT*

*ROA* Return on assets (ni/lag(at)) *COMPUSTAT*

*Leverage* Leverage for the firm ( (dlc+dltt)/at) *COMPUSTAT*

*Size* Log transformation of total assets (at) *COMPUSTAT*

*M/B* Natural log of market value (csho\*prcc\_f) divided by book value (ceq)

*COMPUSTAT*

*Cash/Liability* Cash (ch) to liability (lt) ratio *COMPUSTAT*

*Dividend* Leverage for a firm ( (dlc+dltt)/at) *COMPUSTAT*

*AltmanZ* Altman’s Z-score calculated as 3.3\*(ebit/at) + 0.99\*(sale/at) + 0.6\*(prcc\_f\*csho/lt) + 1.2\*(wcap/at) + 1.4\*(re/at)

*COMPUSTAT*

*Firm Age* The number of years listed on the stock exchange *COMPUSTAT*

*ICW\_SOX* The number of internal control weaknesses disclosed in SOX Section 404

*ICW\_Doyle* The fitted values obtained from the following model, as estimated by Doyle et al. (2007):

Internal Control Weakness = b0 + b1\*Size + b2\*log(Firm Age)

+ b3\*Losses + b4\*Segments + b5\*Foreign Trans + b6\*Extreme SG + b7\*Restructure + error.

Size and Firm Age are already defined above, Losses is an indicator variable equal to 1 if earnings before extraordinary items in the two most recent years sum to less than zero, and 0 otherwise, Segments is the log of the number of operating and geographic segments reported by the Compustat Segments database, Foreign Trans is an indicator variable equal to 1 if the firm has nonzero foreign translation, and 0 otherwise, Extreme SG is an indicator variable equal to 1 if year-over-year industry- adjusted sales growth falls into the top quintile, and 0 otherwise, Restructure is the aggregate restructuring charge in the two most recent years, scaled by the firm's market capitalization.

***Channel Tests & Cross-sectional Analysis Variables***

*Audit Analytics*

*COMPUSTAT*

*Green Patents* The number of green patents filed in a year *KPSS (2017)*

|  |  |  |
| --- | --- | --- |
| *Green Patents/log(mv)* | The number of green patents filed in a year divided by log  transformation of market value | *KPSS (2017)* |
| *Green Patents/log(at)* | The number of green patents filed in a year divided by the log  transformation of total assets | *KPSS (2017)* |
| *HHI* | The HH Index to proxy for market competition | *Hoberg and Phillip (2016)* |
| *TSIMM* | The product similarity to proxy for market competition | *Hoberg and Phillip (2016)* |
| *Indus\_FCA* | The industry exposed to more FCA monitoring | *Lee et al. (2024)* |
| *Pos\_Q (D\_Pos\_Q)* | the number of environmental questions (dummy variable of have or not have environmental questions) with a positive tone that  analysts asked in the conference call. | *Own calculation* |
| *Neg\_Q (D\_Neg\_Q)* | the number of environmental questions (dummy variable of have or not have environmental questions) with a negative tone that  analysts asked in the conference call. | *Own calculation* |
| *Net\_Q* | *Pos\_Q-Pos\_Q* | *Own calculation* |
| *Net\_Q\_intensity* | *(Pos\_Q-Pos\_Q)/(Pos\_Q+Pos\_Q)* |  |
| *Short-seller Coverage* | The proportional of stocks held in the short position | *COMPUSTAT* |
| *Analyst Coverage* | The number of financial analysts following the firm | *I/B/E/S* |
| *Audit Quality* | The number of audit fees divided by the total fees charged by the  audit firm | *Audit Analytics* |
| *High Polluting* | The high-polluting industries are based on the classification  from the Commission for Environmental Cooperation (CEC). | *CEC* |
| ***Other variables*** |  |  |
| *State False Claims Acts* | An indicator takes the value of 1 if the firm is located in states that promulgate their general False Claim Acts and zero  otherwise. | *COMPUSTAT* |
| *GDP per Capita* | State-level Growth Domestic production per capita | *COMPUSTAT* |
| *GDP Growth* | State-level GDP Growth | *COMPUSTAT* |
| *Political Balance* | State political balance | *COMPUSTAT* |

**Appendix B. Other Robustness Checks**

**Table 1 Robustness Checks (different time windows)**

This table presents the robustness test of the baseline results in Table 2 using a shorter time window [-3,+3] (Panel A) and a sample without the period of global financial crisis (Panel B). Our identification strategy relies on the firm’s previous FCA lawsuits with three shocks induced by US appeals courts. The dependent variable *Log(toxic releases)* and *Log(toxic releases/sale)* is the plants’ toxic release and release intensity obtained from EPA TRI datasets, and the independent variable of interest is *Courts×Post×Case*. *Courts* takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Post* takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock. All control variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Panel A. Shorter Time Window** | | | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | | |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts×Post×Case*** | **-0.174\*\*\*** | **-0.171\*\*\*** | **-0.173\*\*\*** |  | **-0.164\*\*\*** | **-0.143\*\*\*** | **-0.144\*\*\*** |
|  | **(-6.99)** | **(-6.79)** | **(-6.82)** |  | **(-6.25)** | **(-4.75)** | **(-4.82)** |
| *Courts×Post* | -0.009 | -0.018 | -0.015 |  | -0.048 | -0.029 | -0.026 |
|  | (-0.08) | (-0.16) | (-0.13) |  | (-0.45) | (-0.26) | (-0.24) |
| Firm-level Controls | No | Yes | Yes |  | No | Yes | Yes |
| State-level Controls | No | No | Yes |  | No | No | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| # of Observations | 6,960 | 6,960 | 6,960 |  | 6,960 | 6,960 | 6,960 |
| Adjusted R2 | 0.908 | 0.909 | 0.909 |  | 0.898 | 0.899 | 0.899 |
| **Panel B. Drop the period with the global financial crisis.** | | | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | | |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts×Post×Case*** | **-0.218\*\*\*** | **-0.219\*\*\*** | **-0.219\*\*\*** |  | **-0.184\*\*\*** | **-0.166\*\*\*** | **-0.165\*\*\*** |
|  | **(-4.72)** | **(-4.66)** | **(-4.63)** |  | **(-4.76)** | **(-3.53)** | **(-3.51)** |
| *Courts×Post* | 0.131 | 0.118 | 0.132 |  | 0.122 | 0.128 | 0.142 |
|  | (0.84) | (0.75) | (0.83) |  | (0.80) | (0.83) | (0.91) |
| Firm-level Controls | No | Yes | Yes |  | No | Yes | Yes |
| State-level Controls | No | No | Yes |  | No | No | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| # of Observations | 7,447 | 7,447 | 7,447 |  | 7,447 | 7,447 | 7,447 |
| Adjusted R2 | 0.868 | 0.869 | 0.869 |  | 0.868 | 0.869 | 0.869 |

**Table 2 Other Robustness Checks**

This table presents the robustness test of the baseline results in Table 2 using a sample without relocated firms (Panel A), falsification tests with pseudo FCA Cases (Panel B) and a baseline test with state-by-year FE (Panel C). We build an estimation window of [-5,+5] for each shock and perform stacked difference-in-difference regressions. Variable definitions are reported in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* ,

\*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Panel A. Drop Relocated Firms** | | | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | |  |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts×Post×Case*** | **-0.140\*\*\*** | **-0.139\*\*\*** | **-0.140\*\*\*** |  | **-0.141\*\*\*** | **-0.138\*\*\*** | **-0.139\*\*\*** |
|  | **(-3.04)** | **(-3.22)** | **(-3.23)** |  | **(-3.94)** | **(-3.46)** | **(-3.46)** |
| *Courts×Post* | 0.045 | 0.038 | 0.046 |  | -0.007 | 0.024 | 0.030 |
|  | (0.33) | (0.28) | (0.34) |  | (-0.05) | (0.18) | (0.23) |
| Firm-level Controls | No | Yes | Yes |  | No | Yes | Yes |
| State-level Controls | No | No | Yes |  | No | No | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| # of Observations | 9,254 | 9,254 | 9,254 |  | 9,254 | 9,254 | 9,254 |
| Adjusted R2 | 0.879 | 0.881 | 0.881 |  | 0.866 | 0.867 | 0.867 |
| **Panel B. Falsification test with pseudo FCA Cases** | | | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | |  |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts×Post×Case\_pseudo*** | 0.018 | -0.013 | -0.014 |  | -0.066 | -0.023 | -0.025 |
|  | (0.34) | (-0.23) | (-0.24) |  | (-0.96) | (-0.41) | (-0.44) |
| *Courts×Post* | 0.007 | 0.008 | 0.016 |  | -0.013 | 0.002 | 0.009 |
|  | (0.06) | (0.07) | (0.13) |  | (-0.10) | (0.01) | (0.07) |
| Firm-level Controls | No | Yes | Yes |  | No | Yes | Yes |
| State-level Controls | No | No | Yes |  | No | No | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| # of Observations | 10,386 | 10,386 | 10,386 |  | 10,386 | 10,386 | 10,386 |
| Adjusted R2 | 0.883 | 0.884 | 0.884 |  | 0.869 | 0.871 | 0.871 |
| **Panel C. Baseline test with State-by-year FE** | | | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | |  |
| Variables | (1) |  | (2) |  | (3) |  | (4) |
| ***Courts×Post×Case*** | **-0.093\*\*** | **-0.094\*\*\*** | |  | **-0.094\*\*\*** | **-0.084\*\*** | |
|  | **(-2.53)** | **(-2.66)** | |  | **(-2.90)** | **(-2.39)** | |
| Firm-level Controls | No |  | Yes |  | No | Yes | |
| Cohort-Firm FE | Yes |  | Yes |  | Yes | Yes | |
| Cohort-State-by-Year FE | Yes |  | Yes |  | Yes | Yes | |
| # of Observations | 10,271 | 10,271 | |  | 10,271 | 10,271 | |
| Adjusted R2 | 0.892 |  | 0.894 |  | 0.879 | 0.881 | |

**Table 3 Control for Internal Whistleblowing**

This table presents the baseline results with additional controls of internal whistleblowing. We follow Doyle et al. (2007), Call et al. (2016), and Heese et al. (2021) and use ***internal control weakness*** to proxy for the effectiveness of internal whistleblowing. Our identification strategy relies on the firm’s previous FCA lawsuits with three shocks induced by US appeals courts. We build an estimation window of [-5,+5] for each shock and perform stacked difference-in-difference regressions. The dependent variable *Log(toxic releases)* and *Log(toxic releases/sale)* is the plants’ toxic release and release intensity obtained from EPA TRI datasets, and the independent variable of interest is *Courts×Post×Case*. *Courts* takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Post* takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock. All control variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Panel A. SOX Section 404 Measure** | | | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | | |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts×Post×Case*** | **-0.123\*\*\*** | **-0.121\*\*\*** | **-0.121\*\*\*** |  | **-0.128\*\*\*** | **-0.120\*\*\*** | **-0.120\*\*\*** |
|  | **(-2.66)** | **(-2.97)** | **(-2.97)** |  | **(-3.33)** | **(-3.13)** | **(-3.13)** |
| *Courts×Post* | -0.178 | -0.167 | -0.171 |  | -0.257 | -0.213 | -0.220 |
|  | (-0.97) | (-0.95) | (-0.97) |  | (-1.46) | (-1.22) | (-1.26) |
| ICW\_SOX | -0.082 | -0.048 | -0.047 |  | -0.096 | -0.112 | -0.111 |
|  | (-0.57) | (-0.36) | (-0.35) |  | (-0.74) | (-0.83) | (-0.82) |
| Firm-level Controls | No | Yes | Yes |  | No | Yes | Yes |
| State-level Controls | No | No | Yes |  | No | No | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| # of Observations | 2,939 | 2,939 | 2,939 |  | 2,939 | 2,939 | 2,939 |
| Adjusted R2 | 0.916 | 0.919 | 0.919 |  | 0.909 | 0.910 | 0.910 |
| **Panel B. Doyle et al. (2007) Measure** | | | | | | | |
| Dependent Variable | ***Log(toxic releases)*** | |  |  | ***Log(toxic releases/sale)*** | | |
| Variables | (1) | (2) | (3) |  | (4) | (5) | (6) |
| ***Courts×Post×Case*** | **-0.158\*\*\*** | **-0.155\*\*\*** | **-0.155\*\*\*** |  | **-0.153\*\*\*** | **-0.141\*\*\*** | **-0.141\*\*\*** |
|  | **(-3.36)** | **(-3.56)** | **(-3.58)** |  | **(-4.59)** | **(-4.06)** | **(-4.10)** |
| *Courts×Post* | 0.027 | 0.025 | 0.033 |  | -0.004 | 0.014 | 0.023 |
|  | (0.22) | (0.21) | (0.27) |  | (-0.04) | (0.12) | (0.19) |
| ICW\_Doyle | -0.075\*\*\* | 0.006 | 0.005 |  | 0.023 | -0.027 | -0.027 |
|  | (-2.94) | (0.30) | (0.25) |  | (0.95) | (-1.10) | (-1.14) |
| Firm-level Controls | No | Yes | Yes |  | No | Yes | Yes |
| State-level Controls | No | No | Yes |  | No | No | Yes |
| Cohort-Firm FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| Cohort-Year FE | Yes | Yes | Yes |  | Yes | Yes | Yes |
| # of Observations | 10,364 | 10,364 | 10,364 |  | 10,364 | 10,364 | 10,364 |
| Adjusted R2 | 0.883 | 0.884 | 0.884 |  | 0.869 | 0.872 | 0.872 |

**Table 4 Further Identification**

This table presents the baseline results of whether previous whistleblowing experience affects corporate environmental performance. We split the observations into high/low polluting groups based on their industries. Our identification strategy relies on the firm’s previous FCA lawsuits with three shocks induced by US appeals courts. We build an estimation window of [-5,+5] for each shock and perform stacked difference-in-difference regressions. The dependent variable *Log(toxic releases)* and *Log(toxic releases/sale)* is the plants’ toxic release and release intensity obtained from EPA TRI datasets, and the independent variable of interest is *Courts×Post×Case*. *Courts* takes the value of 1 if the plant is located in states which have been affected by the court rulings that increase the financial incentives for whistleblowers and zero otherwise. *Post* takes the value of 1 if the observation is in the period after the relevant court rulings and zero otherwise. *Case* is the number of previous FCA lawsuits before each shock. *High Polluting* industries are based on the classification from the Commission for Environmental Cooperation (CEC). All control variables are defined in Appendix A. The numbers reported in parentheses are t-statistics based on the standard errors clustered at the firm level. \* , \*\*, \*\*\* denote statistical significance at the 10%, 5% and 1%, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Dependent Variable | ***Log(toxic releases)*** | |  | ***Log(toxic releases/sale)*** | |
| Variables | (1) | (2) |  | (3) | (4) |
|  | High polluting | Low polluting |  | High polluting | Low polluting |
| ***Courts×Post×Case*** | **-0.504\*\*\*** | **-0.138\*\*\*** |  | **-0.443\*\*\*** | **-0.130\*\*\*** |
|  | **(-5.55)** | **(-5.48)** |  | **(-4.69)** | **(-5.79)** |
| ***Courts×Post*** | 0.037 | 0.084 |  | 0.026 | 0.066 |
|  | (0.22) | (0.48) |  | (0.16) | (0.37) |
| Firm-level Controls | Yes | Yes |  | Yes | Yes |
| State-level Controls | Yes | Yes |  | Yes | Yes |
| Cohort-Firm FE | Yes | Yes |  | Yes | Yes |
| Cohort-Year FE | Yes | Yes |  | Yes | Yes |
| **[P-Value Test Differences]** | **<0.01** |  |  | **<0.01** |  |
| # of Observations | 6,062 | 4,256 |  | 6,062 | 4,256 |
| Adjusted R2 | 0.890 | 0.868 |  | 0.877 | 0.858 |

**Appendix C. Matching the FCA cases with Compustat Firms.**

I manually match over 9,000 FCA cases from 1987-2013 to Compustat listed firms. My manual matching follows three steps. Firstly, I manually extract each defendant’s name (focusing on the companies but not individual persons) from the case caption. Secondly, I manually check each defendant company’s name using Google. I look at the history of each company to determine if it has ever changed its name or been acquired. Finally, I use the Compustat North America company code lookup tool from Wharton Research Data Service (WRDS) to search for the company name that I had extracted and checked through the first two steps. When searching for names, I simultaneously remove all punctuation marks and delete corporate designators, such as “Corporation,” “Company,” “INC,” or “LLC,” If it yields a result, I will then assign the unique GVKEY identifier to that case; if there is no result I will then search for the old name or the parent company’s name of the defendant company in the company code lookup tool. I repeat these three steps for each FCA case.

Then, I will use an example to illustrate how these steps work. In the case “***US ex rel Goodstein, David v Kaplan Inc; Washington Post Co (2007)***”, I first extract two defendant’s names: Kaplan Inc and Washington Post Co. Secondly, I utilize Google to search for “Kaplan Inc” and find that it is now a wholly-owned subsidiary of Graham Holdings Company. I then search for “Washington Post Co.” and find that it changed its name to Graham Holdings Company in 2013. Finally, I use the company code lookup tool in Compustat North America provided by WRDS. I first search for “Kaplan” in the tool and it yields two results: one is “KAPLAN INDUSTRIES INC” and another is “LAZARE KAPLAN INTERNATIONAL.”

However, these two companies are not Kaplan Inc., an education company, which I am targeting since I check their names using Google and find that “KAPLAN INDUSTRIES INC” produces compressed gas cylinders and equipment, and“LAZARE KAPLAN INTERNATIONAL” is a diamond manufacturing company. Thus, my first search yields no effective result. Then I search for “Graham Holdings” in the company code lookup tool and it only yields one result: GRAHAM HOLDINGS CO, which is the parent company of Kaplan I am looking for. Therefore, I assign the GVKEY—011300 to the case ***US ex rel Goodstein, David v Kaplan Inc; Washington Post Co (2007)***.

**Mapping Supply Chain Shifts under Widespread Supply Chain Risks Taking the Global Battery Industry as An Example**

1. **Introduction**

The global-level exchanges of raw materials, manufactured goods, and information are highly intertwined (Fan et al., 2024). Multiple factors, including the rapid development of emerging technologies and digital technologies, geopolitical uncertainties (e.g. trade protectionism and nationalism), natural disasters (e.g. earthquakes and tsunamis), and large- scale outbreaks such as the COVID-19 pandemic, result in supply chain disruptions (Cajal- Grossi et al., 2023). Supply chain disruptions, such as semiconductors and some critical raw materials, happen from time to time, combined with demand adjustments in different periods. Such disruptions raise both scholars’ and enterprises’ attention to the effective management of inventory and suppliers (MacCarthy et al., 2022).

Therefore, knowing what happened and what is changing in the global supply chain is a prerequisite for multinational corporations and governments to discover the potential supply chain risks and improve industrial practice. The main objective of this research is to integrate the efficient supply chain information among the upstream and downstream suppliers to generate supply chain maps based on different time points by the supply chain mapping method (Culot et al., 2022). However, research related to drawing a supply chain map mainly focused on particular companies or products on a small scale, such as in a short time period or only obtaining first-tier suppliers. The large-scale buyer-supplier relationship network is limited in access and presence because of the difficulty of obtaining multi-tier supplier relationship data (Culot et al., 2022; Dong et al., 2024; Liu & Zhang, 2014). Another characteristic that troubles researchers in mapping the global supply chain is that today’s global supply chain is more transient and intricate, which increases the difficulty of constructing a supply chain map and updating such a map regularly.

While past research related to the supply chain level could only present a static supply chain map by a certain time, this research addresses this gap by presenting the dynamic supply chain network using the buyer-supplier relationship data, with the starting date and ending date of the relationship, over eight continual years, from 2017 to 2024. Despite the high unavailability of the multi-tier supplier data, this study aims to improve the accuracy of the buyer-supplier network by the material/good flow to enhance supply chain transparency and visibility and to propose a method to construct a dynamic global supply chain network in a particular industry. Industries previously selected by supply chain mapping are primarily concentrated in the clothing, vehicle, and energy industries because they are relatively less volatile in the supply chain contribution. However, the battery industry is more volatile since the technology is not tech-intensive, which could be adjusted timely according to the national industrial development. For example, the U.S. announced a $1 billion US battery plant plan to reduce reliance on China in October 2024.

Therefore, this study will mainly concentrate on two aims. First, the construction of the global supply chain, specifically in the lithium-ion battery industry. Second, discover changes at the supply chain level. Changes will be carried on from geographical changes, network changes, ownership changes, structural changes, and technological/knowledge changes. These dimensions could help better explore the underlying mechanisms in the global supply chain.

Research Questions are as follows:

1. What is the configuration of the global battery supply chain in different years?
2. What are the changes in the battery supply chain after 2020?

Supply chains are increasingly seen as networks, which is a complex adaptive system (Ivanov & Dolgui, 2020). Normally, the complete upstream and downstream information are difficult to collect and compile. This research will mainly choose the supply chain mapping method. This method could improve the visibility and transparency of the supply chain and learn about the reasons for supply chain disruptions.

This research will provide three meaningful contributions. Firstly, it improves the method of large-scale, multi-tier supply chain relationships by using the secondary data obtained by the FactSet Reserve Database. Secondly, instead of analyzing the supply chain configuration at a particular time, this research applies the dynamic supply chain management perspective, which could identify transient changes happening in the supply chain. Thirdly, this study chooses the lithium-ion battery industry to test the changes, offering insights for multinational enterprises and policymakers to mitigate risks associated with unexpected situations and plan ahead.

The structure of this paper is as follows. In the second section, I will explain what is supply chain mapping. Then, I develop a theoretical framework for supply chain changes. In the third section, I detail the method, dataset and company this research chooses. In the fourth section, I present the expected empirical results.

1. **Literature Review**
   1. **Supply Chain Mapping**
      1. *The Definition of Supply Chain Mapping*

Supply chain mapping is defined as the linking of activities and actors in the supply chain. Supply chain mapping looks at the whole chain as a whole, including the flow of products and other information such as transaction volume, the starting and ending date of the buyer-supplier relationship, the company’s geographical location, etc. (Ivanov & Dolgui, 2020; Kusi-Sarpong et al., 2022). It is a simplified yet accurate map, in which supply network relationships, flows, and dynamics are captured (Theodore Farris, 2010). In short, supply chain mapping provides visibility of the network that links suppliers and customers together and helps organizations make operation decisions.

The supply chain map contains three parts inside the supply chain: upstream, midstream, and downstream supply chain. Upstream SC represents the network of a firm’s suppliers and sub-suppliers. Midstream SC refers to all activities and processes that are performed within the company to convert the raw material to a value-added product. Whereas downstream SC refers to the coordination of the flow of information and goods with clients and customers (Mubarik et al., 2023).

Scholars and firms map the supply chain according to their research questions. For example, Roy (2011) focused on the key stages of production, lead times, transportation modes, and inventory points of three focal firms (a wine producer, an olive grower, and a job shop manufacturer) in New Zealand, while De Marchi and Di Maria, (2019) mapped the leather industries’ global value chain that investigates the role of buyers in supporting environmental upgrading of suppliers’ products and processes. The advantage of the supply chain mapping

method is that it can provide a valuable vision of the whole supply chain and offer some insights on key elements or key processes of the supply chain, encouraging firms and countries to prepare ahead before the happening of supply chain risk and buffer supply chain disruptions.

* + 1. *Why do supply chain mapping*

Previous literature concluded four aspects to do the supply chain mapping, including the intensified supply chain risks, technological improvement and digitalization, environmental protection requirements, and country-level policy and geopolitical factors.

1. Widespread risks in the global supply chain

Today’s global supply chain is highly intertwined and has multiple production stages. A single move affects the entire system. While most literature from the 2000s and 2010s analyzed the global supply chain under a low-tariff and relatively stable environment, the global supply chain after 2015 has faced huge challenges, such as unexpected natural disasters and epidemic situations, which increase the uncertainty of the global supply chain (MacCarthy et al., 2022; Simchi-Levi et al., 2015; Van Den Brink et al., 2020). Supply chain risks are prevalent, becoming a more pressing problem in supply chain management.

1. Technological improvement and digitalization

Digitalization and emerging technologies, such as Digital Twins, the Internet of Things, and Blockchain, have dramatically changed the configuration, management and control of the supply chain. The advent of digital technologies has opened up opportunities for companies to gather large volumes of data alongside the upstream and downstream suppliers and goods to make better decisions (Bansal et al., 2020).

1. Environmental protection requirements and sustainability goals

Sustainable development strategies, such as the low-carbon 2050 strategy, are a dominant concern for contemporary operation management. On the one side, companies and suppliers are mostly profit-oriented and do not pay too much attention to sustainable production and their suppliers’ suppliers. Based on a survey by MIT and CSCMP (2020), 35% of 1128 supply chain professionals don’t know about their Environmental, Social and Governance (ESG) goals. They have a weak understanding of supply chain transparency and sustainability (Gualandris et al., 2021). On the other side, customers and investors are eager to obtain more information about the upstream and downstream of the supply chain before they purchase and invest in the products of the company (MacCarthy et al., 2022). Therefore, it puts forward higher requirements for the transparency of the total supply chain.

1. Country-level policies and geopolitical tensions

Geopolitical tensions and corresponding industrial policies improve the vulnerability of the global supply chain. Due to the intensified global geopolitical conflicts, some countries, led by the U.S., started to implement trade protectionism and technological blockade in order to ensure their own autonomy in key products, decrease the export dependency on other countries, and increase the competitiveness of their enterprises in the domestic and international markets. For example, based on the aggregate level of trade data, China’s share of US goods imports peaked at 21.6% in 2017. But China’s share of US goods imports experienced a sudden drop to 16.5% because of the US government trade limitation starting from 2018 (Alfaro & Chor, 2023). After the COVID-19 pandemic and the trade war between China and the US, supply shortages in the global supply chains happened from time to time

(Alfaro & Chor, 2023; Goldberg & Reed, 2023). One classical example is that during the trade war between China and the US, the supply chain for semiconductors was severely impacted, resulting in a global shortage of chip manufacturers and related products. Another example is that the Russia-Ukraine conflict resulted in the energy supply crisis in the West countries. They need to search for alternative energy. Before countries formulate appropriate policies, they need to have a clear view of the configuration of the global supply chain.

* + 1. *Relative Methods to Do Supply Chain Mapping and Their Advantages and Disadvantages*

In order to get an objective and comprehensive understanding of the global supply chain, scholars adopted different ways to collect supply chain data to analyze. The data to collect depends on the purpose of supply chain mapping.

Wichmann et al. (2020) tried to use Deep Learning and Natural Language Processes (NLP) to extract individual buyer-supplier relations automatedly from the Web (unstructured text). Although machine learning could decrease the workload by manpower, it still has many disadvantages that should be improved later. First, researchers have to construct a large-scale corpus that covers all the suppliers’ and supply-relationship-related keywords before using the machine learning method to identify supplier-buyer relationships. Second, incorrect information may be mixed in the large volume of data on the website, which may decrease the accuracy and reliability of the research result. Third, this method may have severe information missing. Although researchers like Wichmann could extract buyer-supplier relationships from the unstructured texts, other essential information, such as the good to supply, the volume to supply, and the starting date and the ending date of the supply, may be lacking. This may influence the quality of the analysis.

Different from Wichmann et al.(2020) who collected unstructured text data, Van Den Brink et al. (2020) combined country-level mining data with individual-level mining data to get the supplier data because in the raw material industry, mines are the key suppliers. The country-level mining data came from the British Geological Survey and the United States Geological Survey. Scholars applied an online global overview of cobalt deposits, company reports, a list of cobalt-producing mines, research reports, media articles, and related websites to collect the individual cobalt mines. Therefore, scholars could find potential supply chain risks in the supplier dataset.

Besides, in some complex supply chains, scholars distinguished key segments (up, mid, and downstream) by-product codes (Caravella et al., 2024).

Finally, MacCarthy et al. (2022) concluded that there are two kinds of data to collect: primary data and secondary data. Primary data usually collects interview data, direct observation, company reports, and firms’ information systems (ERP systems). Secondary data has usually been applied at a macro level, such as the global value chain level, industry level, and country level. Industrial and country-level data can be accessed from a number of national and international organizations. Among them, UN ComTrade offers monthly international trade data and some specific trade data with products. But the limitation of this dataset is that it cannot link the suppliers and buyers together. To solve this problem, Culot et al. (2022) provide a detailed analysis of the secondary database to use to collect the firm-level supply chain relationships. Bloomberg SPLC, FactSet Supply Chain Relationships, and

Mergent Supply Chain offer superior coverage and data quality compared to CompuStat and Mergent (Dong et al., 2024). All three databases allow users to search by firm name or ticker (i.e., the unique identifier assigned to each publicly traded stock). Information on direct suppliers, customers, and competitors is provided. However, supply chain mapping by using firm-level data is still in the beginning stage. In this research, I will mainly investigate the multi-level buyer-supplier relationship, including upstream suppliers and downstream suppliers.

* 1. **Potential Supply Chain Changes from Supply Chain Mapping**

Past literature proved that supply chain structure tends to minor change in the short term (Osadchiy et al., 2016). However, when and how the supply chain changes are still in the early stage of supply chain management literature. Therefore, this research tends to explore global supply chain changes from a dynamic perspective. Based on the above research question, a theoretical framework for changes in the global supply chain is presented below.

Based on the previous studies, this research identified global supply chain changes in five different aspects, including geographical changes (Alfaro & Chor, 2023; Braun et al., 2023; Goldberg & Reed, 2023; Gong, Hassink, Foster, et al., 2022), network changes (Durach et al., 2024; Fan et al., 2024), ownership changes (Antràs, 2020), technological and knowledge changes (Barrientos et al., 2011; Gereffi et al., 2019), and structural changes (Antràs & Chor, 2018).

|  |  |  |  |
| --- | --- | --- | --- |
| **External changes** | | | |
| No. | Types of Change | Possible manifestations | Measurements |
| 1. | Geographical Changes | Reshoring, nearshoring,  friendshoring, FDI flows at a country level | The whole chain suppliers’ country distribution  in different years; the change in FDI flows from National Bureau of Statistics |
| 2. | Network Changes | Companies in the supply chain may have different suppliers and  customers | The number and density of the network; the duration of buyer-supplier relationship |
| **Internal changes** | | | |
| 3. | Ownership  Changes | The change in company’s ownership  from one country to another | The ownership changes from one country to  another |
| 4. | Structural Changes | Vertical integration | The length of supply chain related to the  company |
| 5. | Technological/ knowledge Changes | Upgrading and downgrading | The comparison position in the global supply  chains |
| FDI flows at a firm level | FDI flows got from financial statements |
| Research output | R&D output got from financial statements |
| Patent (number, forward citation) | The application date and forward citations from  the Worldwide Patent Statistical Database (Patstat) |

*Table 1. The theoretical framework of global supply chain changes*

This research tries to identify the difference between external and internal changes.

External changes refer to the supply chain changes outside the organization. Therefore, the measurement of the external changes will focus on the upstream and downstream suppliers of the focal company to get an overview of the transformation of the supply chain in one specific industry. Internal changes refer to the supply chain changes within the organization. It will focus on the ownership changes, upgrading, and vertical integration.

1. Geographical Changes

In recent years, the geographical location of manufacturers has changed frequently. Past scholars have classified these phenomena into three dimensions: reshoring, nearshoring, and friendshoring. Reshoring refers to the supply chain returning to the consumer countries instead of outsourcing to other countries. Based on the research of Gong et al. (2022), the US reshored their core industries, such as the aerospace and medical industry, from China to the US to decrease the trade dependency of China and guard its supply chain safety. Nearshoring refers to companies moving their suppliers to countries near the mainland (Braun et al., 2023). Based on the survey of IBM Global Locations Trends 2020, they found that 40% of respondents thought that the trend of nearshoring would increase. Accordingly, Alfaro & Chor (2024) discovered that the US moved its supply chain from China to Mexico based on the export trade data. Friendshoring refers to the change of manufacturers to places near the consumer country. For example, the US moved its supply chain from China to Mexico after 2021 (Alfaro & Chor, 2023).

Geographical changes are mainly influenced by market demand, political environment, local institutions and trade policy (Alfaro & Chor, 2023; Gereffi et al., 2019). However, most of the past research was based on the research on the tendency of executives of multinational enterprises by researchers’ surveys. There is no actual evidence to show such migration in the supply chain and why they change. Besides, researchers know little about the period for enterprises to adjust their suppliers and the adjustment of geopolitical range. Are they adjusting within a country level or choosing other countries’ suppliers (Gualandris et al., 2021)?

This study will be based on three focal companies to collect lists of upstream and downstream companies in the battery industry, along with their suppliers, to determine the geographical changes of suppliers across the entire industry from a macro perspective. Besides, country-level inward and outward foreign domestic investment (FDI) flows could help learn the degree of geographical changes as building factories locally is highly related to FDI (Alfaro & Chor, 2023; Antràs, 2020). FDI can be observed in the outward and inward FDI data of every country (Antràs, 2020; Goldberg & Reed, 2023).

1. Network Changes

Buyers and suppliers are interdependent to acquire critical resources to ensure business continuity and long-term survival. The supply chain uncertainty happens when an external party exerts huge control over the resources and there are limited alternatives available. Therefore, knowing the upstream and downstream suppliers’ network could help identify relevant suppliers. The supplier-buyer network changes refer to the adjustment of industrial upstream and downstream supplier relationships. Network changes could reflect the cooperation level between companies and the duration of the network. Scholars used the network analysis method to know what are the critical nodes, that is suppliers, in the global supply chain and whether such critical suppliers change in different years or keep stable. Another application of network changes is using the number of suppliers to estimate its supply chain heterogeneity.

Previous scholars have proved that the supplier’s network change has a positive relationship with technological level, cost, local policy and institute, policy environment, and market demand (BRINZA et al., 2024; Gong, Hassink, Foster, et al., 2022; Gong, Hassink, & Wang, 2022).

This study will use three focal companies’ supplier networks as the main network, measuring the number of links to the focal company, the core of the network, and the density of the network in different years to investigate the cooperation level and degree among companies and countries. Also, I will measure the duration of the supply chain relationship to measure the resilience of the supply chain.

1. Ownership Changes

The change in a company’s ownership from one country to another may be led by the trade policy, policy environment, and the strategy of the company (Carbonara et al., 2002). For example, after the trade war between China and the US, the trade barrier was increased between China and the US. In 2019, Ningbo Jifeng Auto Parts Co., a Chinese automotive parts manufacturer, acquired a controlling stake in Grammer AG, a German company specializing in automotive interior components. This acquisition allowed Ningbo Jifeng to expand its market in North America and learn the latest European technologies simultaneously. Therefore, understanding the change in ownership could help investigate the company’s development direction, including where it decides to develop. In this study, I will collect the ownership change from the official website of the company.

1. Structural Changes

The structural change inside the company that could influence the supply chain is vertical integration. Vertical integration is defined as a list of decisions on whether the company should manufacture inside or buy outside the company (Guan & Rehme, 2012). For some automotive companies, they decided to integrate upstream and downstream chains together and produce in-house (Sturgeon et al., 2008). In the real world, enterprises may choose to have larger production units within the company and decrease the number of suppliers (Abrahamsson & Brege, 1997). In some other cases, the situation is totally different. The reasons for structural changes are multiple, including costs, the consideration of strategy, price advantage, and uncertainty in cost/product/price. Under the influence of the current political instability, the main consideration of enterprises is how to solve the problem of uncertainty. In this study, I will measure whether the company does vertical integration in different years.

1. Technological/Knowledge Changes

The change in technology and knowledge is highly related to geographical change, ownership change, and network change because knowledge and technology are intangible, accompanied by people and particular products. Therefore, when other changes happen, technological and knowledge changes occur as well.

Technological/ knowledge changes have several forms in the supply chain. The first one is upgrading and downgrading. Upgrading refers to the process of economic actors moving from low-value to relatively high-value activities. Downgrading refers to the process of economic actors lowering their rank, value, or quality in economic activities (Gereffi et al., 2005). Incremental upgrading may be realized through learning by doing or the allocation of new tasks by the chain’s lead firm, which reflects knowledge/technology changes (Humphrey & Schmitz, 2002). Humphrey and Schmitz (2002) identified four types of upgrading: (1) product upgrading,

which refers to increased unit values; (2) process upgrading, which refers to making the input- output process more efficient by introducing better technology or adjusting the production process; (3) functional upgrading, which refers to applying new functions or abandoning old functions to increase the overall skill content of activities; (4) inter-sectoral upgrading, which refers to firms move from one product line to another product line by acquired competence. Although there are four types of upgrading, it is hard to identify the boundary between different types of upgrading in the real world. Also, supplying a whole range of goods in one place does not fit the concept of upgrading (Gereffi, 2019). For example, Antràs & Chor (2018) and Frederick (2019) also used the World Input-Output Database (WIOD) to trace the countries’ GVC positioning (upstream, midstream, and downstream) and the changes in different years. In this study, I will use the suppliers’ comparison positions (upstream or downstream), and the change in the length covered in the chain to measure upgrading and downgrading.

The second one is the FDI flows at a firm level. This indicator could reflect the change in companies’ collaboration level with other companies. Typically, a high FDI amount reflects the high level of knowledge/technology transfer (Isaksson et al., 2016). This data could be collected from the firm’s financial statements.

The third one is the R&D output. Dohse et al. (2024) found that research output could reflect firms’ supply chain constraints. Therefore, research output could be seen as an indicator to measure technological/knowledge changes. This data could be also collected from the firm’s financial statements.

The fourth one is patent. Patent reflects the change in technology/knowledge level in the company. Although previous research proved that it is not accurate to use patents to measure technology transfer, it does indicate communication between two sides(Jaffe et al., 2000). Isaksson et al. (2016) suggested that the buyer-supplier relationship produces knowledge spillover, which can be measured by patents. Therefore, in this paper, I choose to collect the date of patent application and patents’ forward citation from suppliers. The patent application date could reflect the time that knowledge/technology was created, and the forward citation could reflect the quality of the patent, which indirectly proves the change in the supply chain.

In the third section, this research will combine the below indicators with the supply chain mapping method.

1. **Methodology**
   1. **Supply chain mapping method**

To deeply understand the changes behind the global supply chain, the first step is to know who supplies, what to supply, and who purchases. A supply chain map could visually display by presenting appropriate and accurate information in a manner that can be easily understood and, at the same time, be sufficiently informative to aid supply chain visibility, analysis, and integration (MacCarthy et al., 2022; Mubarik et al., 2023).

There are two roles of supply chain mapping when faced with such changes in the supply chain. From a macro level, we could have a comprehensive understanding of the real effects of the policies and decoupling sentiment, including where the location of the production transfer, how large the scope of the transfer, will affect the power relations of existing suppliers, and how will there be a large number of supplier relationship reconstructions.

From a micro level, we can understand the strategy change of multinational enterprises when they face global political uncertainty. Although previous scholars interviewed executives of multinational corporations about their future plans for reshoring or nearshoring, there has not yet been a clear conclusion on what their options for choosing the place to manufacture. Therefore, this study could provide an empirical perspective on the choices of multinational corporations by combining their activities and plans. For example, the ownership change and financing change could reflect executive choices.

In this research, I choose the FactSet Supply Chain Relationship Database to collect three focal companies’ multi-tier buyer-supplier relationships. The FactSet Supply Chain Relationship Database is a commercial supply chain database that covers business relationship interconnections among companies globally. FactSet analysts systematically collect companies’ relationship information exclusively from primary public sources such as SEC 10-K annual filings, investor presentations, and press releases, and classify them through normalized relationship types. Company information is fully reviewed annually, and changes based on corporate actions are monitored daily. The result is a comprehensive, detailed and up-to-date dataset of material intercompany relationships.

FactSet Supply Chain Relationships currently covers more than 25,000 publicly traded companies around the world, comprising over 270,000 business relationships, normalized into 4 main categories and 13 types, with historical data going back as far as 2003. Percentage revenues between suppliers and customers are disclosed, as available. In addition, supply keywords are captured where available to provide meaningful context to the nature of the relationship between companies. As for the data Maintenance, FactSet Supply Chain Relationships is maintained and updated on an ongoing basis as companies release their annual financial filings throughout the calendar year. Relationships information for IPOs is derived from the prospectus.

* 1. **Dataset**

This study will choose three lithium-ion battery companies that deeply participate in global supply chain as the main study object. Reasons to choose the lithium-ion battery industry are multiple. First, the production of lithium-ion batteries is highly dependent on critical materials, such as cobalt, lithium, and nickel. Supply chain mapping could reveal the geographical information of the main suppliers and potential supply risks of these raw materials and help manufacturers predict and mitigate supply disruptions due to political instability, trade policies or natural disasters. Second, Mapping the supply chain helps increase transparency in the industry, allowing companies to more accurately understand every link in their supply chain. This is particularly important for ensuring compliance with ESG standards, as the extraction and manufacturing of lithium-ion batteries can involve environmental damage and labour rights issues. Third, lithium-ion batteries have a long production chain all over the world, which is a proper industry for observing changes in the global supply chain.

The three companies in this research are Contemporary Amperex Technology Co., Limited (CATL), Automotive Cells Company (ACC), and Tesla.

Contemporary Amperex Technology Co. Limited (CATL): A global leader in lithium battery manufacturing, specializing in EV and energy storage batteries, with advanced technology and large-scale production for major global automakers.

Automotive Cells Company (ACC): A European battery manufacturer co-founded by Stellantis, TotalEnergies, and Mercedes-Benz, focusing on localized high-performance battery production to support Europe’s EV supply chain.

Tesla: An American EV and energy company, producing high-energy-density lithium batteries at Gigafactory for electric vehicles, energy storage systems, and renewable energy applications.

* 1. Data analysis process

The data collected from the dataset includes: Supplier\_ID, Supplier\_Name, Company\_ID, Company\_Name, Supplier\_Country, Supplier\_Region, Revenue\_Percentage, Relationship\_Start\_Date, Relationship\_End\_Date, Supplier\_Keyword，Customer\_Keyword, relationship\_keyword. This research will be based on the relationship’s keyword to judge whether this supply chain relationship belongs to the battery industry.

As multi-tier supply chains may cover around 100,000 supply chain relationships, natural language process and big data model is the most efficient method to do the data process, which select the relevant battery suppliers in the different tiers.

In particular, this research choose RAG to construct the thesaurus, a word bank for upstream and downstream battery keywords, to select suppliers.

|  |  |  |
| --- | --- | --- |
| **Upstream Keywords** | **Midstream Keywords** | **Downstream Keywords** |
| aluminum foil | Lithium Battery Anode | Power Battery Manufacturer |
| Cobalt salt | Lithium battery cathode materia l | Power battery packaging |
| Copper Foil | Lithium-Ion Battery Electrolytes | battery formation and testing equi pment |
| Electronic Copper FoilPr oducts | Lithium-  ion Battery Separator Film | new energy vehicle cooling power battery |
| Graphite | battery materials | new energy vehicle power lithium batteries |
| Lithium | Cathode active materials | power battery |
| Copper | cathode material | power battery boxes |
|  | cathode materials | power battery companies |
|  | graphite anode | power battery module |

|  |  |  |
| --- | --- | --- |
|  | lithium battery electrolyte manu facturers | vehicle battery tray production eq uipment |
|  | lithium battery materials |  |

*Table 2. The thesaurus for upstream and downstream battery keywords*

1. **Potential Results**

This research is expected to offer several meaningful conclusions that will contribute to both academic literature in supply chain management and practical applications, particularly within the lithium-ion battery industry. Firstly, by constructing dynamic global supply chain maps over multiple years (2017 to 2024), the study will reveal the evolving configurations of the battery supply chain. This analysis based on time series will highlight trends such as shifts in supplier-buyer relationships, the emergence or disappearance of key players, and changes in the geographic distribution of supply chain activities. In particular, this research will try to find out the average time customers spend replacing suppliers. Such insights can be a pre-step for researchers to investigate the reasons behind such changes.

Secondly, the research will likely uncover specific changes that have occurred in the battery supply chain after 2020—a period marked by significant global disruptions due to the COVID-19 pandemic and increasing geopolitical uncertainties. The study may reveal how companies have adapted their supply chain strategies in response to these unexpected challenges, such as diversifying their supplier base, reshoring manufacturing processes, or investing in alternative raw materials and technologies. Understanding these adaptive strategies can provide valuable lessons for enhancing supply chain resilience and flexibility.

Thirdly, the analysis of geographical changes will shed light on the shifting clusters of production and consumption within the battery industry. The study might find, for example, a movement of manufacturing hubs from one region to another due to factors like geopolitical tensions, access to raw materials, or supportive government policies. This could have implications for regional economic development and international trade relations.

Moreover, examining network changes and structural shifts within the supply chain will provide insights into the complexity and interconnectivity of the industry. By applying network analysis techniques to the buyer-supplier relationship data, the research may identify key nodes and clusters within the supply chain, as well as bottlenecks and vulnerabilities. This can help in assessing the overall robustness of the supply chain and in designing strategies to mitigate risks associated with over-reliance on specific suppliers or regions.

The study may also reveal ownership changes and technological or knowledge transfers that are reshaping the industry. For instance, increased mergers and acquisitions could indicate a trend toward vertical integration, while partnerships and joint ventures might reflect collaborative efforts to innovate or enter new markets. Analysis of patent data from the Worldwide Patent Statistical Database (Patstat) could uncover shifts in technological leadership and the diffusion of innovation across the industry.

Finally, the methodology developed in this research—utilizing the FactSet Database for multi-tier supply chain mapping—could serve as a valuable framework for future studies in other industries. By demonstrating the feasibility of constructing dynamic and detailed supply chain networks despite data limitations, the research may encourage more comprehensive analyses of global supply chains in sectors beyond the battery industry.

Overall, the potential results aim to enhance the understanding of how global supply chains evolve over time in response to various risks and challenges. The findings could inform multinational corporations on how to optimize their supply chain strategies and assist policymakers in developing regulations that promote supply chain resilience and sustainability. By providing a clearer picture of the global lithium-ion battery supply chain, this research contributes to the broader goal of mitigating risks associated with supply chain disruptions and supporting the development of sustainable energy solutions.

1. **Conclusion**
   1. **Limitations**

Although the FactSet Database could provide a significant tool for researchers to deal with large-range supply chain relationships, we still need to watch out for the accuracy and comprehension of the data. This data set is not designed for research. Therefore, it is hard to identify product flows between firms. The number of supplier relationships may be influenced by the company’s popularity. Large companies disclose more supply relationship information, and people are more likely to pay attention to them, which increases the chance for FactSet to collect their data into the database. Compared to Bloomberg, the number of supply relationships is less (Culot et al., 2022). Maybe buyer-supplier relationships from another dataset will be included in this research. Second, although the FactSet database provided 10 keywords of the supply chain, in some cases, the keyword is not equal to the product in the supply chain relationship, which requires further verification.

* 1. **Research contributions**

First, this study will make a methodological contribution to improving the feasibility of supply chain mapping. While previous studies collected supplier relationships through news online as the data source and used the Machine Learning method to map the supply chain, this study will use the FactSet Database to collect supplier relationships in the battery industry to guarantee a more accurate relationship. Despite the difficulty of obtaining the material flow in the supply chain, this research covers multiple-tier supplier information, which could be collected and assessed by the keywords of supply transaction.

Second, this research offers a dynamic supply chain management perspective using the starting date and ending date of the buyer-supplier relationships, which could investigate the cooperation between companies and identify the potential risks and vulnerabilities behind such buyer-supplier relationships.

Third, this study is also relevant for practice as it uses the lithium-ion battery industry to further explore the changes in the supply chain and develop strategies for multinational companies and policymakers to mitigate risks associated with uncertain events, such as raw material shortages, geopolitical uncertainties and natural disasters.

* 1. **Conclusion**

Under the complex geopolitical environment, the global supply chain faces great challenges in keeping resilient. The supply chain mapping method could serve as a feasible tool to improve the visibility of the supply chain, thereby allowing scholars to know the specific problems occurring in the global supply chain, such as supplier dependency, supply

chain bottlenecks, etc., to do the supply chain risk management. As it is a map that covers up, mid, and downstream global supply chains, it could help understand the establishment and termination of relationships between suppliers in different years. Therefore, companies in the supply chain could make efficient strategies to adjust supplier relationships.

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**Orphan drug development by large pharma:**

**The dynamic stakeholder engagement perspective**

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**Inroduction**

Developing treatments for rare diseases is an urgent medical and social need that must be met globally. A rare disease is a condition that affects a very small portion of the population. In the European Union (EU), for instance, disorders that have a prevalence of no more than one person in 2000 are qualified as rare diseases (European Commission, 2023). So far, over 7,000 rare diseases have been discovered (Haendel et al., 2019), most of which lack a cure. The number of people worldwide living with a rare disease is estimated at 300 million (Nguengang Wakap et al., 2019). Over 80% of rare diseases are genetic-related (Melnikova, 2012), meaning the hereditary nature of these diseases will continue to affect patients for generations if no permanent medical solution is available. The scale, severity and complexity of rare diseases make this issue a “grand challenge” in healthcare.

The development of orphan drugs to address unmet medical needs for treating rare diseases has been a challenge. Along with the small patient population, this process is also negatively affected by a relatively elusive perspective of financial returns because of the market size, as well as the limited disease knowledge base, which makes all the drug development activities more difficult (Fonseca et al., 2019; Wästfelt et al., 2006). Large pharmaceutical firms remain the primary entity for orphan drug applications and commercialization these days (Giannuzzi et al., 2017; Schuhmacher et al., 2023). However, even such organizations have to face those challenges in developing orphan drugs for rare diseases, resulting in the undersupply of those drugs (Joppi et al., 2006). A significant research effort has been directed at finding ways to help facilitate the process in order to make these drugs available to those in need.

Regrettably, the literature that explores the development of orphan drugs remains scarce and fragmented. For example, much of the existing research focuses on the design of policies related to incentivising orphan drug development (Franco, 2013; Minn, 2017; Yin, 2008). In addition, considerable attention has been given to the discussion of market incentives and barriers hampering orphan drug development (Heemstra et al., 2008; Meekings et al., 2012; Phillips, 2012). Lastly, some studies examine the role of individual stakeholders and their contributions to the development process (Gentilini & Miraldo, 2023; Kesselheim et al., 2015; O’Neil, 2014; Vavassori et al., 2024). There is a lack of a holistic view of how different stakeholders are collectively engaged in the process, or how efforts from these stakeholders should be coordinated. The current fragmented approach is inadequate to account for the complex, multi- stakeholder environment in which rare disease R&D and orphan drug development take place, leading to suboptimal solutions, especially in policy design (Rohde, 2000; Rzakhanov, 2008) and fostering effective collaboration among stakeholders (Joshi et al., 2021; Moors & Faber, 2007).

The development of orphan drugs is rarely a sole endeavour; instead, it involves the interaction with multiple stakeholders, each of which has different incentives, resources, and capabilities. As such, developing a framework that would account for these differences as well as explain how different stakeholders can engage in the process should help us better understand and, hence, support the development of orphan drugs.

In this study, we develop a theoretical framework that utilizes the stakeholder perspective to explain how stakeholders dynamically engage in the development of orphan drugs. We categorize orphan drug development into two primary types of activities: exploration and exploitation, which are dependent on a firm’s knowledge base. Exploration activities correspond to the development of First-in-Class (FIC) drugs for rare diseases, while exploitation activities involve the repurposing of existing drugs for new orphan indication uses. We identify five key stakeholder groups that large pharmaceutical companies should engage with for successful orphan drug development: biotechnology firms and small- to medium-sized enterprises (SMEs), academic researchers, healthcare professionals, patients and patient organizations, and government agencies along with their regulatory bodies. By deconstructing the orphan drug development process into six stages and highlighting how they are different in comparison to the conventional drug development process, we demonstrate that academic researchers, patients and patient organizations, healthcare professionals, and government bodies play a more active role in orphan drug development, each contributing uniquely to the process. Furthermore, we analyze the roles, contributions, and incentives of all stakeholders involved in the orphan drug development process and show that pharmaceutical firms can strategically align the interests of these stakeholders at different stages. And by leveraging these stakeholders’ unique expertise, pharmaceutical firms can overcome some of the challenges in rare disease R&D and facilitate orphan drug development more effectively. Lastly, our framework explains that the selection of stakeholders for engagement depends on the specific stage of drug development and whether the company is pursuing exploration or exploitation activities.

As such, our study makes three important contributions. Firstly, we contribute to the literature on new medical product development by understanding it in the context when market incentives are low for products that are mostly privately supplied. This is important because traditional new product development approaches and strategies are likely to be limiting in this case and, therefore, often result in poor R&D performance, which is less than desirable when it comes to meeting social needs. Secondly, our study adds to the literature on stakeholder engagement by emphasizing the dynamic nature of such engagement and, thus, providing novel insights into how the choice of either the exploration or exploitation of a firm’s knowledge base as the basis for their product development strategy would alter the composition of stakeholder network. Finally, this study contributes to the debate on organizing R&D activities for rare disease treatment by drawing attention to the need to coordinate incentives, resources, and capabilities among different stakeholders involved in the development of orphan drugs.

**Deconstructing the Orphan Drug Development Process**

New drug development is a lengthy, costly, stringent, and knowledge-intensive process. The structure of this process is primarily shaped by the course of risk mitigation associated with the “valley of death” (Gamo et al., 2017) in drug development, the pursuit of efficacy driven by market forces, and the safety standard mandated by regulatory requirements. The process can be broken down into several stages, each with a different set of objectives and the involvement of different types of participants. Compared to the general new drug development process for common diseases, the orphan drug development process differs in both stages and the types of participants engaged in each stage. Such differences exist because the roles and incentives of the participants have changed in the rare diseases R&D context.

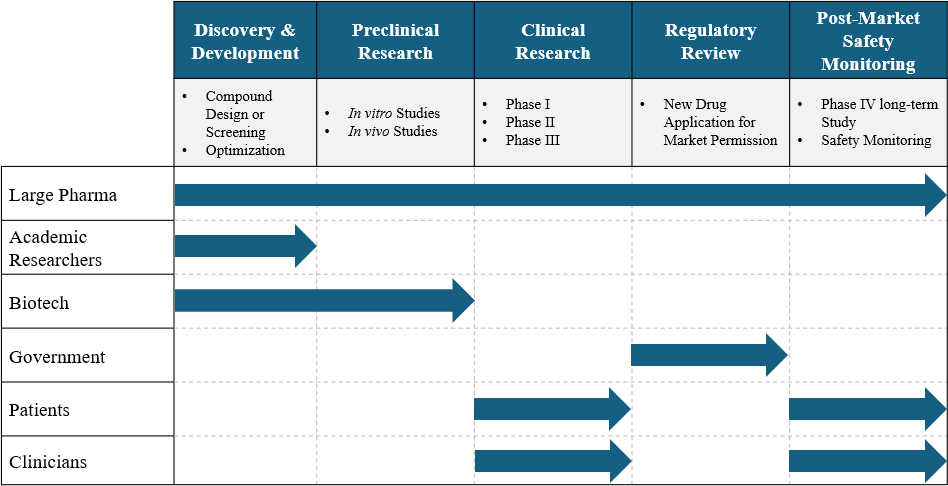
***The Conventional Drug Development Process***

The U.S. FDA summarizes the general new drug development process into five stages: Discovery and Development, Preclinical Research, Clinical Research, FDA Review (or Regulatory Review in other countries), and Post-Market Safety Monitoring (FDA, 2018). At the Discovery and Development stage, disease knowledge enables the design or the screening compounds with potential therapeutic. One or a

few candidates would be selected for optimization based on various biochemical criteria. Optimized candidate(s) then move to the Preclinical Research stage, where cell or tissue-based *in vitro* studies and animal-based *in vivo* studies are conducted primarily to provide detailed information on the candidate(s)’ safety profile. Upon a successful preclinical evaluation, the drug candidate(s) can enter the Clinical Research stage and be tested in humans. The Clinical Research stage is divided into three phases. Phase I focuses on safety and dosage using small groups of healthy volunteers (except for oncology drugs). Phase II evaluates the drug's efficacy in small patient groups, while Phase III assesses efficacy and adverse effects in larger patient populations, sometimes involving thousands of subjects. Study results are submitted to the regulatory agency of the target market. This Regulatory Review process can be lengthy and daunting because every aspect of the drug development will be scrutinized. Once market approval is granted, the drug is commercialized, it enters the Post-Market Safety Monitoring stage. At this stage, Phase IV studies may be required for some drugs in order to assess their long-term safety profiles.

Multiple types of participants are involved in the five stages of the drug development process, each with its unique role and contribution. According to Kaitin (2010), large pharmaceutical companies take part in the entire drug development process but differ in their contribution by stages. In the discovery and early development stages, large pharma coordinates and manages efforts from other participants (Kaitin, 2010; Rafols et al., 2014) while assuming the lead role when clinical trial begins. Academia contributes through basic research and translational medicine, particularly in the Discovery and Development stage. Biotech is an important source of innovation (Schuhmacher et al., 2023) during the Discovery, Development and Preclinical stages, but the technology-push nature of this type of firm has limited its capability to expand and complete the entire development process by itself (Khilji et al., 2006). Governments are mainly involved in the Regulatory Review stage as regulatory agencies. Although some countries have certain expedited programs or advisory services (i.e., EMA’s scientific advice) that allow drug applicants to have early consultations with regulatory agencies, such interaction is usually one-way and question-based. Patients’ involvement tends to be passive, even though they are key beneficiaries of successful drug development. They are recruited at the Clinical Research stage and treated as test subjects following a pre-determined study protocol. From the drug developer’s perspective, patients’ premarket value lies in the clinical data they provide to validate the drug candidate’s potential. Similarly, healthcare professionals are largely involved during the Clinical Research stage because most clinical trials are conducted in hospitals and private clinics.

Figure 1 demonstrates the conventional drug development process and the stakeholders’ involvement at different stages. Recent data suggests that the entire three phases of the Clinical stage for innovative drug development take almost ten years on average to complete (Brown et al., 2021; Darrow et al., 2020). As for the Regulatory Review stage, the FDA takes about ten months to review a new application, whereas the EMA requires a few weeks more (Vokinger et al., 2023). It is very hard to generalize the total time to complete the drug development process from discovery to market approval across different therapeutic areas and the therapeutic modalities of the drugs. But multiple studies throughout the years have shown that it can take ten to fifteen years to bring a new drug from bench to market (Khilji et al., 2006; Mattison et al., 1988; Moors & Faber, 2007; Paul et al., 2010).



*Figure 1. Conventional Drug Development Process*

***Differences in the Orphan Drug Development Process***

Unlike in the conventional drug development process, the research phase and early development phase of an orphan drug development should be separated. Rare disease knowledge is found to be crucial in charting the path for all follow-up orphan drug development activity (Heemstra et al., 2009), yet a comprehensive understanding of the disease is not always available (Blin et al., 2020; Fonseca et al., 2019). It takes longer and requires more effort to study a rare disease, establish valid *in vitro* and *in vivo* models, and find meaningful clinical endpoints because of the low disease prevalence. During the research phase, universities, research institutes, and clinicians from academic hospitals play a crucial role in gathering disease knowledge, which is essential for orphan drug development (Kesselheim et al., 2015; Moors & Faber, 2007). However, these participants may not always be directly involved in the drug development activity themselves, but rather opening a market opportunity for firms in the pharmaceutical industry (Galati & Bigliardi, 2016). Biotech and SMEs remain the primary innovators for orphan drugs during the early development stage (Lincker et al., 2014).

Another salient difference is the involvement of patients and healthcare workers. They are considered an active and integral part of the entire orphan drug development cycle. Patients and patient organizations have been collecting disease data to build patient registries, which provide essential knowledge in early disease research and clinical trial design (Gaillard et al., 2020; Giannuzzi et al., 2017). Patients have also been influencing the funding for rare diseases R&D (Hegde & Sampat, 2015; Wood et al., 2013), and even forming their own non-profit research foundations to take part in orphan drug development themselves (Kucukkeles et al., 2019; Vavassori et al., 2024). In addition, patient advocacy groups have been acting as network facilitators to promote collaboration among industry, academic researchers and clinicians (Shah et al., 2021). Healthcare professionals, particularly clinicians, become a valuable source of knowledge on existing medications because they often prescribe drugs for off-label use to help patients manage disease progression (Rusz et al., 2021). Through this practice, they develop insights into certain medications, which may later be repurposed as orphan drugs.

Governments are more involved in the orphan drug development process as well. From a funding perspective, governments are major funding providers to aid and incentivize rare diseases research (Davies et al., 2017; Hartman et al., 2019; Kesselheim et al., 2015). The European Joint Programme on Rare Diseases (EJP RD)[1](#_bookmark45), the National Institute for Health and Care Research (NIHR)[2](#_bookmark46) in the UK, and the National Institute of Health (NIH)[3](#_bookmark47) are some of the most active public funders to bolster rare disease research. From a regulatory perspective, many governments are more engaged in providing assistance to orphan drug developers throughout the development process (Franco, 2013). For instance, the EMA and FDA’s Office of Orphan Products Development (OOPD) have a protocol assistance service to help the drug developer prepare and design the clinical studies to ensure quality before study initiation, therefore increasing the transparency and lowering the regulatory risk for drug developers. To further expedite the process, regulatory review time for orphan drugs can also be shortened. Applicants may seek priority review[4](#_bookmark48) from the FDA or accelerated assessment[5](#_bookmark49) from the EMA, which require the agencies to complete the review process within six months (24 weeks) and 150 active days (21.4 weeks), respectively.

Compared to the standard clinical study processes, orphan drug clinical trials tend to be much smaller, less robust, and use more surrogate endpoints for evaluation (Joppi et al., 2006; Kesselheim, 2011; Michaeli D.T et al., 2023). Moreover, it is not uncommon for orphan drugs to bypass large-scale clinical trials such as a phase III study and receive market approval based on results from only one pivotal trial (Bouwman et al., 2024). These differences are associated with the challenges in rare disease R&D, including the lack of disease understanding, difficulties in patient recruitment, and varying regulatory and ethical concerns (Fonseca et al., 2019; Wästfelt et al., 2006). Such challenges also lead to an uncertain timeline for orphan drug clinical research. While some studies suggest that orphan drugs may complete clinical trials more quickly (Kumar Kakkar & Dahiya, 2014; Meekings et al., 2012), others argue the opposite, especially when the rarity of the disease and the recruitment process are taken into account (Brown et al., 2021; Michaeli T et al., 2023; Reichert, 2003).

Figure 2 illustrates the orphan drug development process. Compared to conventional drug development, the overall timeline from initiation to market entry for orphan drugs is considerably more uncertain. Although the discovery strategies that result in drug approvals for rare diseases and common diseases are very similar (Swinney, 2016), the added complexities associated with rare disease research and the challenges inherent to orphan drug clinical trials introduce significant variability. The development timeline for an orphan drug targeting a specific rare disease is heavily influenced by factors such as the comprehensiveness of existing research on that disease, the availability of disease natural history data and patient data. These factors, in turn, directly affect how well the clinical trials are designed, as well as the pace of patient recruitment and study execution.

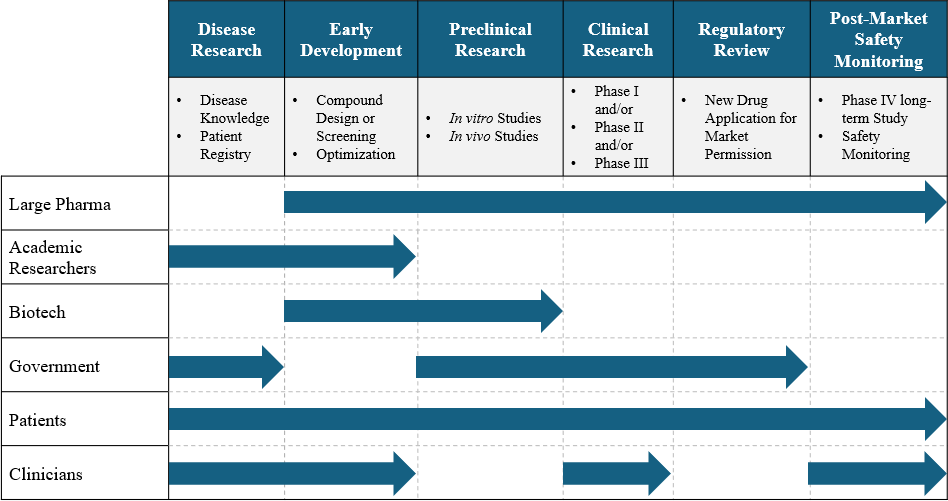
1 <https://www.ejprarediseases.org/what-is-ejprd/project-structure/>

2 <https://www.nihr.ac.uk/about-us/news/funding-and-support-rare-diseases-research-will-drive-progress-patients>

3 <https://www.nih.gov/news-events/news-releases/nih-funding-bolsters-rare-diseases-research-collaborations>

4 <https://www.fda.gov/patients/fast-track-breakthrough-therapy-accelerated-approval-priority-review/priority-review>

5 <https://www.ema.europa.eu/en/human-regulatory-overview/marketing-authorisation/accelerated-assessment>



*Figure 2. Orphan Drug Development Process*

**Exploration and Exploitation Activities in Orphan Drug Development**

Drug development can be classified in various ways, such as by the intended indications, therapeutic modalities, route of administration, and other criteria. This paper proposes a classification framework for orphan drugs development based on the types of activities developers undertake during the drug development process. These activities can be classified into two main categories: exploration and exploitation. Exploratory drug development produces New Molecular Entities (NMEs), which include the invention of First-in-Class (FIC) and Best-in-Class (BIC) products. In contrast, exploitative drug development is centered on the repurposing of available drugs, which can be further subdivided into identifying new therapeutic indications or supplementing existing ones.

***NMEs Drug Development vs. Repurposing Drug Development***

Developing orphan drugs for rare diseases can be viewed as either an exploration or exploitation activity. According to March (1991), key traits of exploration include search, discovery, experimentation, and innovation, while those of exploitation encompass selection, refinement, and efficiency. Developing entirely new drugs for rare diseases is an act of exploration. These “*de novo*” NMEs are normally encompassed of FIC and BIC products. The development of First-in-Class drugs is based on a novel mechanism of actions (MoA) that no regulatory agency has approved yet. They originated from concepts (target, pathway, or chemotype) in the laboratory and require a target-based discovery or phenotypic screening process (Eder et al., 2014) before the hypotheses are confirmed and product development can be initiated. If they become successful, they have the potential to bring radical innovation into the medical research field and technology utilization in healthcare (i.e., personalized medicine). The development of Best-in-Class drugs, on the other hand, is creating NMEs for established targets or MoAs. These BIC drugs need to demonstrate superior performance compared to existing therapeutics targeting the same biological pathway. Their advantages are typically characterized by improvements in key areas such as

efficacy, safety, or other clinically significant outcomes. The development of these drugs still requires substantial effort, despite the known targets or MoAs. The novelty lies in the structural design and molecular characteristics of these NMEs, necessitating extended research and optimization to achieve their therapeutic superiority.

Contrary to classifying the development of NMEs as exploration, identifying new uses of a successful or failed product – commonly known as “repurposing” or “repositioning” in drug development (Ashburn & Thor, 2004) – can be viewed as an exploitation activity in orphan drug development. There are two general directions for repurposing. First, a drug can be repurposed for a very different indication from its original intent of use. Keytruda (pembrolizumab) is a good example. Initially approved in the U.S. in 2014 for unresectable or metastatic melanoma, it has since been repurposed to treat small cell lung cancer, esophageal carcinoma, and more than a dozen other indications. The second approach to drug repurposing involves extending its approved indication. This can be achieved through several strategies, such as broadening the conditions of use, expanding the target patient population (e.g., to include pediatric patients), or developing combination kits that pair the drug with other approved therapies.

Regardless of the way it is repurposed, a drug that is being “repurposed” into treating rare diseases should have gone through the necessary preclinical testing and early human clinical trials during its original development cycle. This means its safety profile and formulation development are readily available (Parvathaneni et al., 2019; Pushpakom et al., 2018). Most importantly, the mechanism of action of such tested drug is studied or already known. From the disease perspective, repurposing is an in-depth systematic screening approach, focusing on advanced known candidates either approved or failed with some knowledge of their safety and mechanism of action (Cha et al., 2017). It is a selection process that tries to associate disease knowledge with a library of rapidly available solutions, hoping to find “hits” that potentially have therapeutic effects on the disease or disease symptom.

***Development Timeline, Risk, and Performance Variance.***

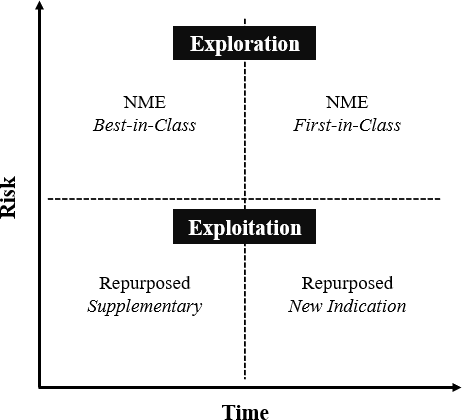
Developing “*de novo*” NMEs and repurposing possess other important characteristics of exploration and exploitation activities. First, exploitation offers more proximate benefits, while the return from exploration is more remote in time (Greve, 2007; March, 1991). The two different ways to address the needs of rare diseases share very dissimilar development timelines. On the one hand, the median times from concept establishment to FDA approval for FIC target- and non-target-based drugs are 20 years and 25 years, respectively (Eder et al., 2014). This may lead to a revolutionary cure for the disease, but it is a significant wait time for generation(s) of patients. On the other hand, repurposing has a much-reduced development time frame because most of the preclinical testing, safety assessment, and sometimes formulation development has already been done for the original use (Pushpakom et al., 2018; Tambuyzer et al., 2019) and the regulatory approval process is often quicker (Shah et al., 2021). Consequentially, repurposing drugs is viewed by medical practitioners and patient advocacy groups as an attractive option to provide immediate symptomatic relief for patients suffering from rare diseases that have no cure yet (Kucukkeles et al., 2019). Second, exploration has a higher level of uncertainty and risk when compared to exploitation (Greve, 2007; March, 1991). Developing NMEa is a risky endeavor because the nature of scientific discovery is unpredictable. Problems can appear from any aspect of the development cycle – from the viability of the MoA and the safety and efficacy profile of the product itself to the manufacturing and quality control – and the innovator can suffer significant losses in investment because of them. Comparatively, repurposing has a higher level of certainty through development because existing knowledge is available for assessment, learning, and improvement. Lastly, from a firm-level perspective, exploration brings an increased performance variability, while exploitation leads to low variance (and a decline) in performance (Osiyevskyy et al., 2020). Not all NMEs are successful by market standards. The actual clinical benefits they bring to the patients vary (Osipenko et al., 2023). Such clinical variations can lead to unpredictable sales and market performance. Furthermore, if an NME development program fails,

the sunk cost of time and capital invested in the program can be punishing for the firm. As for drugs chosen for repurposing, they are studied not only during the development cycle but also for their post- market performances in their original therapeutic area(s). Additionally, if such drugs are no longer under patent protection, the availability allows any interested parties to develop and commercialize them. As a result, more information becomes available to help inform the firm on the potential return of a product, and consequently lead to a more predictable performance. However, the absence of patent protection can also lead to a saturation of the repurposed products in the market for off-label uses, which lowers the profit margin and competitiveness of the firm.

***Categorizing Orphan Drug Development***

By aligning the fundamental characteristics of exploration and exploitation with the traits of various orphan drug types, the four primary approaches to orphan drug development – invention of novel First-in- Class (FIC) and Best-in-Class (BIC) drugs, as well as drug repurposing for new indications and supplementary indications – are represented in the framework illustrated in Figure 3. Developing new molecular entities (NMEs) faces significantly greater risk compared to drug repurposing, as the safety and efficacy profiles of both first-in-class (FIC) and best-in-class (BIC) drugs within the NME category remain unknown. The inherent uncertainties associated with the novelty of the mechanisms of actions and/or compound designs contribute to the complexity of NME development, posing substantial scientific, regulatory, and commercial challenges. Consequently, both FIC and BIC drugs are positioned on the upper section of the diagram, reflecting their alignment with exploration due to the novelty and uncertainty they involve.

Development time time further differentiates the four approaches. First-in-class drug development, as the most novel and exploratory process, typically requires the longest timeline since it involves completing the entire drug development cycle outlined earlier. Conversely, supplementary repurposing requires the least time, as it primarily requires additional tests with expanded patient inclusion criteria for the same drug and indication. The positioning of best-in-class drug development and new indication repurposing is comparatively nuanced. At first glance, BIC development may appear more time-intensive due to the need for extensive preclinical studies. However, if the search for a new indication and the screening of existing compounds are taken into consideration, new indication repurposing can have a much more unclear timeline. Furthermore, when disease-specific knowledge or candidate drug information is limited – as is often the case in rare disease research – the repurposing process can become significantly prolonged. Therefore, BIC drug development occupies the upper-left section of the diagram, representing higher risk but shorter relative timelines compared to FIC drugs. In contrast, new indication repurposing is positioned in the lower-right section, reflecting its association with exploitation strategies but potentially longer and less predictable timelines.



*Figure 2. The four types of orphan drugs, categorized by exploration and exploitation*

***Balancing Exploration and Exploitation Activities in R&D.***

There has been an extended discussion over the tension between exploration and exploitation activities in an organization. March (1991) believes that an organization needs to maintain an appropriate balance between exploration and exploitation in order to survive and prosper. And firms should engage in both in order to secure the long-term performance (Lennerts et al., 2020). However, both types of activities compete for resources. When the resources needed to pursue both exploration and exploitation become scarcer, the likelihood of them being mutually exclusive to each other becomes greater (Gupta et al., 2006). Different ways to reconcile the tension between exploration and exploitation have been proposed by scholars. Tushman & O'Reilly (1996) suggest that firms become ambidextrous in achieving a balance. Gupta *et al.* (2006) later propose the concept of Structural Ambidexterity and Punctuated Equilibrium. Lavie *et al*. (2010) then summarize the four different fundamental modes for resolving the tension: contextual ambidexterity, organizational separation, temporal separation, and domain separation.

In the context of rare diseases R&D, it is highly challenging to develop NMEs and repurpose products simultaneously. Exploration and exploitation activities on a firm level are competing because both require firms to invest time, capital, and human resources. In addition, the two types of activities differ in the team composition that they require – developing “*de novo*” products demands specialists who focus on early discovery and MoA stages, while repurposing needs people who are trained in optimization and clinical testing, or those who have experience in the product itself. The firms capable of utilizing the contextual ambidexterity or organizational separation mechanisms to carry out both exploration and exploitation activities at the same time are most likely to be big pharma and large international organizations. Because they have enough resources, headcounts, and capabilities to form different functional divisions or subunits to succeed in both. However, this does not mean that smaller firms must choose to stay specializing in one type of activity, nor does the discussion here suggest that one type of activity is superior to the other. The decision to engage in either NME development or repurposing should be fluid. A firm can assess the external and internal conditions and choose to operate at any point on the exploration-exploitation continuum as long as it strives to reach its natural balance on that continuum (Lavie et al., 2010). Furthermore, such balance may not need to be achieved in-house. Individual organizations may justifiably focus solely on exploration or exploitation while delegating the task of achieving a balance between the two to the social system. (Gupta et al., 2006). In the pharmaceutical

industry, inter-organizational collaborations, strategic alliances, and contract research are all common practices for firms to engage in different product development programs.

**Stakeholder Analysis**

With the orphan drug development process in place, the next step is to examine the stakeholders participating in the development activities. Stakeholders, as explained by Freeman (2010), are a broad range of groups and individuals that can affect or are affected by the achievement of an organization’s purpose, despite the various values and agendas held among them. In the context of orphan drug development, the idea of an organization might not be confined to one single entity throughout the entire development process. Instead, it is more fluid and project-centered. It should be viewed as whoever is working on the orphan drug project at the particular development stage, as the ownership and sponsorship of the developing orphan drug can shift as the project progresses.

|  |  |  |  |
| --- | --- | --- | --- |
| **Stakeholder** | **Motivations** | **Contribution/Role** | **References** |
| Large Pharma | * Economical returns * Policy and legislation incentives * Social image | * Provide experience * Provide resources and commercial capability * Provide drug library | Bruyaka et al., 2012; Heemstra et al., 2008; Ku, 2015;  Meekings et al., 2012; Pariser et al., 2012; Philippidis, 2011; Tambuyzer et al., 2019 |
| Biotech Companies | * Economical returns * Ethical duty and social responsibilities | * Engage with clinicians and patients * Provide innovation specialties * *Expand market and create demand* | (Bruyaka et al., 2012) (Ekins & Wood, 2015) (O’Neil, 2014)  (Pariser et al., 2012) (Phillips, 2012)  *(Rzakhanov, 2008)* |
| Patients and Patient-led organizations | * Disease treatment * Orphan drug costs * Value creation for society | * Quantify market and justify unmet needs * Provide disease data and de-risk R&D * Influence policy and public funding, steer early R&D activities * Provide various types of resources (financial, logistical, social, etc.) * Mobilize collaboration and patient participation * Disseminate research result | (Beaverson et al., 2023) (Davies et al., 2017) (Gentilini & Miraldo, 2023) (Wood et al., 2013)  (Hegde & Sampat, 2015) (Wästfelt et al., 2006)  (Kucukkeles et al., 2019) (Shah et al., 2021) (Nguyen et al., 2022) |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | * Drug repurposing |  |
| Academic Researchers | * Scientific discovery and technology advancement * Orphan drug costs | * Provide disease knowledge * Drug repurposing | (Das et al., 2019) (Joshi et al., 2021\*)  (Davies et al., 2017) (Kesselheim et al., 2015) (Shah et al., 2021)  (Moors & Faber, 2007) |
| Clinicians | * Scientific interest * Patient wellbeing | * Provide insight of treatment design * Provide clinical knowledge & data * Create clinical trial & network * Drug repurposing | (Das et al., 2019) (Kesselheim et al., 2015)  (Moors & Faber, 2007) |
| Government | * Equality of access | * Fund basic science, translational science, and important R&D organizations * Establish infrastructure to catalyze public- private collaboration * Provide regulatory guidance and help * Provide “push” and “pull” incentives | (Das et al., 2019) (Davies et al., 2017) (Franco, 2013) (Gamba et al., 2021) (Heemstra et al., 2008) (Michaeli et al., 2023) (Pariser & Gahl, 2014) (Rzakhanov, 2008) (Scott et al., 2001) |

***Large Pharma***

Large pharmaceutical companies that develop orphan drugs are after several economical returns. First and foremost is the premium price that many orphan drugs can be sold at (Meekings et al., 2012). The orphan drug market, which is less competitive, also provide an opportunity for large pharma to switch its failing blockbuster business model to a more promising niche-buster business model (Bruyaka et al., 2012). Furthermore, there are possibilities for breakthrough innovations obtained from orphan drug development to be used in common disease, which greatly increase the potential return-of-profit (Bruyaka et al., 2012; Caetano et al. 2021). Large pharma is also motivated by different forms of incentives from the

governments such as tax credit and market exclusivity (Franco, 2013). These policy and legislation incentives have proven to be a major driving force to attract the industry to develop orphan medicinal products (Attwood et al., 2018; Brown & Wobst, 2021). Finally, by engaging in rare diseases research and orphan drug development, large pharmaceutical companies aim to generate public attention and enhance their social image (Philippidis, 2011).

Large pharmaceutical companies contribute to the development of orphan drug mainly with their experience in the drug development process and in those existing molecules that are associated with orphan drug designations (Heemstra et al., 2008; Pariser et al., 2012). Their substantial financial and human resources to carry out clinical trials and large-scale manufacturing, along with their commercial capabilities to bring an orphan drug on a global scale, also make them an integral part of the orphan drug business cycle (Ku, 2015). In addition, these companies often possess extensive compound libraries due to their internal R&D activities across various development stages and different therapeutic areas. These libraries, which contains both successful and shelved molecules, serve as valuable sources for repurposing compounds into orphan drugs (Tambuyzer et al., 2019).

***Biotech Companies***

Biotech companies also seek economic returns in the orphan drug market, though the types of returns they pursue are different. When a biotech has a promising orphan drug program, it often looks for acquisition opportunities from large pharma (Levine & Stemitsiotis, 2023). For instance, a biotech named Amolyt Pharma that owns a phase III new drug program targeting rare endocrinology was acquired by AstraZeneca for 1.05 billion USD (AstraZeneca, 2024). Biotech can also profit from the resale of Rare Pediatric Disease Priority Review Vouchers at a premium price (Ekins & Wood, 2015). Any company that receives an US FDA approval for an pediatric orphan product may qualify for a voucher that can be redeemed to receive priority review for a different product. And the recipient is allowed to sell this voucher to another company (FDA, 2024). One example is the voucher Ipsen received after the approval of Sohonos™ (palovarotene). It was sold to a large pharma for 158 million USD (Ipsen, 2024). The final motivation for biotech to get involved with orphan drug development is social responsibilities. Because many of these companies are founded by researchers and patient groups, the main objective for them becomes addressing the ethical duty for treating rare diseases (Bruyaka et al., 2012; Phillips, 2012).

Biotech companies are often highly innovative and willing to develop novel clinical programs (Pariser et al., 2012), providing specialized expertise in orphan drug development (O’Neil, 2014). Additionally, since many of these companies are founded by patients, they foster stronger engagement with both patients and clinicians (Bruyaka et al., 2012; Phillips, 2012). This connection grants them more direct access to clinical resources and in-depth disease knowledge, which larger pharmaceutical companies may find more challenging to obtain. Biotech companies also help expand the orphan drug market by exploiting the existing technology and products they have for new rare disease indications. By testing one drug for multiple rare and non-rare indications, with the strategy such as sub-dividing a non-orphan indication, biotech companies help discover new market opportunities and therefore create additional demand for orphan drugs (Rzakhanov, 2008).

***Patients***

The main goal for patients and patient-led non-profit organizations is to treat and cure their conditions. Additionally, since orphan drugs are often sold at a premium price, patients are hoping to reduce the orphan drug cost by searching for alternative treatment options such as repurposed drugs (Davies et al., 2017). There is also a sense of ethical responsibility to create value for the society from the patients themselves, especially when the lack of orphan drugs for rare diseases becomes a societal problem perpetuated by market and government failure of innovation (Kucukkeles et al., 2019; Shah et al., 2021).

Patients and their organizations are actively involved in all stages of orphan drug development, covering the scientific, financial, logistical, educational, social and even political aspects of the orphan drug development process (Nguyen et al., 2022). Their experiences with a rare disease are the key to quantifying a rare disease market for the profit-centric industry, justifying the unmet medical needs for policy support, and de-risking the drug development process by providing insights to treatment expectation and meaningful endpoints (Beaverson et al., 2023). Various forms of patient organizations have multidimensional contributions to orphan drug development. First, patient advocacy groups are shaping public research funding decisions that can direct the course of early R&D activities, while simultaneously influencing government reimbursement decisions, which have significant impacts on the sale’s performance of an orphan drug's post-approval (Gentilini & Miraldo, 2023; Wood et al., 2013). Second, some patient and philanthropic groups would fund rare disease research directly (Hegde & Sampat, 2015; Wästfelt et al., 2006) and establish biotech companies or research foundations to develop orphan drugs themselves (Kucukkeles et al., 2019; Lim et al., 2016; Marra, 2022). They can both mobilize collaboration across different knowledge fields through community building and leverage the knowledge creation potential within the patient community, thereby providing unique advantages particularly to the drug repurposing process (Kucukkeles et al., 2019). Third, patient groups provide important scientific and operational resources to drug development. They gather value data, such as the natural history of a rare disease, to create diseases and patient registry, which are extremely helpful with trial design and disease-stage stratification. Their patient outreach, network building, and community support activities can help disseminate information about clinical trials and ongoing R&D programs, increasing the clinical trial recruitment rate and research awareness (Beaverson et al., 2023; Wood et al., 2013). The National Organization for Rare Disorders (NORD) is a strong example of a multifunctional, patient-led organization that encompasses all the contributions mentioned above. They catered different resources to patients, clinicians, researchers, and drug developers, acting as one of the most active POs in rare disease research and orphan drug development.

***Academic***

Academic researchers’ involvement in orphan drug development arises from their interest in rare disease research, an area offering significant opportunities for scientific discovery and technological innovation. Consequently, their focus is primarily on the earliest stages of disease research, concentrating on disease mechanisms or biological targets rather than specific drugs (Das et al., 2019; Joshi et al., 2021). Nonetheless, academic researchers' efforts in developing repurposed drugs indicate that they may share patients' concerns regarding high orphan drug prices (Davies et al., 2017), which could serve as an additional motivation for their participation in orphan drug development.

Through their studies, academic researchers provide valuable knowledge and data on rare diseases. Their studies can reveal the underlying molecular mechanisms of compounds, the pathogenesis of diseases, and potential therapeutic approaches (Moors & Faber, 2007), all of which are critical for the successful development of orphan drugs. Furthermore, academic researchers play a crucial role in making orphan drugs more accessible by advancing drug repurposing initiatives. They are able to achieve this primarily through two approaches: drug rediscovery and redirection (Kesselheim et al., 2015). First, researchers often test drugs that have lost patent protection or investigate compounds shelved by companies due to unsuccessful development projects. Through both deliberate study and occasional unexpected findings, they may uncover new therapeutic effects of these compounds on biological targets associated with rare diseases, thereby giving these drugs “a second life”. Second, researchers specializing in certain disease mechanisms may be able to align existing drugs with these diseases, thereby guiding subsequent development efforts for those drugs.

***Clinician***

There is limited discussion regarding the motivations of clinicians and healthcare professions to participate in orphan drug development. However, clinicians from academic hospitals and university medical centers might share the same interest as academic researchers in advancing scientific discovery in rare diseases. Moreover, the practice of off-label prescribing (Dooms et al., 2016; Rusz et al., 2021) suggests that clinicians are genuinely motivated to improve the health and well-being of patients with rare diseases, and being involved in orphan drug development may further reinforce this commitment.

Clinicians, as both care providers and primary investigators in clinical trials, can obtain first-hand knowledge of the clinical presentation and progression of rare diseases in patients. Through their treatment experiences, clinicians accumulate critical insights into effective therapeutic approaches for these conditions. Such insights can facilitate the effective treatment design, including key elements of an ideal drug such as dosage form and delivery method (Das et al., 2019). Furthermore, clinicians can form an extensive research and clinical networks focused around rare diseases of their interests. This serves as a valuable resource for drug developers, as clinical trials for rare diseases often need to be conducted across multiple centers and internationally, due to the limited and geographically dispersed patient population (Moors & Faber, 2007). Lastly, clinicians contribute to orphan drug repurposing. The off-label use of common and orphan drugs for secondary indications allows clinicians to observe unexpected effects, thereby identifying potential new applications for these drugs (Kesselheim et al., 2015). While off-label use carries certain risks (Verbaanderd et al., 2020), this practice can guide future research and facilitate the formal clinical evaluation of these drugs for new therapeutic purposes.

***Government***

The government is concerned with orphan drug development because treating rare diseases is part of the broader public health initiatives. More specifically, it is an issue related to the equality of access (Franco, 2013; Gamba et al., 2021). The government needs to ensure rare disease patients also benefit from medical progress, and drug developers will not focus their attention and resources only on making blockbuster drugs. Legislation effort such as the 1983 Orphan Drug Act in the U.S. and subsequent orphan drug policy development effort from countries in Europe and Asia (Chan et al., 2020) demonstrate the global commitment to fostering equity in orphan drug development for rare diseases.

The government contribute to orphan drug development mainly through its research bodies (i.e. the NIH in the U.S. and the NIHR in the UK) and regulatory agencies (i.e. the FDA and EMA). At the early stage of orphan drug development, government research bodies provide fundings in the form of grants to facilitate disease research and translational science (Davies et al., 2017; Pariser & Gahl, 2014). Initiatives are also taken to fund smaller organizations that focus on different segments of the development process, as well as programs that target at establishing the infrastructure to catalyze collaboration between the public and private sectors (Das et al., 2019). Once orphan drug projects receive orphan drug designation, regulatory agencies provide guidance and support, particularly to smaller and less experienced companies, to advance these projects further (Heemstra et al., 2008). Additionally, these agencies offer a range of “push” and “pull” incentives (Michaeli et al., 2023; Rzakhanov, 2008; Scott et al., 2001), therefore reducing investment costs and enhancing the economic feasibility of orphan drug development for drug developers.

The motivation analysis highlights that various stakeholder groups have distinct incentives. Large pharma and biotechnology companies are drug (product) oriented, while patients, academic researchers and clinicians are primarily disease focused. The government concerns with both perspectives but maintains an overarching aim of enhancing public health. These differing motivations may be one of the factors resulting in the varied perceptions and prioritizations of the challenges associated with orphan drug

development (Moors & Faber, 2007). But at the same time, these differences also drive the stakeholder groups to engage in specific stages of the orphan drug development process. This is supported by the contributions analysis, which illustrates the unique inputs each stakeholder group offer. These contributions are difficult to replace, as they are closely linked to the stakeholders’ roles and are heavily reliant on their respective resources and expertise. The activities undertaken are also interconnected and interdependent. For example, the development of patient registries is typically led by patient organizations, but it can also include inputs from clinicians. Such data can subsequently be utilized by academic researchers to advance their studies and by pharmaceutical companies to design clinical trials. Similarly, the presence of research and R&D networks is essential before the government can set up programs to foster partnerships among these entities. Lastly, contributions from patients, clinicians and government demonstrate that these stakeholder groups are not passively involved in orphan drug development. On the contrary, their active participations are as critical and irreplaceable as those from the private sector.

**Discussion**

Orphan drug development is different from that of conventional drugs. The development timeline consists of a much more uncertain early research period and case-by-case clinical trial process. Using the framework of exploration and exploitation in organization learning, we categorize orphan drugs into four type: first-in-class, best-in-class, repurposed (new indication), and repurposed (supplement), where FIC and BIC are exploratory drug development activity and both kinds of repurposed are exploitative activity. The differences between exploration and exploitation mean the knowledge, resources and capability required to develop the different types of orphan are not the same. Through an in-depth literature analysis of the motivations and roles of different stakeholder groups, this paper shows that these different groups play critical roles in orphan drug development. Their unique capabilities are irreplaceable in both the development of NMEs and repurposed drugs. Therefore, orphan drug development should be viewed as a co-creation process instead of a privately funded, industry-led, for-profit business endeavor. Active engagement from different stakeholder groups is required for developing both NCEs and repurposed orphan drugs.

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How Do Multinationals React to Political and Social risks through Adopting Nonmarket Strategies?

**Abstract**

Amidst the increasingly turbulent international arena, multinational enterprises (MNEs) face a wide range socio-political risks that are complex and multifaceted. This systematic literature review documents findings from 147 peer-reviewed articles to synthesize how MNEs employ nonmarket strategies to manage socio-political risks. Our review identifies the variety of socio-political risks confronted by MNEs and introduces a new typology that categorizes these risks based on their geographical reach and temporal persistence. Our findings uncover how MNEs implement nonmarket strategies to navigate these risks in the face of heightened geopolitical conflict, protectionism and anti-globalization sentiment. The study contributes to the literature by proposing a new typology of socio-political risks, offering a consolidated view of nonmarket strategies, and identifying gaps for future research. In doing so, we extend scholarly knowledge of nonmarket strategy in managing socio-political risks that can have important implications for enhancing the resilience and performance of MNEs in turbulent environment.

**Keywords: MNEs, Nonmarket Strategies, Socio-Political Risks, Performance, Literature Review, Turbulent Environments**

1. INTRODUCTION

The increasingly turbulent and complex international environment in last decades present a multitude of challenges to multinational enterprises (MNEs), thus making the management of risk pivotal to their operation and performance. MNEs operate globally integrated investment networks often within a fractured nonmarket environment of different national political and social systems, characterised by increasing conflicts within and between countries. This highlights the importance of addressing socio- political risks in cross-border business operations (Kobrin, 2015; Shirodkar, Liedong, Rajwani & Lawton, 2024). Rising geopolitical tensions, protectionism, and the Global North – South divide have spurred scholarly debates in international business (IB) and strategic management (Contractor, 2022; Petricevic & Teece, 2019), these tend to advance knowledge on how firms use market strategies such as location choice or global value chains restructuring to achieve resilience and sustainable growth (Chen, Giroud, Rygh & Han, 2024; Gereffi, Lim & Lee, 2021; Gereffi, Pananond & Pedersen, 2022). A more recent body of knowledge explores the use of nonmarket strategies to overcome heightened turbulences within and across borders.

As an integral part of business success, nonmarket strategies (NMS)[1](#_bookmark50) refers to ‘a firm’s concerted pattern of actions to improve its performance by managing the institutional and societal contexts of economic competition (Mellahi, Frynas, Sun & Siegel, 2016, p.144). To date, extant literature has looked at how firms implement nonmarket strategies, corporate political activity (CPA) and corporate social responsibility (CSR), to safeguard business operations in adverse political and social environment (See John & Lawton, 2018; Sun, Doh, Rajwani & Siegel, 2021 for reviews). Research has shown how MNEs, predominantly from developed countries, use lobbying, inducement and low visibility to mitigate their vulnerability against discretionary policy change, corruption, social upheaval and warfare in developing host countries (Keillor, Wilkinson & Owens, 2005; Puck, Rogers & Mohr, 2013). Research also draws attention to the rise of developing country firms in past two decades and how those firms devise NMS to navigate hazardous political environment, leveraging

1 In line with Sun, Doh, Rajwani and Siegel (2021), we use the term nonmarket strategy and its abbreviation NMS when looking at the research domain. The plural form of nonmarket strategies refers to specific strategies implemented by MNEs to address socio-political risks

intergovernmental agreements and political skills honed by their underdeveloped home-country institutional environment (Shapiro, Vecino & Li, 2018). Thus, this literature shows the critical role of NMS for MNEs to operate in and from risky environments. Becoming resilient through such strategies becomes all the more important given recent events such as global powers’ rivalry for economic and technological dominance, onsets of wars in different parts of the world, the rise in social risks linked to increasing inequalities, aftermaths of the COVID-19 crisis, populism movements and a renewed appetite for protectionism by governments in developed and developing countries alike (Lundan & Cantwell, 2020; Zhan & Santos-Paulino, 2021). Heightened socio-political risks are inter- related, they change and evolve continuously – often in a co-evolutionary process with MNE strategies (Cantwell, Dunning & Lundan, 2010; Sun et al., 2021), and have profound influences over cross-border business activities (Contractor, Cantwell, Gereffi, Sauvant & Zhan, 2023). Yet, to date, research has not consolidated existing knowledge on how NMS respond to the variety of existing and novel risks (White III, Rajwani & Lawton, 2021). Research tends to focus on specific types of NMS or specific types of risks. Thus, it becomes imperative to synthesize extant literature to better understand how MNEs manage socio-political risks through effective deployment of non-market strategies in today’s ever changing and turbulent world.

The goal of this review is to consolidate the fragmented literature on MNEs’ NMS in the context of socio-political risks by presenting existing conceptual and empirical results, proposing frameworks and identifying critical gaps in knowledge. Our review addresses the following questions: (1) *what nonmarket strategies have MNEs adopted in contexts where socio-political risks prevail*, and (2) *what are the frontier issues in the field that warrant scholarly attention for future research?* To provide answers to these questions, we conduct a systematic literature review, analysing a database of carefully identified 147 papers published from 2002 to date in international business, general management, strategy, business history, social sciences and organisational sciences journals.

Undertaking a review focused on MNEs’ NMS in addressing socio-political risks, we make several key contributions. First, we identify the variety of socio-political risks analysed in previous research and provide a new typology by accounting for the increasingly complex and turbulent international

environment manifest socio-political risks in terms of their geographical reach, i.e. within and cross- country risks; and temporal persistence, i.e. ongoing and abrupt risks faced by MNEs. Second, based on our typology, we critically review extant body of literature on NMS that have been developed and implemented by MNEs to address socio-political risks. By doing so, we extend previous research that focused on political risk management (e.g., John & Lawton, 2018) by integrating social risks for a holistic understanding of CPA, CSR and their interplay in shaping MNEs’ performance. Third, we identify frontier issues and propose ways to move the research agenda on our topic forward.

The next section explains our review boundary and methodology. Section 3 provides a descriptive overview regarding article distributions, methodological approaches, country and regional focus, and theoretical perspectives being used by previous research. Section 4 presents our typology to categorize socio-political risks faced by MNEs, hence synthesizing the NMS being implemented and associated firm performance. This is followed by discussion about future research directions in Section 5.

1. REVIEW BOUDARY AND METHODOLOGY
   1. **Review Boundary**

To provide a coherent review, we draw the boundaries of our work by defining the disciplinary scope and key concepts. In line with the seminal work by Sun et al. (2021), our review of MNEs’ strategies to address socio-political risks and performance implications locates in the domain of NMS research. This line of literature seeks to explain the development and implementation of various NMS that may allow MNEs to prepare for, engage, respond to and/or overcome risks arise from the external political and social environment. Managing the complex interplay of these environmental challenges through effective CPA, CSR and their integration at firm, industry and country levels are not only critical to MNEs’ pre-entry decisions, but also performance outcomes thereafter (John & Lawton, 2018).

Given the sizeable body of NMS research, review works have delved into, for example CPA including its antecedents, implementation and outcomes (Hillman, Keim & Schuler, 2004; Lawton, McGuire & Rajwani, 2013); political risk management (John & Lawton, 2018); and generic strategies in

explaining MNEs’ entry and operation in different market contexts (Dorobantu, Kaul & Zelner, 2017; Rajwani & Liedong, 2015). Additionally, the firm – government interaction through various CPAs and their ethical implications have motivated NMS research to bridge CPA and CSR literature, hence call for unpacking MNEs’ NMS from multiple theoretical lenses and research disciplines (Mellahi et al., 2016; Sun et al., 2021). Concurrently, international business environment in last decades has experienced dramatic change from economic cooperation to increasing tensions between major economies, geopolitical conflicts, protectionism and bottlenecks faced by international institutions in moving forward multilateral agreements for sustainable development agenda (Contractor, 2022; Gereffi, 2023; Sauvant, 2015). The increasing range of socio-political risks within and across state borders as well as their ongoing and episodic influence on business operations have stimulated discussions in IB and strategic management (Contractor et al., 2023; White III et al., 2021). Therefore, it suggests the need to structure the scholarly debates by integrating these latest trends. Our review identifies and analyses the state of knowledge about MNEs’ NMS in addressing socio-political risks in today’s increasingly turbulent world, hence their performance implications. Next, we explain the review methodology and process.

* 1. **Methodology**

With the aim of synthesizing extant research on MNEs’ NMS for managing socio-political risks, we adopted a systematic literature review approach. We focused on peer-reviewed articles published in English within leading journals in the fields of General Management, IB, Strategy, Business History and Economic History, and Organization studies, and Social Sciences. In line with journal selection method that has commonly adopted in IB reviews (e.g., Zhao, Liu, Anderson & Shenkar, 2022), we looked at journals ranked 3 and above, as defined by the Association of Business Schools (ABS).

To provide a clear path for the review process, we take a structured approach to search and select articles following the steps outlined by Webster and Watson (2002). Overall, we proceeded in three stages of keywords identification and refinement for article searching, article selection and coding.

*Stage 1. Identifying and refining keywords*

There are three constructs in the review question namely: (1) socio-political risk, (2) nonmarket strategy (NMS), and (3) MNEs. We started with reading into review articles on socio-political risk management and its anchoring field of NMS to identify keywords (e.g., John & Lawton, 2018; Sun et al., 2012). This generated an overarching set of keywords include “socio-political risk”; “political risk”; “corporate political strategy”; “corporate social responsibility”, “nonmarket strategy” and “multinational enterprises”. Guided by this initial set of keywords, we conducted the pilot search from Web of Science Core Collection database, which is known for its broad coverage in the social sciences, arts, and humanities (Gurzki & Woisetschläger, 2017). The pilot search yielded 56 articles. This narrow body of results alert us that research about MNEs’ NMS in addressing socio-political risks may become increasingly sophisticated in kinds and coverage, which commanded us to complement the initial searching terms with an expanded set of keywords.

Building from the pilot search, and in line with previous research (Han, Lukoianove, Zhao & Liu, 2024), we adopted a literature-reasoning based approach for keyword expansion (e.g., Kobrin, 2015; Röell, Osabutey, Rodhers, Arndt, Khan & Tarba, 2022) to refine our search. Firstly, we analysed the keywords and abstracts of an initial set of 56 articles to establish a foundational list of terms related to the socio-political risks faced by MNEs and their adopted NMS. This step ensured we captured essential terminology frequently used in discussions about MNEs and socio-political risks. Moreover, we conducted a thorough review of theoretical and perspective articles (e.g., Kobrin, 2015; Röell et al., 2022) to enhance our understanding of new and emergent socio-political risks. This review helped us identify additional complex terms such as "populism", "geopolitical risk", "diplomatic tension", "terrorism", and "military conflicts", which are increasingly relevant in today’s turbulent international environment. Furthermore, the overarching terms of CPA and CSR were decomposed to specific strategies deployed by MNEs like “lobbying”, “political connection”, “bribery” and “political donation”.

Next, we conducted a new round of search by utilizing the refined and updated search strings (see Appendix A), with 214 papers turned up in our result that comply with the specified criteria for article type, language, and publication title. The last search was conducted on 15 February 2024.

*Stage 2. Article selection process*

In the second stage, we engaged in article selection based on a number of inclusion and exclusion criteria. To make sure coverage, the authors independently screened the title and abstract of each paper, followed by discussions to evaluate their relevance. Differences in understanding have been reconciled through constantly reflecting upon our central research question(s) (1) does the paper look at MNEs’ NMS in addressing socio-political risks?; and (2) whether it discussed the performance implications for MNEs?. We discarded research examining NMS to deal with socio-political risks in domestic setting. Moreover, we excluded papers that look at risks such as resource shortage, exchange rate volatility and natural disaster that arise from market and natural forces. These steps based on the exclusion criteria provided us a sample 156, which we then exported to the Endnote reference manager software. After reading all the articles in full and conducting a comprehensive assessment, our final sample comprised 147 papers. Table 1 presents the process of keywords identification and article selection.

|  |  |
| --- | --- |
| **Table 1. Overview of the search strategy** |  |
| **Databases used: Web of Science Core Collection database**  **Filters:**  Only peer-reviewed articles Only English  Only categories of International Business, General Management, Strategy, Business History and Economic History, and Organization studies, and Social Sciences  Only Journals ranked 3, 4 and 4\* by the ABS ranking | |
| **STEPS in Inclusion/Exclusion** | **Number of articles** |
| Pilot study to identify relevant search strings | 56 |
| Initial sample with refined search strings | 707 |

|  |  |
| --- | --- |
| Sample after filtering by language, article type and publication title | 214 |
| Sample articles after initial relevance check:  Reading the titles, keywords, and abstracts, and eliminating any non-relevant articles | 156 |
| Sample articles after in-depth relevance check:  Reading the full texts of articles and eliminating any non-relevant ones | 147 |
| **Final sample:** |  |
|  | 147 |

*Stage 3. Coding and analysis strategies*

We proceeded with the analysis of the articles in our database, first coding the literature across descriptive dimensions, including publication title, author details, publication time, citation number. Our coding then focused on identifying the primary theories within the studies, research methodologies adopted, and contexts of the research. The theories encompassed broad social science theories like institutional theory, as well as narrower ones, such as agency theory. We coded the research methodology used in the studies. We firstly distinguished between conceptual and empirical articles. The former included theory-building works, literature reviews, perspectives, and overviews of journal special issues (Sun et al., 2021). The latter was subsequently categorized into quantitative, qualitative, and mixed methods research. Additionally, we also coded the geographical context of empirical research, categorizing into developed economies (e.g., North America, Europe) and developing economies (e.g., East and South-East Asia, Latin America and the Caribbean).

Secondly, to conduct the analysis of the complex dynamics between MNEs’ NMS in addressing socio- political risks and firm performance, we synthesize extant literature on socio-political risks, MNEs’ NMS and their performance implications into an initial framework (see Fig. 1). The framework guided coding of different categories of socio-political risks encountered by MNEs and the various NMS they employ to manage these risks. To assess risks, we identify and code types of socio-political risks faced by MNEs, encompassing both *political* and *social* dimensions. Based on insights from the

literature (Cuervo-Cazurra, Duran, Arregle & van Essen, 2023; White III, Hemphill, Joplin & Marsh, 2014), we broadly code the political risks encountered by MNEs into four main categories: political stability risks, legal and regulatory risks, government governance risks, and international relations and geopolitical risks.

Moreover, we establish a detailed socio-political risks typology (see Findings section) that classifies these risks based on their geographical impact scope and temporal characteristics. Next, to account for the breadth of existing NMS and the objective to analyse MNEs’ strategies towards both social and political risks we adopted the categories proposed by Dorobantu et al. (2017), who suggest that firms can manage institutional environment in three ways: by *adapting* to existing institutional environment; by adding to the institutional contexts by establishing supplementary local institutional structures; or by transforming the institutional context itself. Firms undertake these strategies either independently or in collaboration with others. The strategic intent (whether adaptive, additive, or transformative) and the governance mode (independent or collaborative) determine the categorization of the NMS into six types of post-entry: internalization, partnership, proactive, collective, influence, and coalition. We also coded the associated firm performance to assess the effectiveness of these strategies. This theory-led approach enabled us to identify and code various NMS employed by MNEs to address socio-political risks. The final part of the framework guided coding on performance outcomes – e.g. how, in environments characterized by high socio-political risks, NMS affect firm performance. Here, coding was drawn from the sample, and resulted in two distinct types of performance outcomes, namely external outcomes such as reputational effects and stakeholder relationships, and internal outcomes including financial performance and innovation capabilities.

**Figure 1. Review framework of socio-political risks, MNEs’ nonmarket strategies and performance outcomes**

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1. DESCRIPTIVE OVERVIEW OF THE LITERATURE

In this section, we present descriptive results of our literature review, organized according to the key data coding categories we adopted. Our analysis of these findings has yielded some insights into the evolution and focus of research on MNEs’ nonmarket strategies in addressing socio-political risks.

* 1. **Results by Year**

A temporal analysis of the 147 papers in our sample shows that 105 (71%) were published after 2015 (see Fig. 2). The rapid increase of publications over the last decade could be attributed to a range of factors. Notably, the threats of terrorism, rising populism and anti-globalization sentiment, U.S. – China trade tension and techno-nationalism that have been accelerated by the COVID-19 pandemic. The dramatic change of international political and economic environment not only requires MNEs to undertake strategic transformations, but also more academic research on socio-political risk management (White III et al., 2021).

**Figure 2. Number of publications per year**

20

18

16

14

12

10

8

6

4

2

0

17

18 18

12

9

7 7

8

7

7 7

5

6

4

1 1

2

3 3

1

2

2

0

Number of Publications

* 1. **Results by Journal**

2002

2003

2004

2005

2006

2007

2008

2009

2010

2011

2012

2013

2014

2015

2016

2017

2018

2019

2020

2021

2022

2023

2024

Appendix B reports the distribution of articles across different journal outlets. As shown in the table, a total of 62 articles were published in IB journals, contributing 42.2% of total publications. Within this category, Journal of International Business Studies has published 20 articles (13.6%), which indicates the popularity of NMS research in this journal. In addition, General Management journals also contribute a significant number of articles (39.5%) on the topic.

* 1. **Results by Method**

Of the 147 articles, 25 (17.0%) were conceptual in nature, taking the form of theory development works, literature reviews, and introductory article of journal special issues, with IB journals publishing 44% of these. The sample dataset includes 7 literature review articles that has explored the multifaceted impact of corruption on MNEs (Bahoo, Alon & Paltrinieri, 2020; Frei & Muethel, 2017), strategic decisions firms make to navigate corrupt environments and their subsequent effects on performance (Galang, 2012), the interactions between digital technologies and corrupt practices (Malik & Froese, 2022), the impact of ESG issue on business risk management (Gomez-Valencia, Gonzalez-Perez & Gomez-Trujillo, 2021), the dynamics between MNEs and supranational institutional environments (Hartmann, Lindner, Müllner & Puck, 2022), and the intricate relationships between host country politics and MNEs’ internationalization strategies (Cuervo-Cazurra et al., 2023).

The majority were empirical, with 81 articles (55.1%) using quantitative research methods and 34 (23.1%) employing qualitative methods. Only 7 article (4.8%) combined qualitative and quantitative methods. Within the quantitative research category, 63 articles (77.8%) collected secondary data, 11 (13.6%) used survey, 5 (6.2%) combined survey with archival data, and 2 (2.5%) adopted content analysis. Moreover, 64 articles explored one type of NMS in the study, while 17 articles examined multiple NMS in the study. Additionally, quantitative research predominates in General Management journals. Regarding qualitative studies, IB journals accounted for approximately 44% of the total, and they predominate in the Business History and Economic History field. Among these qualitative articles, the majority are case studies, accounting for 29 articles. Additionally, there are 4 articles that used interviews and 1 article that employed ethnographic fieldwork.

* 1. **Results by Country/Regional Focus**

In this section, we review the home and host country/regional contexts that have been discussed by the articles in our sample (see summary table in Appendix C). Looking into the home dimension, there has been a significant concentration of research on MNEs from developed economies, notably North America, Western Europe and Japan. This suggests the salience of these countries/regions as sources of foreign direct investment (FDI) and the global reach of their MNEs. Moreover, there has been a burgeoning interest in MNEs from emerging markets, include China, India, Latin America and the Caribbean, and Southeast Asia that echo their rapid economic growth and eagerness for catching up through outward FDI.

On the vantage of the host country, research predominantly focuses on emerging markets, such as Other Africa, China, Latin America and the Caribbean, Southeast Asia, and Eastern Europe and Russia. The effective deployment of NMS against the lack of political constraints on policymakers, unexpected change of political regime and weak legal enforcement are critical for MNEs’ survival and success in these markets. However, a limited number of publications examined MNEs operating in West Asia and North Africa.

It is interesting to note that throughout both the home and host country dimensions, research in the Chinese context is notably prevalent. This not only underscores China’s significance in both inward

and outward FDI, but also the daunting challenges facing MNEs originated from and operating in the country.

* 1. **Results by Theory**

Our analysis of the sample articles reveals a number of interesting patterns about the theoretical perspectives that have been incorporated to explain how MNEs use NMS to deal with, respond to and overcome socio-political risks. First, extant literature integrates a diverse range of theoretical perspectives, primarily from management and IB fields, but are increasingly enriched by arguments from political science (14 instances). These evidenced endeavours of NMS scholarship in calling for the cross-fertilization of knowledge by incorporating research from other disciplines (e.g., Jandhyala & Weiner, 2014; Shirodkar et al., 2024). Second, similar to previous reviews in NMS research (e.g., John & Lawton, 2018; Sun et al., 2021), institutional theory and its variants emerge as the dominant paradigm, accounting for 64 instances. This highlights the role of institutional environment that may present both opportunities and challenges for MNEs to devise effective NMS in managing socio- political risks. Third, other prominent theories in this field include stakeholder theory (16 instances), resource and capability-based view (14 instances), and resource dependence theory (14 instances).

Appendix D presents major theoretical perspectives that have been used by research on MNEs’ NMS in addressing socio-political risks.

1. FINDINGS ON MNEs’ NONMARKET STRATEGIES and SOCIO- POLITICAL RISKS

This section synthesizes the findings of the literature on MNEs’ NMS for managing socio-political risks.

* 1. **Socio-political Risk**

Drawing on the literature, we characterize socio-political risks as comprising: (1) political risk, defined as the 'unpredictability and instability of political, legal, and regulatory conditions' stemming from government (Panibratov, Herrera, Esquerdo & Klishevich, 2023, p. 185); (2) social risk,

originating from broader societal dynamics and manifesting in various forms like social unrest, riots, and demonstrations (Miller, 1992).

* + 1. *Political risk*

Political risk has been an enduring topic in IB and strategic management scholarship (Chen et al., 2024). Our review suggests that research has predominantly focused on political risks and their profound influence on cross-border business operations (e.g. 127 publications, see Appendix E). Using initial main categories: political stability risks, legal and regulatory risks, state governance risks, and international relations and geopolitical risks, our review helps us uncover types of risks MNEs address through NMS.

Political stability risks, associated with shifts in the political regime and acts of political violence, can manifest in extreme forms such as military coups, revolutions, or other forms of political unrest (Miller, 1992). It can also take on moderate form, as in election-induced changes in party in power (Hung, Kim & Li, 2018) and shifts in key leadership positions (Nayak, 2021), impacting the continuity and predictability of governmental regulatory policies.

Legal and regulatory risks studied are associated with abrupt changes in judicial decisions arise not only from the overthrow of the ruling regime, but also from governmental discretion in policy making and limited credibility of its commitments for policy stability (Jiménez, Benito-Osorio & Palmero- Cámara, 2015). The presence of legal and regulatory risks such as deficient protection of Intellectual Property Right and ownership/control restrictions represent significant threats for MNEs’ innovation and financial performance (Amankwah-Amoah, Boso & Kutsoati, 2022; Keillor et al., 2005).

Among government governance risks, public corruption, which is defined as “an agreement between two parties where public power is abused for private ends” (Sampath & Rahman, 2019, p. 819), has garnered significant attention in our literature review (some 89 studies cover these risks, see Appendix E). Beyond corruption, government governance risks also stem from cumbersome bureaucratic processes that complicate tasks such as obtaining licenses or settling taxes (Yi, Chen, Meng, Li & Shaheer, 2023), and from erratic and arbitrary enforcement due to a lack of uniform and transparent

governance standards (Albino-Pimentel, Dussauge & Shaver, 2022). Additionally, MNEs may encounter government interventions risks that range from protectionism in favour of domestic firms (Teece, 2022) to home government interferences to pursue political objectives (Detomasi, 2015).

Other types of political risks presented in studies include the “distance between home and host government relations” (De Villa, Rajwani, Lawton & Mellahi, 2019). Ideological differences, contest for technological dominance, and reduced economic interdependence evidenced by the U.S. – China tensions across a number of domains can pose perpetual and complex challenges to MNEs. Sanctions or other punitive measures from either side of the geopolitical divide can, complicate their operations and strategic planning (Teece, 2022). Despite the significance of these issues, only a small number of studies in our dataset—12 articles focus on risks arise from an increasingly tensed international political environment. The relative scarcity of research in this area pinpoints the opportunity for future research to explore how MNEs manage risks in the broader geopolitical environment.

* + 1. *Social risk*

Our analysis of extant literature suggests that social risk received considerably less attention than political risk, appearing in only 45 papers (see Appendix E). Social risk refers to the potential for social disturbance, conflicts, and social damages that arise when the beliefs, values, and attitudes prevalent among a population do not align with existing government policies or business practices (Lupu, 2019; Miller, 1992).

This type of risk often originates from identity-based factors, such as national, ethnic, racial, religious, or other demographic divides (Ganson, He & Henisz, 2022). The divisions between these different identity groups can foster social risks by intensity feelings of relative deprivation and injustice among disadvantaged groups, leading to heightened intergroup conflicts (Ganson et al., 2022). A historical manifestation would be the rise of economic nationalism and anti-capitalist sentiments in less developed countries where MNEs were viewed as symbols of imperialism and economic neo- colonialism (Decker, 2011; Kaplan, 2024).

Moreover, social risks can be triggered by public demonstrations and movements advocating societal changes against human rights abuse. This may present substantial challenges for MNEs to manage protests, demonstrations, corporate campaigns, and boycotts in home country aimed at pressuring them to withdraw their investments (Soule, Swaminathan & Tihanyi, 2014). Additionally, social risks can stem from various forms of crime and violence within local communities that undermine public safety, social cohesion, and the stability of business operations (Kehoe & Greenhalgh, 2019).

* + 1. *The interplay between political risk and social risk*

It should be noted that political risk and social risk are interrelated and often coexist rather than function independently (Miller, 1992). Social risk can indeed be a precursor to political risk, as seen when social movements precipitate legal and regulatory changes (Meyer & Thein, 2014).

Concomitantly, political risks can give rise to social risks as antagonistic political relationship between home and host governments can provoke negative public sentiment and backlash that adversely impact on cross-border business activities (Decker, 2011).

* + 1. *Socio-political Risk Typology Within-country risk vs. Cross-country risk*

Based on the scope of impact, socio-political risks are categorized into within-country risk and cross- country risk. Studies in the sample focus either on within or cross-country risks. Within-country risks are typically associated with weak institutional environments within home or host countries, such as bureaucratic inefficiencies and incomplete judicial system. In contrast, cross-country risks include bilateral risks between two countries, regional and international socio-political risks. As socio- political risks evolve over time, the focus of research is also in transitions. Early research has predominantly focused on within-country socio-political risks that reflects a generally cooperative international environment featuring economic liberalization, multilateralism, and free trade during the early 2000s (Dreiling, 2020). However, recent years have seen a rise in anti-globalization movements, populism, sanctions, and geopolitical tensions, highlighting rising conflicts between major economies and protectionism as significant sources of risk for MNEs (White III et al., 2021).

*Ongoing risk vs. Abrupt risk*

From our sample, research also differentiates between ongoing or abrupt risks. Ongoing risks are characterized by their persistence and gradual development over a prolonged period, often arising from structural issues within a government and society, such as pervasive corruption and continuous government interference. These risks are relatively predictable and can be mitigated through continuous monitoring and pre-emptive risk management strategy (Ballesteros & Magelssen, 2022). However, abrupt risks are sudden and unexpected events that can significantly disrupt the status quo without warning, including the outbreak of military conflicts, abrupt legislative changes, and the overthrow of political regime. These risks are challenging to predict and monitor, requiring MNEs to adopt immediate and often flexible measures to manage their impacts.

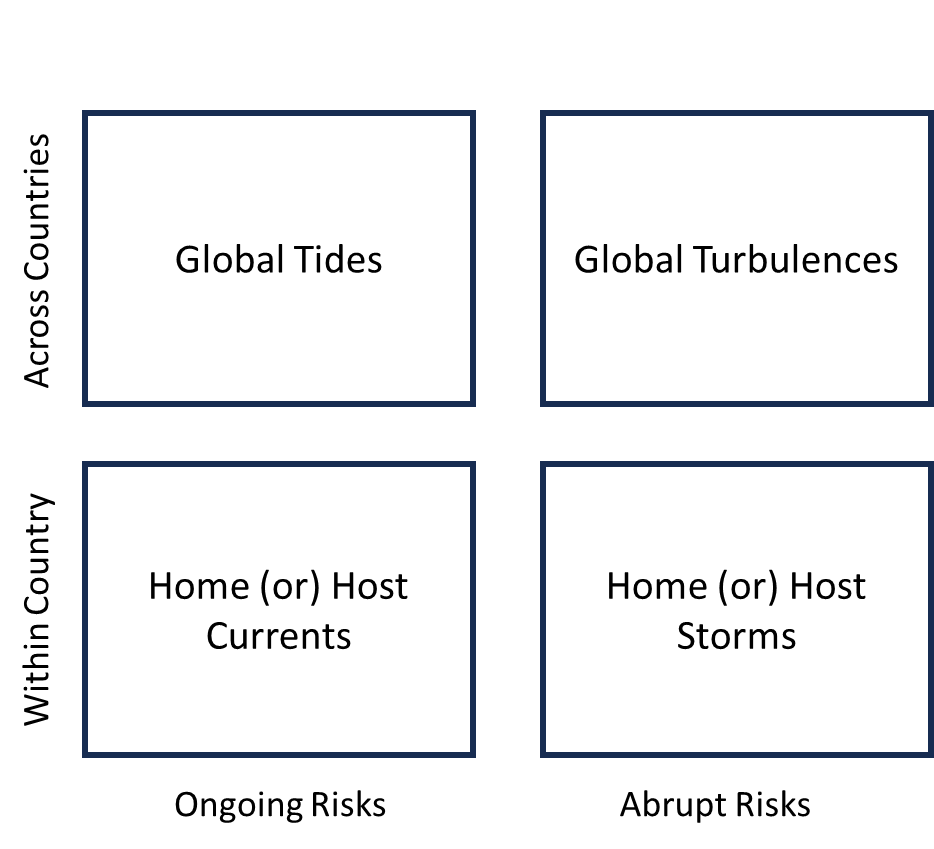
*Socio-political Risk: A 2 x 2 matrix*

Based on results regarding the geographical impact scope and temporal persistence of socio-political risk, we propose a Socio-political Risk Matrix that guides various types of NMS adopted by MNEs (see Fig. 3). The matrix compromises four quadrants: Home/host Currents presents within-country and ongoing risks that continuously present and shape the landscape quietly but powerfully, such as enduring government corruption, persistent judicial system incompleteness and prolonged ethnic conflicts; Home/host Storms captures the disturbances that arrive unexpectedly like sudden change in political regime and outbreaks of intrastate political violence. On a broader scale, Global Tides denotes ongoing and cross-country risks like ocean tides, affecting regions beyond national boundaries enduringly such as nationalistic rhetoric and stringent international sanctions. Lastly, Worldwide Turbulence encapsulates abrupt, cross-country risks such as the sudden onset of geopolitical conflicts and the outbreak of pandemics, such as COVID-19, that spread across multiple countries.

Moreover, the various types of socio-political risks tend to be fluid and dynamic that may transit from one quadrant to another. For example, long-standing ethnic tensions within a country (Homegrown Currents) could escalate into the violent outbreaks and bloody clashes (Homeland Storms). Similarly,

the onset of Russia-Ukraine war (Worldwide Turbulence) could prompt the ongoing stringent regulatory restrictions or sanctions imposed by Western countries against selected Russian firms (Global Tides).

**Figure 3.** Socio-political Risk Matrix



* 1. **MNEs NMS to address Socio-political Risk**

Our analysis draws on an existing typology (e.g., Dorobantu et al., 2017), around three core types of NMS (i.e., adaptive, additive and transformative) and six categories, internalization, partnership, proactive, collective, influence and coalition strategies (see Appendix F). This enables us to identify how MNEs respond to socio-political risks in the first instance, and subsequently identify performance outcomes.

* + 1. *Adaptive approaches Internalization strategy*

De Villa et al. (2019) proposed that if a MNE’s senior management perceives high socio-political risk in host countries, the firm is inclined to choose a non-engaged NMS, which involves either avoiding or actively adapting to host country institutional environment. MNEs could deploy rapid low visibility strategy, compliance strategy, reconfiguration strategy and anticipation strategy – conducted within the firm boundary - to actively adapt to host country. Other studies (e.g., Decker, 2011; Akbar &

Kisilowski, 2023) also point to low visibility internal strategies, or high degrees of bureaucratic insularity to overcome riots or continue business through political changes.

*Partnership strategy*

In politically risky institutional environments where firms face the hazard of political regime change or state expropriation associated with this change, firms employ partnership strategies to limit their exposure to the socio-political risk (Dorobantu et al., 2017). At the point of entry, by forming international joint ventures (IJV) and alliances with local partners, MNEs could benefit from increased legitimacy and influence, superior access to information (Dorobantu et al., 2017), protection against expropriation and grand corruption (Boubakri, Mansi & Saffar, 2013), and preferential treatment in government policies (Durnev, Enikolopov, Petrova & Santarosa, 2015). Huang, Ozkan and Xu (2023) examined a large sample of cross-border alliance deals from 59 countries and found that MNEs are more likely to collaborate with local state-owned enterprises (SOEs) when facing high expropriation risks in the host country. However, Moschieri, Ravasi and Huy (2024) cautioned that while IJVs can initially help navigate the local nonmarket environment, overreliance on such partnership without direct engagement in the local community can reinforce a “liability of outsidership” and even inadvertently create a “liability of insidership”, reducing MNEs’ alertness and responsiveness to socio-political risks in host governments. Consequently, MNEs also implement other NMS post-entry to thrive in volatile socio-political landscapes.

Partnership strategies also involve establishing political connections with government officials at various, such as the ruling elite (Darendeli & Hill, 2016), officials in regulatory agencies (Jean, Sinkovics & Zagelmeyer, 2018), or state-supported organizations and enterprises (Huang et al., 2023). The case studies of MNE subsidiaries in sub-Saharan Africa indicate that, given the institutional structures in many African societies concurrently recognize authorities like national government, local chieftaincy, and religious leadership, MNEs operating in these contexts are required to build political ties with national political leaders and regulatory bodies, local kings and chiefs, religious leaders, and local opinion leaders (Amankwah-Amoah et al., 2022). Political connections have generally been perceived as NMS enabling firms to acquire resources and ensure legitimacy when institutional

environment is weak or inefficient (Jean et al., 2018). This is particularly the case for countries with prevalent corruption, low protection of property rights, and a highly interventionist or nondemocratic government that exercise unfettered power over resource possession and allocations (Amankwah- Amoah et al., 2022; Dorobantu et al., 2017). White III, Boddewyn and Galang (2015) found the positive association between managerial perceptions of legal system uncertainty and the intensification of MNEs’ political ties with host government in the Philippines.

Moreover, firms could also adopt partnership strategy by forming ties with other influential and locally knowledgeable stakeholders (Dorobantu et al., 2017). For example, confronted with significant socio-political risks in Spain during a period characterized by economic nationalism and political instability, International Telephone and Telegraph (ITT) formed strategic partnerships with local engineers and businessman. These relationships endowed ITT with crucial local knowledge and influence, thereby mitigating the “liability of foreignness” (Álvaro-Moya, 2015). However, research on this partnership strategy is still in its early stage. Future studies could therefore investigate how MNEs establish connections with these influential stakeholders to mitigate socio-political risk.

* + 1. *Additive approaches Proactive strategy*

Additive approaches supplement local institutional structures and hence lowering institutional costs for those firms that voluntarily participate in these strategies (Dorobantu et al., 2017). Firms can pursue an additive approach independently by proactively volunteering to share value with others unilaterally in the expectation of being rewarded for doing so by relevant stakeholders (Dorobantu et al., 2017). CSR, which refers to “the practice of incorporating stakeholder and shareholder interests in firm decision making, with an eye to increasing societal and shareholder value” (Detomasi, 2008, p. 807), could be considered as a form of proactive strategy. CSR activities, especially those providing basic infrastructure for local communities and filling development gaps in emerging countries, could enable firms to develop positive social reputation enhance the legitimacy of the firm in the eyes of community actors and politicians (Detomasi, 2008; Liedong, Rajwani & Mellahi, 2017). As a result, the increased legitimacy could reduce the exposure of firms to the socio-political risk such as political

authority’s intervention, discrimination or community revolts (Liedong et al., 2017). For instance, eight Turkish multinational construction firms invested in a wide range of public-benefit projects, including infrastructure such as road and water systems and development-oriented projects like universities and hospitals, to improve the legitimacy among their local stakeholders (Darendeli & Hill, 2016). Moreover, Shou, Shan, Shao, Lai and Zhou (2023) found that foreign small and medium-sized enterprises (SMEs) tend to employ corporate philanthropy and workforce localization as strategies to buffer against the violent risks associated with operating in conflict-prone zones.

*Collective strategy*

Firms could also augment the institutional environment by collectively developing new rules and norms with others such as trade associations and industry peer networks, to jointly create and manage common pool resources (Dorobantu et al., 2017). Keillor et al. (2005) proposed that forming alliances with other organizations within the same industry equips individual MNEs with a broader range of resources, which can be strategically directed towards addressing issues in the complex political environment. However, our dataset contains only four studies that explicitly detail how MNEs utilize collective strategies to mitigate socio-political risks, highlighting a potential avenue for future studies.

* + 1. *Transformative approaches Influence strategy*

Intended to alter the existing institutional environment, firms pursuing transformative approaches undertake various forms of influence strategy, including lobbying (Yu & Lee, 2021), campaign contributions (Jiménez, Luis-Rico & Benito-Osorio, 2014), political participation (Li, Wei, Cao & Chen, 2022), and engaging in actions of bribery solicitation (Akbar & Kisilowski, 2023). Galang (2012) contends that MNEs are not merely victims of corruption but are active participants in such practices. In order to hedge against political risk, companies seek to influence regulatory institutions by proactively offering financial inducements or specific information to legislators who formulate and modify regulations and policies, or to the regulators who implement and enforce them (Heidenreich, Mohr & Puck, 2015). Moreover, when confronted with adverse government actions, MNEs may

resort to legal challenges, including pursuing cases in domestic and international courts to protect their interests (Bucheli & Aguilera, 2010). For instance, in response to administrative bans imposed by the Swedish government, Huawei sought legal recourse through the Swedish courts to counteract the restrictions on its operations (Fjellstrom, Bai, Oliveira & Fang, 2023). Additionally, facing the threat of expropriations, MNEs may leverage legal agreements under international treaties or organizations, such as the World Bank, as a last resort to safeguard their investments (Moschieri et al., 2024).

*Coalition strategy*

Moreover, firms could also adopt coalition strategies to affect institutional changes by building horizontal coalition with any interest group that have the same demand for regulatory policy outcomes (Kingsley, Vanden Bergh & Bonardi, 2012). For example, a Chinese telecommunication company successfully built coalitions with local telecom service providers in India, enabling it to influence federal and local governments to secure preferential policies (Zhu & Sardana, 2020). Beyond local stakeholder alliances in host country, MNEs also form coalitions with their home country governments to leverage diplomatic relations for high-level political lobbying, aiming to navigate socio-political challenges more effectively (Nayak, 2021). An illustrative case is the Chinese government's support for Huawei, where the Chinese ambassador to Sweden publicly cautioned that Sweden's decision to ban Huawei might adversely affect Swedish companies like Ericsson operating in China (Fjellstrom et al., 2023).

* + 1. *Nonmarket strategies for managing various categories of socio-political risks*

This section first synthesizes key results, identifying the distribution of articles studying strategies utilised by MNEs in risky environments (see Appendix G), before presenting framework for analysing NMS and socio-political risks (see Fig. 4) drawn from the analysis of the papers.

For Home/Host Currents, there is a high utilization of proactive and influence strategies, with 45 and 44 articles respectively highlighting their prominence. Internalization (28 articles) and partnership strategies (38 articles) also play significant roles. The emphasis on proactive and influence strategies

suggests that MNEs actively seek to shape their operating legal and regulatory and social environment to mitigate long-term socio-political risks.

In contrast, when dealing with abrupt within-country socio-political risks (Home/Host Storms), there is a significant drop in the use of proactive (11 articles) and influence strategies (10 articles).

However, internalization (17 articles) and partnership strategies (15 articles) remain vital. This shift suggests that in the face of sudden within-country socio-political disruptions, MNEs might prioritize Adaptative strategic intent over Additive and Transformative strategic intent. The immediate and unpredictable nature of Home/Host Storms demands more reactive and flexible responses from MNEs.

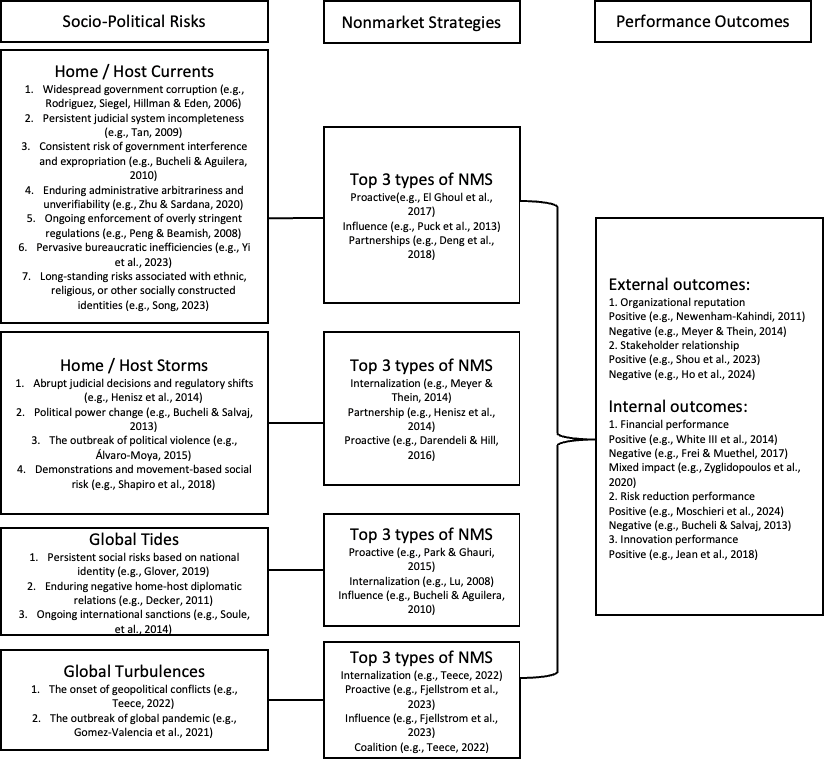
With respect to ongoing, cross-country risks (Global Tides), proactive strategies dominate, as evidenced by 16 articles. This suggests that MNEs prefer to take the initiative in establishing supplementary local institutional structures to create more stable and predictable operating environments amidst enduring socio-political risks that span borders.

In the context of abrupt cross-country risks (Global Turbulence), the distribution of strategies is more evenly spread. Internalization (3 articles), partnership (2 articles), proactive (3 articles), collective (1 article), influence (3 articles), and coalition strategies (3 articles) are all utilized. This even distribution may reflect the complex and multifaceted nature of sudden international risks, where MNEs must employ a diverse range of strategies to effectively manage the unpredictable and wide- reaching impacts. However, this result may also stem from the lack of studies exploring how to implement NMS to manage Global Turbulence, indicating a potential future research direction.

In addition, the percentage of employing collective governance method by MNEs for managing abrupt risks increases compared to ongoing risks. This trend suggests that abrupt risks, due to their sudden and severe nature, necessitate a collective approach, pooling resources and efforts across multiple stakeholders to effectively respond to disruptions. Moreover, comparing within-country to cross-country risks, the adaptive approach (internalization and partnership strategy) is more prevalent

for within-country risks, indicating that MNEs prioritize building strong local ties and adapting their operations to fit the local socio-political environment when dealing with within-country risks.

**Figure 4. An integrated framework of the research on MNEs’ nonmarket strategies for managing socio-political risks and firm performance**

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* 1. **MNEs’ Nonmarket strategies, Socio-Political Risks and Firm Performance**

An analysis of the literature revealed a range of outcomes resulting from NMS in high socio-political risk contexts. Drawing upon Mellahi et al.'s (2016) classification, our review identified evidence of two broad categories of outcomes: external and internal.

* + 1. *External outcomes*

External outcomes refer to the performance outcomes that primarily affect external stakeholders (Mellahi et al., 2016). Most research has focused on two types of external outcomes: organizational reputation and stakeholder relationship.

First, *organizational reputation*, refers to “a set of beliefs about an organization’s capacities, intentions, history, and mission that are embedded in a network of multiple audience” (Carpenter, 2010, p. 33). Newenham-Kahindi (2011) suggests that implementing CSR initiatives and engaging with local communities can enhance an MNE’s reputational capital. Park and Xiao (2021) specifically found that foreign subsidiaries’ engagement in anti-corruption practices is positively associated with enhanced firm reputation. However, Meyer and Thein (2014) discovered that MNEs' partnerships with local governments known for poor human rights records can tarnish their reputations and provoke increased activism from NGOs and consumer boycotts in their home countries.

Second, *stakeholder relationship* is a widely studied external outcome variable. For example, researchers have argued that MNEs could build closer and more trustworthy relationships with key stakeholders by implementing CSR activities (Shou et al., 2023). In a related study, using the before– after natural experiment occasioned by the Arab Spring in Libya, Darendeli and Hill (2016) found that MNEs that survived the regime change were those that invested in development-oriented local projects, thereby earning legitimacy in the eyes of local stakeholders, rather than those that maintained close ties with the Qadhafis. However, Ho, Oh and Shapiro (2024) highlight a challenge in regions characterized by intense ethnic tensions and community polarization. They found that CSR initiatives implemented by MNEs often struggle to meet the varied demands of diverse ethnic groups, leading to widespread mistrust, diminished social license, and even conflicts with the local community.

* + 1. *Internal outcomes*

Internal outcomes relate to the performance outcomes that primarily affect shareholders and internal stakeholders (Mellahi et al., 2016). This category of outcomes includes financial performance, risk reduction performance, and innovation performance.

First, several studies have explored *financial performance* as a significant internal outcome of employing NMS in volatile and high-risk environments. Some researchers suggest that the employment of NMS could positively influence on MNEs’ financial performance. White III et al. (2014) stated that the greater the strength and frequency of forming relational ties with government and business actors in highly risky environment, the more likely that a MNE will establish market based and nonmarket-based embedded assets, thereby leading to the enhancement of firm’s long-term financial performance. This perspective aligns with Luo and Zhao (2013), who reported that relational political strategy, which refers to the proactive efforts to cultivate long-term relationships with host country governments, positively influence subsidiary financial performance. In addition, Lee, Mutlu and Lee (2023) discovered that in transition economies, bribes can boost firms' sales growth by “greasing the wheels” - eliminating bureaucratic hurdles, securing preferential treatment, and facilitating getting things done. However, some studies propose the different arguments. For instance, Frei and Muethel (2017) highlights the detrimental effects of bribery, describing it as “sand in the wheels”, which impairs firm performance by incurring additional direct and indirect costs. Moreover, Zyglidopoulos, Dieleman and Hirsch (2020) explored the heterogeneous impact of bribery on individual firm performance, identifying four specific conditions under which organizations can profit despite ethical concerns.

Second, research on internal outcomes has highlighted *risk reduction performance* as a prominent outcome. The scholarship suggests that MNEs develop extensive networks with local businesses, NGOs, and other influential local actors could reduce their risks of becoming the target of hostile actions (Moschieri et al., 2024). Moreover, MNEs’ implementing CSR initiatives and engaging with local communities enables MNEs to mitigate operational risks such as protests, disruptions, and legal challenges. For instance, Shou et al. (2023) discovered that corporate philanthropy and workforce localization strategies employed by Chinese foreign SMNEs significantly mitigated the adverse effects of violent conflict risk on firm’s operations and performance in host countries. However, drawing on the concept of obsolescing political legitimacy, Bucheli and Salvaj (2013) argued that in countries experiencing dramatic and rapid institutional changes, such as revolutions or decolonization,

MNEs closely tied to the former social and/or political regime would be viewed as illegitimate or archaic, leading to an increased risk of expropriation in the host country. Additionally, Idemudia (2018) discovered that Shell's partnership with NGOs in the Niger Delta Region helped to mitigate cultural sources of violence, though it did not address the structural causes of direct violence, suggesting that business-NGO partnerships are more effective in preventing rather than resolving conflicts.

Finally, *innovation performance* refers to the ability of firms to transform innovation inputs into outputs and to acquire achievements and outcomes through the innovation process (Lee, Yeh, Yu & Luo, 2023). For example, Jean et al. (2018) reported evidence to suggest that political connections in China can serve as an effective mechanism of relational governance and knowledge appropriation that enables foreign MNEs to gain access to relevant information and protect their intellectual property and interests, which in turn enhances its product innovation performance.

1. FUTURE RESEARCH DIRECTIONS

Our analysis of extant literature pinpoints to the nonmarket strategies incorporated by MNEs to bolster performance in the context of socio-political risks. Based on the identified the knowledge frontier issues, we suggest the following prospective future research directions.

* 1. **Degree and Cross-border Nature of Turbulences and the Effectiveness of Nonmarket Strategies**

Our systematic review on MNEs’ nonmarket strategies for managing socio-political risks reveals a prevailing focus on ongoing risks, such as ongoing enforcement of overly stringent regulations and widespread corruption, which allows for some degree of prediction and preparatory adjustments (Ballesteros & Magelssen, 2022). However, abrupt turbulences, such as sudden political upheavals (e.g., Darendeli & Hill, 2016), rapid or unpredictable policy shifts (e.g., Nayak, 2021) have received insufficient attention. The reality of today's global environment demands a deeper examination of these less predictable and abrupt changes. The rising number of conflicts across the world underscores

the urgency for this research focus, especially in regions that deserve more nuanced analysis given their complexity in history and demographic movement.

It is imperative for future research to investigate how MNEs employ nonmarket strategies to navigate turbulent environments. Our literature review indicates an increase in the adoption of collective governance methods by MNEs to manage abrupt risks. Future research could further explore the effectiveness of these strategies over time, consider whether other NMS arise and how MNEs combine strategies. This leads us to propose the following future research questions:

* Which NMS do MNEs use in turbulent environments and how do these evolve over time?
* How do MNEs combine NMS to overcome more turbulent environments?
* Under what conditions are NMS most effective to address abrupt socio-political risks?
  1. **Interaction Between Political and Social Risks and MNEs’ Nonmarket Strategies**

Our review highlights that political risks have been most extensively studied, compared with social risks. This discrepancy underscores a critical gap, especially as social risks are on the rise and increasingly influencing the international business environment. For instance, food security issues, climate risks, heightened by water scarcity and geopolitical tensions, pose significant risks that can trigger social unrest and political instability, and in turn affect MNEs’ global supply chains and operational capability (Smith, 2014; Ghadge, Wurtmann & Seuring, 2020). These emerging social risks necessitate a deeper understanding and integration into the strategic frameworks of MNEs, especially discovering how MNEs utilize nonmarket strategies to address these burgeoning challenges.

Our review also demonstrates political and social risks can be interrelated (Miller, 1992). Future research should examine whether MNEs respond and act upon the way in which political and social risks coalesce and influence each other. Our review suggests that studies rarely combine the analysis of political and social risks, typically treating them as separate domains. Thus, future research should consider:

* How do MNEs deploy nonmarket strategies to manage emergent social risks?
* What is the interplay between political and social risks, and how do MNEs adopt nonmarket strategies to address the combined effects of these risks?
  1. **Integrating Nonmarket Strategies and Market Strategies to Overcome Socio-Political Risks** Existing literature has delineated several market strategies that MNEs employ to manage socio- political risks. For example, research has shown socio-political context in the home market affects MNEs’ willingness to invest and operate in similar – potentially risky – contexts abroad (e.g., Cooke, Wang & Wood, 2022; Cuervo-Cazurra, 2006). Post-entry nonmarket strategies for managing socio- political risks also highlight market manoeuvres like strategic decoupling, where firms reduce reliance on volatile regimes by diversifying their supply chains (Teece, 2022), or even divesting from high-risk regions (Soule et al., 2014). Despite these insights, the scholarly understanding remains fragmented regarding how MNEs combine market and nonmarket strategies to compete and achieve resilience. Hence:
* How do MNEs combine market and nonmarket strategies to achieve resilience in contexts with socio-political risks?
  1. **Co-evolution of MNEs’ Nonmarket Strategies and Socio-Political Risks**

The co-evolutionary perspective (e.g., Cantwell et al., 2010) provides a rich theoretical foundation for examining how MNEs' strategies evolve in response to changing socio-political landscapes and how these strategies in turn reshape such environments. For example, MNEs often forge close political connections with host-country government officials to navigate underdeveloped institutional environment, which can potentially undermine their legitimacy and provoke a negative backlash from the local public (Brown, Rasheed & Bell, 2022). In this case, MNEs may need to further adjust in response to such rising risks. Our review suggests sparse attention has been paid to NMS effectiveness in shaping local policy environments, or to co-evolution of risks and NMS over time.

Therefore, future research could utilize longitudinal studies that track how MNEs’ nonmarket strategies evolve in response to changes in socio-political risks over time, which could provide insights into the triggers that prompt strategic shifts, the lag time between environmental changes and

nonmarket strategy adjustments, and the effectiveness of these adaptions. Accordingly, future research should consider exploring:

* How do MNEs’ nonmarket strategies evolve over time in response to socio-political risks?

6 CONCLUSION

Amid escalating socio-political risks, MNEs increasingly take nonmarket strategy for mitigating their exposure, sparking burgeoning research interest in the role of nonmarket strategy in managing socio- political risks. Our study systematically reviewed relevant studies published in high-ranking business journals and developed a holistic framework that elucidates the interplay between socio-political risks, nonmarket strategies, and firm performance. Through the analysis, we uncovered the key remaining gaps in the literature and identified potential avenues for future research.

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**Appendix A. Search strings**

|  |  |  |
| --- | --- | --- |
| No. | Search Theme | String |
| 1 | Nonmarket strategy | “nonmarket strateg\*” OR “corporate political strateg\*” OR “corporate political activit\*” OR “politic\* connection\*” OR “politic\* tie\*” OR “politic\* link\*” OR “business- government relation\*” OR “firm-government tie\*” OR “relational-based strateg\*” OR “business tie\*” OR “business connection\*” OR “business link\*” OR “coalition\*” OR “politic\* activt\*” OR “politic\* strateg\*” OR “CSR\*” OR “corporate social responsibility\*” OR “political networking\*” OR “campaign contribution\*” OR “briber\*” OR “politic\* donat\*” OR “PAC contribution\*” OR “political action committee” OR “political contribution\*” OR “soft money” OR “institutional  strateg\*” OR “lobbying” |
| 2 | Socio-political risk | “soci\* risk\*” OR “politic\* risk\*” OR “socio-politic\* risk\*” OR “populism” OR “geopolitical risk\*” OR “geopolitical uncertaint\*” OR “nonmarket risk\*” OR “uncertaint\*” OR “risk\*” OR "instabilit\*" OR "politic\* tension\*" OR "trade war\*" OR "diplomatic tension\*" OR “war\*” OR “terroris\*” OR “militar\* conflict\*” OR “social unrest\*” OR “riot\*” OR “nationalistic rhetoric\*” OR “protest\*” OR “revolution\*” OR “violence\*” OR “social conflict\*” OR “corruption\*” OR “nationalisation\*” OR “expropriation\*”  OR “weak institution\* environment\*” |
| 3 | Multinational enterprise | “multinationals” OR “multinational\* firm\*” OR  “multinational\* enterprise\*” OR “multinational\* |

|  |  |  |
| --- | --- | --- |
|  |  | compan\*” OR “multinational\* corporation\*” OR “MNE\*” OR “TNC\*” OR “MNC\*” OR “FDI\*” OR “Foreign Direct Investment\*” OR “Foreign Investment\*” OR “foreign subsidiar\*” OR “foreign affiliate\*” OR “global\* firm\*” OR “global\* enterprise\*” OR “global\* compan\*” OR “global\* corporation\*” OR “transnational\* firm\*” OR “transnational\* enterprise\*” OR “transnational\* compan\*” OR “transnational\* corporation\*” OR “foreign\* firm\*” OR “foreign\* enterprise\*” OR “foreign\* compan\*” OR “foreign\* corporation\*” OR “international\* firm\*” OR “international\* enterprise\*” OR “international\* compan\*” OR “international\* corporation\*” OR “cross-border\* firm\*” OR “cross-border\* enterprise\*” OR “cross-border\* compan\*” OR “cross-border\* corporation\*” OR  “International Business\*” |

**Appendix B. Article distribution across academic journals**

|  |  |  |
| --- | --- | --- |
| Publication Title | AJG ranking | Total number (%) |
| **International Business** |  | **62 (42.2%)** |
| Journal of International Business Studies | 4\* | 20 (13.6%) |
| Journal of World Business | 4 | 14 (9.5%) |
| International Business Review | 3 | 13 (8.8%) |
| Management International Review | 3 | 7 (4.8%) |
| Asia Pacific Journal of Management | 3 | 4 (2.7%) |
| Journal of International Management | 3 | 3 (2.0%) |
| Management and Organization Review | 3 | 1 (0.7%) |
|  |  |  |
| **General management** |  | **58 (39.5%)** |
| Journal of Business Ethics | 3 | 19 (13.0%) |
| Journal of Business Research | 3 | 9 (6.1%) |
| Business and Society | 3 | 8 (5.4%) |
| Journal of Management Studies | 4 | 6 (4.1%) |
| British Journal of Management | 4 | 4 (2.7%) |
| Journal of Management | 4\* | 3 (2.0%) |
| Journal of Management Inquiry | 3 | 3 (2.0%) |
| European Management Review | 3 | 2 (1.4%) |

|  |  |  |
| --- | --- | --- |
| Academy of Management Journal | 4\* | 2 (1.4%) |
| Business Ethics Quarterly | 4 | 1 (0.7%) |
| Academy of Management Perspectives | 4 | 1 (0.7%) |
|  |  |  |
| **Strategy** |  | **11 (7.5%)** |
| Strategic Management Journal | 4\* | 7 (4.8%) |
| Global Strategy Journal | 4 | 3 (2.0%) |
| Long Range Planning | 3 | 1 (0.7%) |
|  |  |  |
| **Business History and Economic History** |  | **8 (5.4%)** |
| Business History | 4 | 5 (3.4%) |
| Enterprise and Society | 3 | 2 (1.4%) |
| Business History Review | 4 | 1 (0.7%) |
|  |  |  |
| **Social Sciences** |  | **6 (4.1%)** |
| World Development | 3 | 2 (1.4%) |
| Development and Change | 3 | 1 (0.7%) |
| Journal of Development Studies | 3 | 1 (0.7%) |
| Business Strategy and the Environment | 3 | 1 (0.7%) |
| Review of International Political Economy | 3 | 1 (0.7%) |

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| **Organization Studies** |  | **2 (1.4 %)** |
| Organization Science | 4\* | 1 (0.7%) |
| Organization and Environment | 3 | 1 (0.7%) |

**Appendix C. Article distribution across regions**

|  |  |
| --- | --- |
| **Panel A. Home country/regional focus and number of papers** | |
| **Developed economies** |  |
| North America | 28 |
| Western Europe | 26 |
| Other developed economies | 16 |
| **Developing economies** |  |
| Asia |  |
| East Asia | 30 |
| South Asia | 14 |
| Southeast Asia | 13 |
| West Asia | 12 |
| Central Asia | 3 |
| Africa |  |
| North Africa | 4 |
| Other Africa | 10 |
| Latin America and the Caribbean | 13 |
| Eastern Europe and Russia | 12 |
| Oceania | 2 |
| **Unspecified** | 12 |
| **Panel B. Host country/regional focus and number of papers** | |
| **Developed economies** |  |
| North America | 9 |
| Western Europe | 13 |
| Other developed economies | 7 |
| **Developing economies** |  |

|  |  |
| --- | --- |
| Asia |  |
| East and Southeast Asia | 38 |
| South Asia | 15 |
| Southeast Asia | 22 |
| West Asia | 10 |
| Central Asia | 11 |
| Africa |  |
| North Africa | 7 |
| Other Africa | 27 |
| Latin America and the Caribbean | 22 |
| Eastern Europe and Russia | 21 |
| Oceania | 3 |
| **Unspecified** | 8 |

Notes: (1) As some papers looked at more than one home and host countries, we code and count them separately. So, the total number of studies exceeds 147 articles. (2) For consistency, we applied the country category adopted by UNCTAD in their World Investment Report ([http://www.unctad.org](http://www.unctad.org/)).

Given the historical context of our research and the distinct institutional environments in Eastern Europe and Russia, we maintained Eastern Europe and Russia as a separate category within the developing economies. Moreover, due to the significant importance of East Asia, particularly China, we distinguished between East Asia and Southeast Asia to provide a clearer understanding of the geographical distribution of articles in our sample.

**Appendix D. Theoretical perspectives, representative studies and key arguments about MNEs’ nonmarket strategies and socio-political risks**

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| --- | --- | --- |
| **Theoretical Perspective(s) and Total Number** | **Selection of Representative Studies** | **Illustrations of Key Concepts/Arguments about**  **MNEs NMS and socio-political risks** |
| **Institutional theory and variants (64 articles)** | Amankwah-Amoah et al., 2022; Liedong & Frynas, 2018; Luo & Zhao, 2013; Saeed, Riaz & Baloch,  2022 |  |
| * Neo-institutional theory | De Villa et al., 2019; Park & Xiao, 2021; Tracey & Phillips, 2011 | MNEs must adapt to the institutional environments through practices like institutional isomorphism and legitimacy-seeking to manage socio-political risks and  align with local norms and expectations. |
| * New institutional economics | Jiménez et al., 2015 | The institutional context in which the firm operates affects its behaviour and certain socio-political environments offers more favourable environments for  investment. |
| * Institution-based view | Huang et al., 2023; White III et al.,  2015 | MNEs’ NMS is shaped by formal and informal  institutions. Especially, in the environments |

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|  |  | characterized by institutional voids, MNEs leverage  NMS such as political connections to navigate the institutional uncertainties. |
| * Institutional imprinting | Yu & Lee, 2021 | MNEs' NMS and management of socio-political risks  are deeply influenced by the institutional conditions of their home country during their founding period. |
| * Political institutional approach | Adarkwah & Benito, 2023 | The political-institutional approach regards political risk as an endogenous variable, suggesting that MNEs can actively influence and shape policy outcomes to block adverse changes and promote favourable ones, leveraging their strategic actions to mitigate socio-  political risks. |
| * Institutional work | Kaplan, 2024 | MNEs adopt purposive actions aimed at creating,  maintaining, and disrupting institutions to manage socio-political risks. |
| **Resource and capability-based view (14 articles)** |  |  |

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| --- | --- | --- |
| * Resource-based view | Amankwah-Amoah et al., 2022; El Ghoul, Guedhami & Kim, 2017; Nayak, 2021; Pek, Oh & Rivera, 2018 | MNEs can leverage their firm-specific resources and capabilities to formulate and implement NMS that effectively navigate socio-political risks, thereby not only mitigating threats but also gaining access to essential resources and securing a competitive  advantage. |
| * Dynamic capability | White III et al., 2014 | Dynamic capabilities in MNEs facilitate continuous adaptation and reconfiguration of resources and routines to effectively navigate the volatile socio-  political landscapes of host countries. |
| **IB-based perspectives (14 articles)** |  |  |
| * Uppsala model of internationalization | Álvaro-Moya, 2015 | MNEs incrementally increase their commitment to foreign markets as they accumulate experiential knowledge and develop relational networks, which in turn help them mitigate and manage the complexities and uncertainties of operating in diverse and risky  environments. |

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| * The Eclectic paradigm | Driffield, Jones & Crotty, 2013; Teece, 2022 | The OLI paradigm is applied to demonstrate how MNEs expand into conflict zones to exploit local resources and leverage their unique capabilities, while navigating the challenges posed by weak institutional  frameworks in these regions. |
| * Springboard view | Fjellstrom et al., 2023 | International expansion of EMNEs, particularly in geopolitical tensions like the U.S.-China conflict, necessitates integrating nonmarket factors into the ambidexterity model to better navigate socio-political  risks and enhance strategic responses. |
| **Resource dependence theory (18 articles)** | Deng, Yan & van Essen, 2018; Luo & Zhao, 2013; Yang, Ma & Cui, 2021 | MNEs utilize NMS to reduce environmental uncertainty and create a more favourable nonmarket environment that ensures and stabilizes the flow of  critical resources to the focal firm. |
| **Transaction cost economics (17 articles)** | Jean et al., 2018; Sartor & Beamish,  2018; White III, Chintakananda & Rajwani, 2023 | MNEs internalize operations and engage in NMS to  manage socio-political risks, thereby minimizing the costs of transaction and uncertainties across borders. |

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| **Stakeholder theory (16 articles)** | Dang, Jasovska & Rammal, 2020;  Henisz, Dorobantu & Nartey, 2014; Shou et al., 2023 | MNEs could mitigate socio-political risks and enhance  their financial performance by gaining stakeholder support through stakeholder management efforts. |
| **Agency theory (11 articles)** | Boubakri et al., 2013; Gugler & Shi, 2009; Yi, Teng & Meng, 2018 | MNE managers, as agents, may prioritize personal gains by diverting corporate resources in complex socio-political environments, often at the expense of shareholders. Such actions could pose MNEs to greater  NMS. |
| **Social-network theory (6 articles)** | Li, Meyer, Zhang & Ding, 2018; White III et al., 2014; Wöcke & Moodley, 2015 | MNEs leverage their relationships and positions within networks to gain access to critical information, resources, and support, which enables them to navigate regulatory environments, influence policy-making, and  mitigate socio-political risks. |
| **Social contracts theory (5 articles)** | Azizi, Börzel & Hansen, 2021; Ho et al., 2022 | MNEs need to fulfil the implicit social contracts by aligning their operations with the ethical, cultural, and legal norms of their host countries to maintain  legitimacy and social license to operate. |

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| --- | --- | --- |
| **Arguments from political science (14 articles)** |  |  |
| * Selectorate theory | Bucheli & Aguilera, 2010 | Governments manipulate their relationship with foreign  MNEs based on the strategies followed by the host country’s ruler to assure his/her political survival. |
| * Soft-budget constraints theory | Huang et al., 2024 | MNEs establish alliance partnerships with local State-  owned enterprises (SOEs) because of SOEs’ privileged access to financial support from government. |
| * Gramscian concept of hegemony | Kourula & Delalieux, 2016 | MNEs' CSR efforts can be seen as strategies to maintain dominance and manage socio-political risks by securing the active consent of civil society, integrating cultural norms, and aligning with institutions to legitimize their power while containing  potential challenges to their operations. |
| * Public choice theory | Galang, 2012; Mudambi, Navarra & Delios, 2013 | Public choice theory posits that governments are not always benign and regulations can be socially inefficient, with regulatory practices emerging from  political contestations where powerful interest groups, |

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|  |  | particularly large business entities, leverage their  influence to trade or exchange for preferential regulations. |
| **Other theoretical arguments** |  |  |
| * Cross-cultural management | Baughn, Bodie, Buchanan & Bixby, 2010; Gelbrich, Stedham & Gäthke, 2016 | Hofstede’s cultural dimensions and cultural discrepancies influence MNEs’ selection and implementation of NMS to navigate socio-political  risks. |
| * Obsolescing bargaining power theory | Bucheli & Salvaj, 2013; Moschieri et al., 2024 | MNEs invest heavily in fixed assets within a host country, their bargaining power diminishes, making them vulnerable to unfavourable changes in local regulations, such as higher taxes or even expropriation. MNEs could adopt NMS to reduce or to compensate  for obsolescing bargaining power. |

**Appendix E. Different types of socio-political risks**

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| --- | --- | --- | --- | --- |
| **Types of socio-political risks** | **Definition & Examples** | **Potential Implications for MNEs** | **Total number** | **Selection of**  **Representative studies** |
| **Political Risk** | “The unpredictability and instability of political, legal, and regulatory conditions” (Panibratov et al., 2023, p.  185) |  | 127 |  |
| Political stability risk | Risks associated with changes  in the political power structure and acts of political violence. |  | 24 |  |
| Political power change | e.g., regime change, and election-induced change | Political power change can result in shifts in policy, regulatory changes, and altered business  environments. | 16 | (e.g., Bucheli & Salvaj, 2013) |

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| --- | --- | --- | --- | --- |
| Political violence | e.g., revolution, civil wars, and terrorism | Political violence can cause physical damage to assets, disrupting supply chains, and  endangering employees. | 8 | (e.g., Álvaro- Moya, 2015) |
| Legal and Regulatory risk | Risks associated with abrupt and unpredictable changes, gaps, or excessive constraints in the legal and regulatory  frameworks. |  | 56 |  |
| Judicial decisions and regulatory shifts | e.g., frequent changes in governmental policies | Abrupt changes in legal and regulatory frameworks can result in increased compliance costs, operational disruptions, and legal  disputes. | 29 | (e.g., Heidenreich et al., 2015) |
| Judicial system incompleteness | e.g., weak regulatory  protection of intellectual property rights | Weak protection of intellectual property rights and other legal | 29 | (e.g., Tan, 2009) |

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| --- | --- | --- | --- | --- |
|  |  | uncertainties can negatively  influence firm performance. |  |  |
| Overly stringent regulations | e.g., strict ownership/control restrictions on foreign companies | Strict regulations can limit operational flexibility, increase compliance costs, and reduce  competitiveness. | 12 | (e.g., Keillor et al., 2005) |
| Government governance risk | Risks emanating from government actions or inactions that undermine effective governance and  public trust. |  | 89 |  |
| Corruption | e.g., grand corruption, petty corruption | Corruption can lead to increased operational costs, and legal risks and reputational damage from  involvement in corruption. | 59 | (e.g., El Nayal, van Oosterhout & van Essen, 2021) |

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| Bureaucratic inefficiencies | e.g., bureaucratic requirements of obtaining licenses or settling taxes | Inefficiencies in bureaucratic processes can cause delays in obtaining licenses and approvals  and increase administrative costs. | 12 | (e.g., Yi et al., 2023) |
| Expropriation & Government interference | e.g., nationalization of the oil industry in Mexico in 1938 | Risk of expropriation or government interference can lead  to loss of assets and investments. | 32 | (e.g., Bucheli & Aguilera, 2010) |
| Administrative arbitrariness and unverifiability | e.g., ineffective and subjective enforcement of regulations | Administrative arbitrariness and unverifiability results in the potential for biased treatment and favouritism, | 15 | (e.g., Zhu & Sardana, 2020) |
| International relations and geopolitical  risk | Risks stemming from  international engagements. |  | 12 |  |
| Trade war & Sanctions | e.g., Sino-U.S. trade war | Trade wars and sanctions can lead  to increased costs from tariffs and trade restrictions, and reduced | 5 | (e.g., Fjellstrom et al., 2023) |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | market access and potential loss of  revenue. |  |  |
| Geopolitical conflicts | e.g., Geopolitical conflicts between Russia and Ukraine | Geopolitical conflicts can lead to market instability, increased security risks, and disrupted  operations. | 10 | (e.g., Teece, 2022) |
| **Social Risk** | Social disturbance, conflicts, and social damages that arise when the beliefs, values, and attitudes prevalent among a population do not align with existing government policies or business practices (Lupu,  2019; Miller, 1992). |  | 45 |  |
| Identity-based social risk | Risks associated with socially  constructed identity-driven societal divisions, e.g., | Societal divisions based on identity  can lead to conflicts, risk of boycotts and social backlash, and | 25 | (e.g., Glover, 2019; Song,  2023) |

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| --- | --- | --- | --- | --- |
|  | nationalistic rhetoric, ethnic  conflicts, and religious tensions. | increased need for diversity and inclusion initiatives. |  |  |
| Demonstration and movement-based social risk | Risks stemming from public demonstrations and movements advocating for societal changes or expressing dissent against existing conditions, e.g., human rights demonstration, pro-democracy movements, labour rights movements, gender equality activism, and environmental  and climate activism. | Public demonstrations and movements can disrupt business operations, impact brand reputation, and increase the need for engagement with civil society and advocacy groups. | 9 | (e.g., Meyer & Thein, 2014; Shapiro et al., 2018) |
| Crime and violence | Risks associated with high  levels of crime and violence within society, e.g., drug | High levels of crime and violence can endanger employees, disrupt | 7 | (e.g., Kehoe &  Greenhalgh, 2019) |

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| --- | --- | --- | --- | --- |
|  | trafficking and crime of black  markets. | supply chains, and increase  security costs. |  |  |
| Other types of social risks | Risks arising from other  factors in the society. |  | 3 |  |
| Public health risk | COVID-19 | Health crises like COVID-19 can disrupt business operations, reduce workforce productivity, and alter  consumer behaviour. | 3 | (e.g., Teece, 2022) |

**Appendix F. Six types of nonmarket strategies**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Strategy** | **Definition** | **Examples** | **Total Number** | **Selection of**  **Representative Studies** |
| Internalization | Firms coordinate activities within firm  boundaries to reduce uncertainty. | Rapid compliance strategy, low visibility strategy,  “according-to-rule” bribes | 46 | (e.g., Akbar &  Kisilowski, 2023) |
| Partnership | Firms form strategic alliances,  partnerships or building connections with other actors. | Alliances, political connections, joint ventures, ties with other influential stakeholders | 55 | (e.g., White III et al., 2015) |
| Proactive | Firms proactively share value with others  in the expectations of being rewarded for doing so. | CSR (e.g., corporate philanthropy, workforce  localization, local community project investment, responsible tax, anti-corruption practices) | 68 | (e.g., Shou et al., 2023) |
| Collective | Firms define and voluntarily bind themselves to a constitution of shared rules and actions, that enable them to realize mutual gains through  collaboration. | Industrial association, trade association | 4 | (e.g., Keillor et al., 2005) |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Influence | Firms seek to directly influence policymakers, regulations, or public opinion to align with their interest. | Firm lobbying, campaign contributions, political participation, “against-the-rule” bribes, legal challenges and use of international courts, leverage international  agreements and organizations | 53 | (e.g., Li et al., 2022) |
| Coalition | Firms collaborate to effect institutional changes that benefit firms or a subgroup  of them. | Leverage diplomatic support from the home country for high-level political lobbying; political coalitions for  regulatory change | 10 | (e.g., Zhu and Sardana, 2020) |

Note: Out of 147 articles, 139 explicitly detailed various types of NMS. Regarding bribery, we identify two types: "according-to-rule" bribes and "against-the- rule" bribes. "According-to-rule" bribes are directed at low-level public officials to expedite the handling of legitimate firm processes, reducing effort and time (Frei & Muethel, 2017). These bribes typically help firms access their legal rights more swiftly and should be categorized under the Internalization Strategy. Conversely, "against-the-rule" bribes target high-level officials and politicians to influence policy, regulatory, or legislative decisions (Frei & Muethel, 2017), and should be classified under the Influence Strategy category. If an article in our dataset mentions bribery or corruption without specifying the type, we will categorize it under both the Internalization and Influence Strategy categories.

**Appendix G. Article distribution across nonmarket strategies and types of socio-political risks**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Adaptive approach | | Additive approach | | Transformative approach | |
|  | Internalization  Strategy | Partnership  Strategy | Proactive  Strategy | Collective  Strategy | Influence  Strategy | Coalition  Strategy |
| Home/Host  Currents | 28 | 38 | 45 | 3 | 44 | 5 |
| Home/Host  Storms | 17 | 15 | 11 | 2 | 10 | 5 |
| Global  Tides | 5 | 3 | 16 | 1 | 5 | 3 |
| Global  Turbulence | 3 | 2 | 3 | 1 | 3 | 3 |

**The research development of**

“**How does the organizational culture shape the knowledge sharing environment for promoting innovation?”**

**Yunwen Xu 10970458**

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# Introduction

Innovation has always attracted much attention because it can help companies gain competitiveness. However, the management of innovation has always been challenging because it is often accompanied by complex phenomena and interactions (McCarthy et al., 2006). The ability to manage the circulation of knowledge within the organisation has attracted much attention as an important factor in innovation (Wang and Noe, 2010); and culture, as an informal form of coordination, is also seen as one of the effective ways to manage innovation (Schein, 2010; Klein and Kozlowski, 2000). Therefore, this study focuses on how organisational culture affects individual knowledge sharing and thus affects innovation and attempts to explain the complex relationship of organisational culture and knowledge sharing on corporate innovation, to reveal possible paths for increased innovation. The structure of this study is as follows: the following literature review includes discussions and research perspectives on innovation, clarification of the process of knowledge sharing, and highlighting the observable practices of organisational culture. The third part is the research design, including the philosophical stance of this study, the development of research questions at different levels (team and organisation), and their corresponding research designs, with time plan. The last part includes considerations on research ethics and research limitations.

# Literature review

The literature review of this research will start with discussing different perspectives on innovation research and explain that the position of this study on innovation is based on process theory where treats the generation of innovation as the process rather than only focus on the result of innovation (Fagerberg, 2003), and innovation is regarded as a combination of different knowledge resources. By introducing micro-foundation perspectives and a knowledge-based view of organization, it is explained that since most of the knowledge and creativity resources in an organisation exist in the organisation as individuals, innovation at the team or organisational level is ultimately achieved through organisational coordination and integration, so innovation can be regarded as integrated creativity and knowledge creation. The integration process and knowledge creation process involve a large number of knowledge sharing activities, so innovation requires knowledge-sharing activities.

knowledge sharing involves the sharing of explicit knowledge and implicit knowledge. The occurrence of explicit knowledge sharing requires different knowledge backgrounds of employees, which is reflected in the team as the composition of different employees, which can be observed, for instance, in cross-functional teams. As we will see, however, different knowledge backgrounds will cause obstacles to explicit knowledge sharing, while implicit knowledge sharing can adjust these

obstacles by cultivating trust among members and establishing common cognition. The effects of implicit knowledge sharing are similar to the function of corporate culture. Therefore, in some studies, the process of corporate culture coordinating individual activities is also regarded as the process of implicit knowledge sharing and is regarded as the basis for explicit knowledge sharing.

This paper chooses to study its coordination function on employee knowledge sharing from a cultural perspective. The most important mechanism of cultural influence on employees is that observable cultural practices or representations affect employee behaviour, including employee knowledge- sharing behaviours. However, culture exists at multiple levels in an organisation, and the practices and representations at each level are different. For employees, the most direct cultural practices they can receive come from and are shaped by team leaders. Therefore, the cultural practices of leaders have an impact on employee knowledge sharing and thus affect team innovation; for team leaders, corporate-level cultural practices will affect leaders' cross-functional team building and thus affect employee knowledge sharing indirectly.

### Innovation as the team's creativity

###### The perspective of innovation

Innovation can be studied from the results and process perspective, this research choose the process perspective of the innovation because the process is always present, independently from the outcome. However, the process perspective also contains different argument, from the linear innovation model to a more complex chaotic model, as well as dynamic systems (McCarthy et al., 2006; Antonelli 2015). Therefore, from the process perspective, this study focusses on the nature of innovation, which is the process of combining different ideas and knowledges (Fagerberg, 2003).

###### Micro-foundation and knowledge-based views

Based on the view of innovation as combination of knowledge, individuals ’knowledge and creativity are seen as the source of the organisational innovation because most of the creativity and knowledge are stored in the individuals separately within organisations, and knowledge activities often take place on an individual basis (Bhatt, 2002; Argote, McEvily and Reagans, 2003; Kogut and Zander, 1996). Thus, it seems reasonable to study innovation at the firm level from the individual level. The micro- foundation view of studying organisation also support this perspective, which mentions that the achievement of strategy and goals requires the collation and coordination of individuals' knowledge and capability at a high level because the individuals are the organisation’s minimum activity unit, including innovation (Felin et al., 2012). Therefore, combining knowledge-based view and micro-

foundation view, this research sees organisational innovation as the aggregated team creativity from the individuals’s creativity. The reason of focusing on team level is that the team is treated as the basic performing unit in the organisation (Kozlowski and Ilgen, 2006). The research of McAdam and McClelland (2002) conveys a positive relationship between individual creativity and team creativity, where an increase in individual creativity can raise creativity at the team level.

From the micro perspective, two perspectives have emerged in the existing literature on innovation. One of the perspectives treated team creativity as averaging individual creativity (Pirola‐Merlo and Mann, 2004). However, another perspective considers not only individual creativity within a team but also team characteristics that influence the aggregate of individual creativities. The other researchers argue that the average level of individual creativity is not enough to decide the team's creativity, which should include more factors, including the interactions and structure of teams (Taggar, 2002). Acar et al. (2023) concludes that three types of teams with difference of individuals’ characteristics, the interaction among members, and the structure of the team, differ in the impact on the collections of creativity. The consideration of the team characteristics is because the characteristics of the team play a coordinating role in the integration of individual behaviours into the team level. Mathieu et al. (2014) reveal the impact of four different team models on team efficiency, though it did not mention the innovation, it provides a more fundamental view to explain how the team position affects the team’s outcome and how team creativity can be seen as one of the outcomes, based on Kozlowski and Klein’s multilevel model of organisational analysis (2000). The study of Emre Yildiz et al. (2020) concluded that the combination of individual absorptive capacity has minimal results on collective innovation. Therefore, even from the micro-foundation perspective, individuals' ability to understand and utilize new knowledge benefits collective innovation performance only when there is effective coordination from the individual to the team level.

In this research, the creativity at an individual level should be taken into account, though the final outcome and aggregation of individuals’ creativity should be analysed at the team level with consideration of the team characteristics. However, coordination affects individual freedom in the pre-innovation phase, that is, in the idea generation phase, where a higher degree of freedom for employees is beneficial to drive this phase; and in the later implementation phase, where a high degree of coordination is needed to organize implementation and commercialization (Perry-Smith and Mannucci, 2017). Since this study tends to focus on the process of integrating individual behaviours into team-level performance, it concerns the later phases, where the coordination of individuals plays a more important role.

### Innovation requires knowledge-sharing

As mentioned, innovation is the re-combination of existing knowledge and create new knowledge, which requires different knowledge interactions, to generate, disseminate, and incubate creative ideas (Flynn et al., 2003), which is based on the knowledge sharing from individual and team level.

Since the individual is the basic unit of knowledge activities from the knowledge-based view and the micro-foundation view, the knowledge creation process of individuals requires the learning of new knowledge from inside the organisations, such as the different departments, or outside the organisations, such as the employee’s social capital (Kamaşak and Bulutlar, 2010), which can help individuals cultivate their creativity (Kang and Lee, 2017). Knowledge sharing then is the bridge of these individual learning process (Mura et al., 2016; Kang and Lee, 2017).

Moreover, at team level, individual leaning is also the basis for creating new knowledge for team innovation purpose through the knowledge creation process, including internalization, externalization, socialization, and combination among team members (Nonaka, 2009), especially during the experiment and commercialization of the innovation, different expertise with knowledge are required to work together. For example, the experiments of the employees’ creative ideas required evaluation from the technological expertise supporting 3M; and the new product development process requires product changes based markets’ reaction, which involves the sharing between product knowledge and marketing information (Griffin, 1997; Garud et al., 2011 ). During these process, knowledge sharing also is the foundation of knowledge re-combination and creation between different teams or levels (Wang and Noe, 2010).

The forms of knowledge sharing within organisations includes lateral forms between employees at the same level, and vertical forms between different levels, to aggregate individual behaviours into team performance, including the team innovation (Ciabuschi et al., 2011). To study different direction of knowledge sharing, the analysis unit is still based on the individuals (Argote, McEvily and Reagans, 2003), but there are different definitions of knowledge sharing among individuals. The simplest version of knowledge sharing is seen as the knowledge sharing among individuals as the unidirectional knowledge exchange behaviour, which means the employees only donate their knowledge to coordinate with others rather searches and collects new knowledge proactively from others (Wang and Noe, 2010; Ahmad and Karim, 2019). Lin (2007) expands the scope of knowledge sharing to a bidirectional process, which includes knowledge donation and knowledge collection. Knowledge donation refers to employees contributing information and knowledge they already know,

and knowledge collection refers to employees acquiring knowledge from colleagues or others through a series of communication activities. A wider scope of knowledge sharing expands to knowledge- centred activities, including knowledge creation, acquisition, transformation, and implementation, which is close to the definition of knowledge management (Bhatt, 2002). Considering knowledge sharing is often bidirectional during social interactions, the concept of knowledge management might be too broad because knowledge sharing in this research is part of the knowledge management. *Therefore, this study defines knowledge sharing as knowledge donation and knowledge collection.*

### 3 The antecedent of knowledge sharing: team composition and culture

However, knowledge sharing does not happen in a vacuum, it requires the heterogeneity of knowledge, which is affected by the team composition, especially for explicit knowledge sharing. Nevertheless, the heterogeneity of knowledge can create misunderstanding and make knowledge sharing fail, which can be coordinated by the tacit knowledge sharing, also influenced by culture.

###### Explicit knowledge sharing requires team composition

The ‘know-what’ or knowledge that can be coded is defined as explicit knowledge (Grant, 1996; Gaur et al., 2019). The sharing and flow of explicit knowledge requires the existence of knowledge differences and a suitable knowledge-sharing environment.

The heterogeneity of knowledge refers to the degree of knowledge difference between individuals within the team. The relationship between the heterogeneity of knowledge and knowledge sharing performs as the U shape. If the degree of heterogeneity of knowledge is too small, where there is no knowledge distance among individuals, then the need to search for new knowledge from others might not exist so the knowledge sharing will not occur; but if the degree of heterogeneity of knowledge is too large, where the knowledge distance between individuals is too large which can result the lack of overlapping knowledge parts so that no knowledge can build the common understanding, then knowledge sharing and communication tends to be difficult to succeed (Yayavaram and Ahuja, 2008; Zakaryan, 2023). Therefore, for managers, the degree of knowledge difference needs to be considered carefully, since the knowledge is stored in individuals, the team composition is one of the antecedents to facilitate knowledge sharing. A cross-functional team is one of the gathering team forms that meets the standards of knowledge sharing.

Even if the team composition is met, it does not guarantee the success of knowledge sharing. The high failure rate of cross-functional teams verifies this situation to a certain extent. Knowledge hoarding is one of the obstacles to knowledge sharing due to lack of sharing willingness (Ford and Staples, 2010). Therefore, for explicit knowledge sharing, the willingness of individuals to share knowledge is a prerequisite, which is influenced by the social characteristics between team members. Team members with higher levels of trust, more frequent communication, or denser social networks are more likely to actively engage in knowledge-sharing behaviour (Lin, 2007; Argote et al., 2003; Kmieciak, 2021). These social characteristics are influenced by the commonalities between team members. From the social capital view of employees, the same values and goals can influence the relational social capital, i.e. the density of the interaction or networks, therefore influencing the success of knowledge sharing (Ganguly et al., 2019). In addition, team members with the same goals can develop an agent-communicational framework to promote the use and understanding of each other's knowledge domain and behaviour for crossing knowledge boundaries (Majchrzak et al., 2012).

###### Tacit knowledge sharing

Moreover, the development of commonalities between team members also can be explained from tacit knowledge sharing. Tacit knowledge refers to the knowledge that is hard to code, also known as the ‘know-how’ knowledge, which makes tacit knowledge harder to share (Grant, 1996; Gaur et al., 2019). Tacit knowledge sharing involves a series of unconscious or conscious imitations and learning of common behaviour patterns of each other or the surrounding environment, or as known as the socialization process (Nonaka & Takeuchi, 1995). Therefore, the development of tacit knowledge sharing also contributes to social characteristics among team members that are conducive to knowledge sharing, such as trust cultivation and increased social frequency (Levin et al., 2002). This phenomenon is closer to the informal control of enterprises over employees, that is, corporate culture. Some literature treats the influence of corporate culture on individual employee behaviour is regarded as one of the forms of tacit knowledge sharing. Schein (2010) believed that culture influences individual behaviour through the process of socialization. Thus, for managers, in addition to considering the composition of the team, using culture as a means of control of employees is another way to encourage employees' knowledge-sharing behaviour.

* + - 1. **Culture and its function**

In this research, the definition of culture is considered as the culture is a mixed set of values, behaviours, and activities. The way that culture controls individual behaviours focuses on a culture toolkit set rather than single values to build individual action strategies for specific goals, but with

explanation with different concepts of culture controlling in the following. Therefore, this study focuses on how organisational culture shapes the knowledge-sharing environment for promoting organisational innovation.

To better address the function of culture, the nature of the culture is defined first. Generally, culture is defined as the set of complex shared values, beliefs, assumptions, and symbols that can decide the direction of the measure of organisational business (Barney, 1986). Based on this definition, the argument of this opinions leads to another way of explanation of cultural coordination. Schein (2010) proposed that culture is the harmonious paradigm that combines the different cultural elements with different depths that are embedded in the organisations, which are the artifact, value, and assumption, from the surface to the deepest. The surface layer is culture artifact which is the observable perceptible phenomena such as the structure, rituals, and norms in organisations, and it can be seen as the representation and results of the two deeper layers, values and assumption. Values, at the middle layer, are the perceptible values, philosophical regulations, and goals that can reflect the expectations. Assumption is the deepest layer and it means the potential assumption that decides instant reaction. For example, when the reflected routines (reflection) in response to specific situations that happens frequently and have proven efficient, then this routine can develop as the basic assumption to guide the behaviours. Therefore, Schein (2010) thinks these three layers of culture affect the individual's behaviours by socialization though transforming assumptions into the value and artifact layers. The reason the assumption layer was not concerned as the main influence layer is the difficulty of change.

Based on Scheins’ culture model with three cultural elements (assumption, values, and artifact), Hatch and Schultz (2002) developed the dynamic of culture with consideration of extra fourth culture element (symbols), and mainly depict four processes that link different cultural elements, which are that the assumption shapes the values by process of the manifestation, values shape the artifacts by the process of realization, the artifacts shape the symbols by the process of symbolization, and the symbols shapes assumption by the process of interpretation. The starting point of this process is manifestation, which stands for manifesting the intangible assumption into observable values to constitute the organisational culture. and it occurs in two ways: the path of the practice in the assumption influences value proactively (from assumption to value), and the retroactive way influences assumption by recognizing the values (from value to assumption). To follow the internal process between different cultural elements that individuals decode and code cultural artifacts, these processes can deeply explain how the managers can use their assumption to change the observable value and finally reflect on the change of artifacts and symbols, to achieve the goal that effects the

individual's behaviours. Although the above-mentioned influence mechanisms are different, they all focus on the influence of values.

In addition to the focus on culture elements' dynamic transforming process, the culture toolkit perspective pays attention to the direct effects of culture elements, which views the culture as the resource that is used to achieve certain goals, and the representation of the culture can be seen as the common communication code, shared goals, contextual behaviour patterns, and so on (Swidler, 1986). This opinion demonstrates that the culture controls the individuals' behaviours or action strategy through the package of toolkit developed from the culture such as the language, habits, skills, styles, and beliefs, instead of controlling the ultimate values. Therefore, culture is seen as the common and public meaning, which can develop a series of behaviour patterns to promote or stop other activities (Swidler, 1986). Koçak and Puranam (2023) therefore developed the code mapping research, in which they view the culture as the fuzzy mapping principles to translate, communicate, and act between two different groups of codes. For example, for the same goals in the group, the culture has already developed a pattern to understand the goals, such as the regular meeting for discussion of this goal (behaviour patterns), and the developed glossary for explaining academic words, which makes the group members can understand this goal (decoding process), and therefore develop the relevant actives to achieve these goals. Therefore, the culture, as the public meanings and toolkits, controls the people's actions to finish the goals, no matter what the deep personal values and cultural assumptions in their cognition.

Thus, the cultural toolkit perspective provides more specific and clearer cultural boundaries based on Shein's cultural perspective, and culture can be viewed as a tool that managers can use to regulate knowledge sharing among people with different knowledge, especially through observable cultural practices. Meanwhile, this view does not entirely deny the logic that value affects behaviours, it simply discusses the mechanisms by which cultural tools influence individual actions without directly changing values.

* + - 1. **Multilevel of culture**

Culture in organisations have different representations and influences on employees as there are different levels of culture in an organisation from macro to micro, so different concerning of culture should be studied based on different level of organisation. Therefore, in this research, the culture at the team level focuses on the impact of the leader's behaviour on the knowledge sharing within the team; while the culture at the organisational level focuses on the impact of the organisation's formal culture on team building.

In the company, except for the different depths of cultural elements, a multilevel culture exists. The existence of multilevel culture is inevitable because the smaller groups and collectives are created by the differentiation patterns, such as functional differentiation, market and technology differentiation, and hierarchical differentiation, to deal with the decrease of personal coordination ability of the organisation's creators with the increase of the duration of an organisation (Schein, 2010). Therefore, each culture is embedded in and extends within the larger macro culture.

Similarly, from the organisational multilevel system perspective view of culture, Klein and Kozlowski (2000) explore the multilevel culture system with the influences paths of top-down and bottom-up based on the organisational theory. In an organisation, the macro level culture, organisational level, affects the lower level, team level culture by the top-down process with contextual influences. Since the individual is embedded in the team level, the team level is embedded in the organisational level, the higher level’s organisational phenomena have two ways to affect the lower levels phenomena: firstly, the higher level phenomena directly affect the lower level unit; secondly, the high-level phenomena can shape or moderate the relationship or process between lower level units.

The existence of multilevel culture and its influences among different levels leads to the interpretation of different cultural elements at different levels, in order to better understand the configuration of cultural elements in different organisational environments (Sackmann, 1992), which means that different cultural characteristics can have different levels of understanding, and some cultural elements can apply to the entire company, while others apply to smaller cultural units.

Since this research regards team creativity, the team-level culture toolkit is directly influenced by the leadership, which impacts team members more directly and shortly, but with higher flexibility (Katzenbach and Smith, 2015). The question at the team level therefore is: **How do team leaders influence team culture and therefore cross-functional teams' knowledge sharing for innovation?**

At the organisational level, the formal culture of an organisation has a more direct impact on the team level, and it may be hard to change because the structure of an organisation is considered to be one of the key mechanisms for strengthening organisational culture. In the early stages of organisational construction, structure, as one of the main mechanisms for conveying the cultural concepts advocated by the founder of the culture, which supports the development of organisational culture; and as the

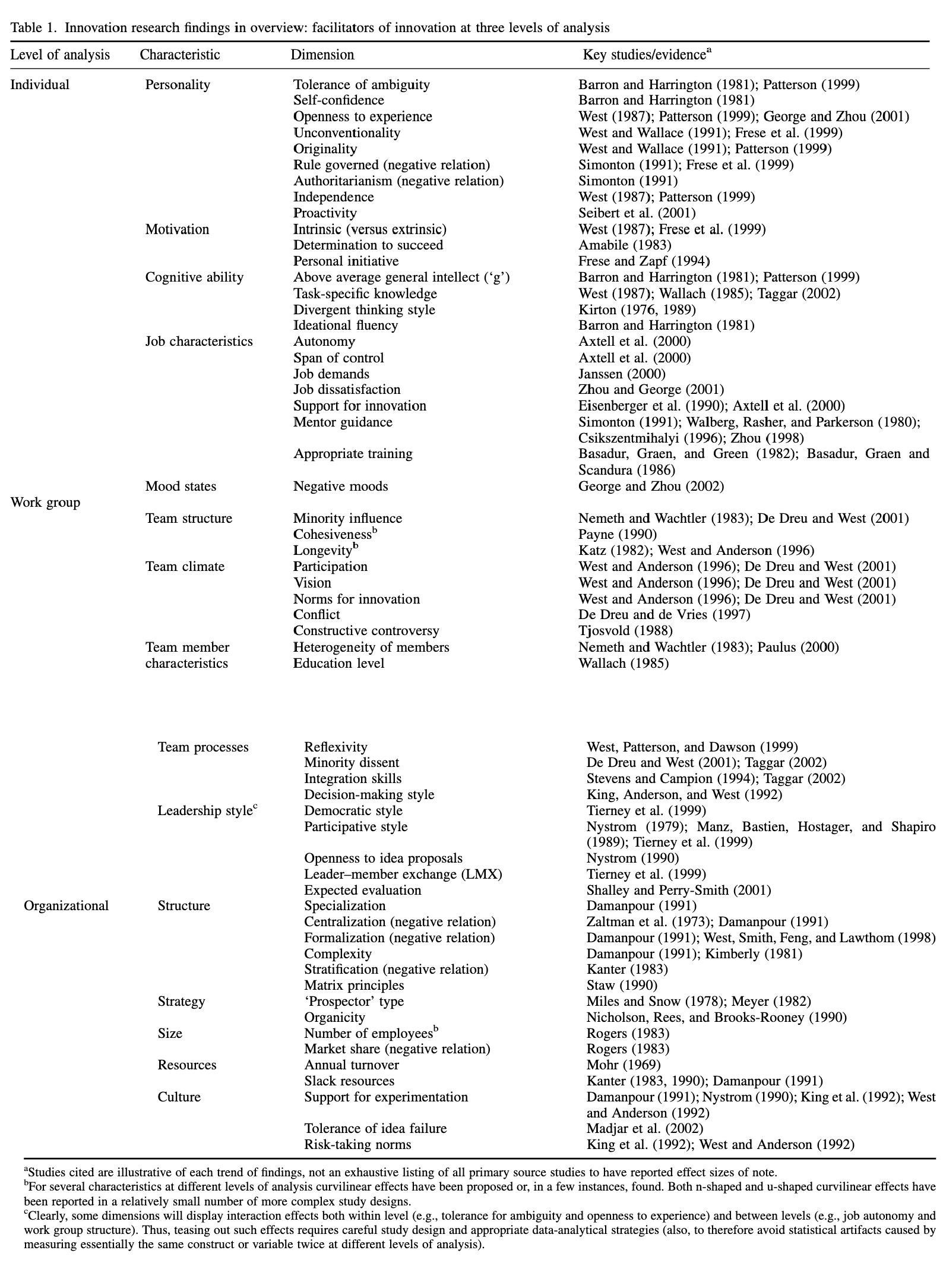
enterprise gradually stabilizes and develops, the existence of the structure further strengthens the value assumptions of the organisational culture behind it (Schein, 2010). Therefore, the relationship between culture and structure can be seen as interactive. Therefore, the formal culture of an organisation may have an impact on the construction of cross-functional teams and indirectly affect knowledge sharing at the individual level (Schein, 2010; Klein and Kozlowski, 2000). So the research question at the organisational level is: **How does the organisational culture affect cross-functional team building?**

### Research question development and research design at the team level

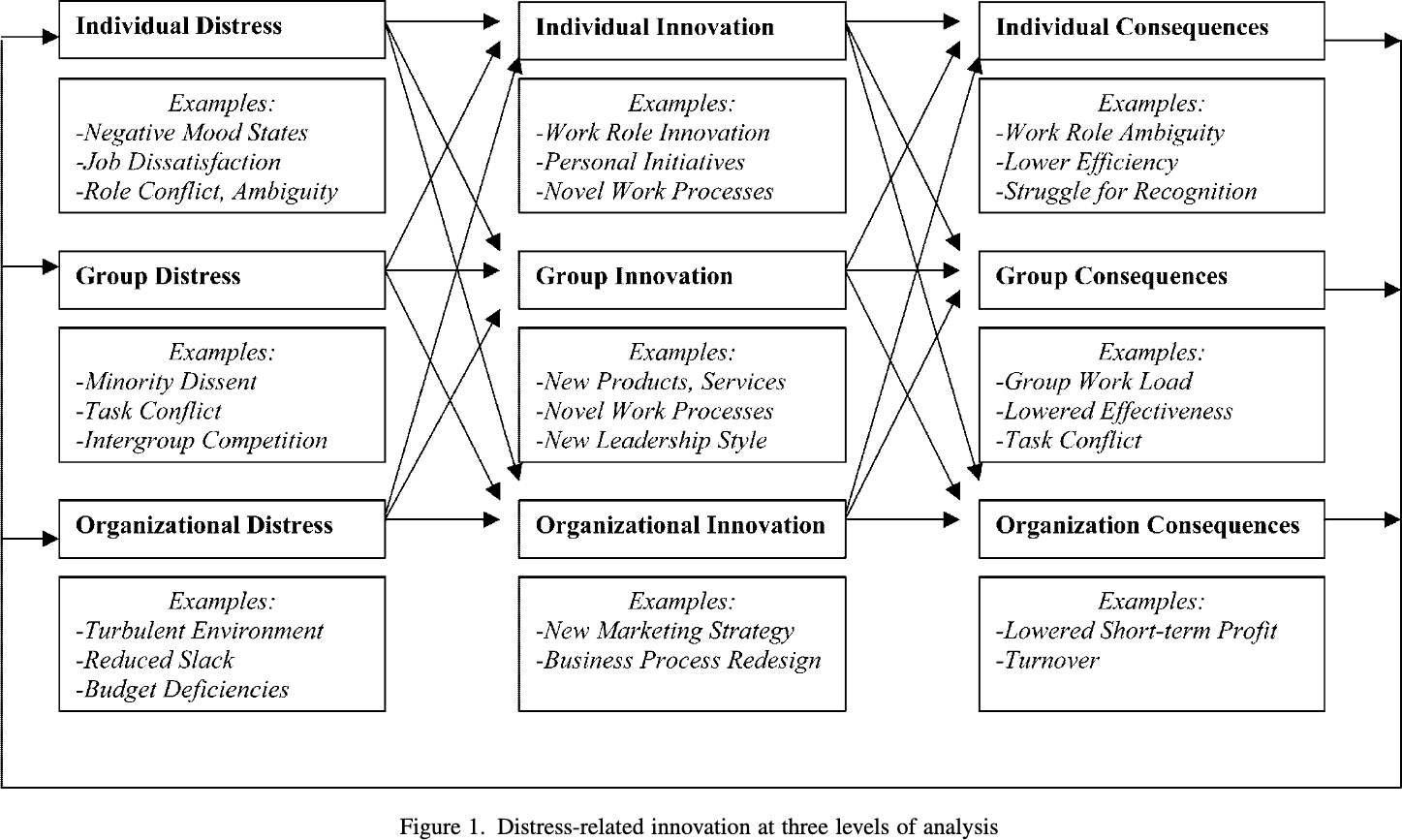
However, team-level autonomy and initiative largely depend on the organisational context due to the multi-level nature of organisations, which is rooted in organisational culture. Anderson, De Dreu, and Nijstad (2004) reveal the different effects that impact innovation at various levels (see Picture 1). For team innovation, the main effects include mood state, team structure, team climate, team member characteristics, team processes, and leadership style. Due to the multi-level nature of organisations, innovation and related effects at different levels are not isolated and can influence each other. Anderson, De Dreu, and Nijstad (2004) also provide a good example of the multi-level relationship between stress and innovation (see Picture 2). Moreover, the different effects at the same level also impact each other.

As a result, although our research mainly focuses on the team level, the effects of other levels should be considered as well. Therefore, the question at the team level adapts to **how do the team leaders manage tasks and the team within a certain organisational context?**

Picture 1



Picture 2



In order to answer this question, phenomena under different scenarios are expected to be captured through qualitative semi-structured interviews. This approach allows the research to cover thematic areas while also offering flexibility for interviewees' responses.

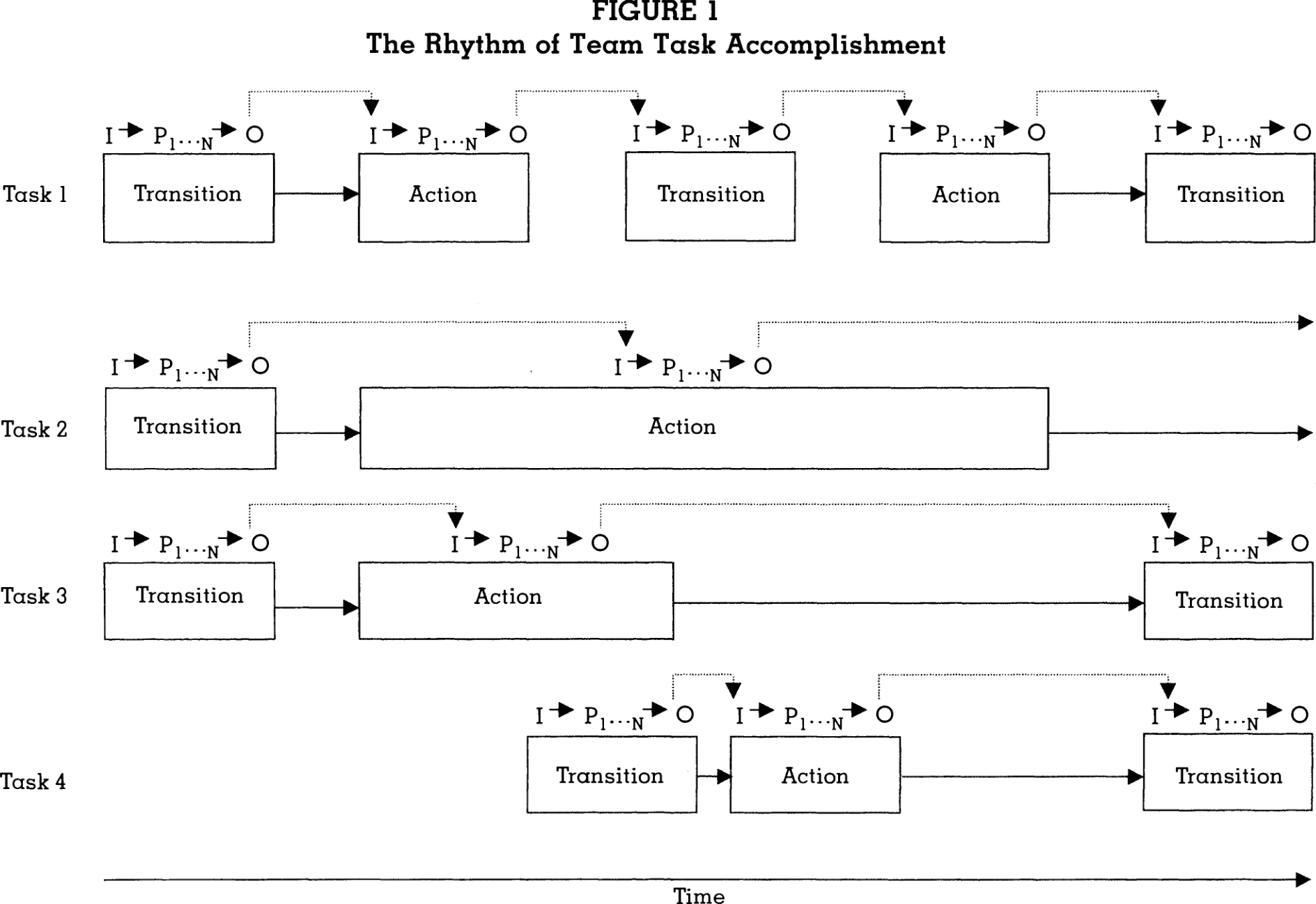
# Interview design

###### Themes identification

**General task process of team in organisation:**

Before identify the different thematics covered in interviews, the nature or basic rules of team’s activities is illustrated for fundaments of understanding the different teams in reality. The team task usually is decided by the top level in the team-based organization, therefore team is defined by its task (West 2002). Similarly, this concept corresponds to the task team in Hackman's (1990) team classification, that is, the team is organised to achieve a clear goal and task. This is also our target team type because the study tries to focus on the team with the task of innovation implementation finished by cross-functional teams, though there are different innovation types based on the classification of innovation outcome. The team with an innovation task we defined as the team that aims to develop or implement something new, including the process, products, service, or models.

Although different team faces different team goals and targets, the general team task is to decide team working progress is similar to that developed by Marks et al. (2001), which captures the time dynamic and treats it as the fundamental team changing principle to reveals the general team dynamic frameworks of task implementation. The main task progression includes three types of phases, which are the transition phase process (including mission analysis, goal specification, and strategy formulation), the action phase process (including monitoring progress, systems monitoring, team monitoring, and coordination), the interpersonal phase process (conflict management, motivation, affect management) (Marks et al., 2001). However, Marks et al.(20001) didn’t deny and ignore the function of the static input-process-output (IPO) model. Instead of considering the whole task process as a single IPO model, Marks et al. (2001) merge the IPO model into the different phases of the task process, in other words, a type of phases, mainly the transition and action phases, can be seen as an IPO process, with recognizable sign of transferring among different phases. Therefore, the whole task process performs as the IPO-type cycle. Based on the nature of the task, the people who will be involved in the task, and the way how the work will be completed, different IPO cycle periods and durations are designed (transition and action), which ultimately form a task action framework (see in figure 1). Compared with the static IPO model that emphasizes static input factors, for example, Costa et al. (2014) used the input-process-output model to try to explain the emergence of teamwork, where the input part includes factors related to team structure, individual characteristics, team characteristics, task characteristics, and work structure, this research prefer to use the Marks’ et al’s (2001) model with combination of statics and dynamics nature of task process, as the fundamental model to explain the implementation of innovation in cross-functional teams.



（Marks et al., 2001）

###### The dynamic of coordination mechanism(process) under the effects of organisational context in the team:

The above model focuses on explaining that the framework of task completion is influenced by the nature of the task, team members, and implementation methods. However, team performance is influenced by the core characteristics of the team, including team composition, task design, and core norms, which are also the main considerations in the process of shaping the team (West et al., 2004, Hackman and Wageman, 2004), or can be regarded as part of the team's coordination mechanism (plans and rules, objects and representations, roles) (Okhuysen and Bechky, 2009).

These characteristics can play different roles in different IPO-cycles of task completion. For example, team members can perform as a certain degree of dynamics, as the inputs are changed in different phases; the initial planning and decomposition of tasks may affect the subsequent stages of IPO- cycles. However, the team's decision-making power over these characteristics is limited by the organisational environment. Therefore, it is necessary to understand the initial setting of the team, that is, the organizational environment in which the team is located. The following sections will explain how different core characteristics affect a team and how these core roles are constrained by the organisational environment.

###### Task design

Task design can be seen as the pre-plan stage before the start of the task, which involves defining the mission, establishing expectations and goals, structure, and plans. In detail, the main decisions needed to be made include structure and plan(how work is done, assigning individual tasks (role clarification), when work is done, etc. )(Morgeson et al., 2010). After determining the team’s task, the effective decomposition of tasks with goals and effective task structure design by leaders can reveal clear different stages of tasks or sub-tasks to drive individual and team activities and cultivate

relevant capabilities to complete tasks， which also can help with the monitor and control overall

task progress. Hackman and Oldham (1976) proposed five characteristics of tasks, task variety, task identity, task significance, autonomy, and feedback, which can effectively motivate employees. Paulus et al. (2012) mentioned that in teams with the purpose of innovative output, effective decomposition and simplification of tasks can help generate new ideas when group members focus on only one sub-topic and task at a time; Whittington et al. (2004) said that diverse tasks and transformational leadership can stimulate employees' intellectual stimulation and learning (Avolio, 1999). In addition, the design of task and goal dependence also helps to cultivate social interaction and interpersonal relationships among team members, which is defined as the degree to which team members must rely on each other to complete the task or goals under the team circumstance (Byron et al., 2023).

For innovation purposes, the design on the appropriate degree of dependence of the subtasks assigned to team members and the coordination and balance between subtasks with different degrees of dependence can affect the coordination between individual activities and team collaboration activities, so as to achieve the requirements of innovation and applicability in team innovation implementation. Paulus et al. (2012) revealed three types of tasks with different degrees of collaboration that may appear in the team process and the requirements for effective coordination of the three types of tasks. Disjunctive tasks refer to the fact that team members are independently responsible for part of the overall task, requiring the effective integration of the results between different subtasks to ensure the success of the final task; addictive tasks refer to the output coming from the joint efforts of all members, such as brainstorming meetings; complementary tasks refer to the fact that during the task process, team members need to pay attention to the contributions of other members and develop their own contributions on this basis to ensure the success of the final project. The balance between these three tasks requires team leaders to effectively decompose and simplify tasks to reduce the cognitive load in the collaboration process; encourage information sharing to ensure information synchronization and correction between team members; and finally, reasonably

set up reflection and feedback procedures to ensure that individuals have the opportunity to reflect and improve their personal ideas and check team activities.

However, the team autonomy of team leaders on the task design is also affected by another— organizational structure characteristics, the degree of formality, especially relates to the performative level of formality (scope of formality) and orientation of formality in practices (implementation), which can reflect on the decision making autonomy of individuals’ work). When the scope of formalization of the organisational structure only covers the organisational level and the team or the orientation of formalization in practice is allowed to independently determine the work content in terms of implementation (Hempel et al., 2012), the design and allocation of tasks within the team can be decided on the team level; but when the formalization of the organisation covers the individual position level or the orientation of formalization in practice emphasized the controlling(Hempel et al., 2012), the team leader and other team members may only be able to follow the standard procedures at their position level, and cannot independently decide on the allocation of tasks and the implementation of cooperation. At this time, the team leader has little flexibility in influencing the interaction of team members by intervening in the allocation of team tasks and resigning/deciding the individuals’ role, because the formal interaction between team members has been limited by the form of individual positions, and the team interaction structure is more likely to be determined at the organisational level.

###### Team composition

The composition of the team is the second focused factors, which plays an important input role in different IPO-cycles. However, with the emergence of dynamic teams, the team composition does not remain unchanged throughout the task. Therefore, we will first explore the impact of the functional heterogeneity of team members participating in the entire task on the team's innovation performance, and then explore how the organizational environment affects the dynamic nature (degree) of team members.

For the team composition, the decision about the choice of team members in different stages can determine the available labour and knowledge base or pool that can be used during the team process. For innovation tasks, the team composition requires the diversity of team members’ functional backgrounds, which can bring different perspectives and support to the team, increase the team’s information resource pool, and build the basement that advantage to communication, sharing, and integration of different knowledge, therefore increases the possibility of innovation and creativity (van Knippenberg, 2017; Mathieu et al., 2019).

During this stage, the decision-making about the team composition can happen in organisational level or team level, which is decided by the organizational context, especially the organisational structure (Kock 2016). The organizational structure characteristics, especially the degree of decentralization of organisational structure can affect the decision-making level of team composition, which can constrain the team leaders’ power of team composing.

Except for the decision making (happened level and autonomy on own work decision), the improvement of communication flow also is another result of decentralization with decision-making power. The improvement of communicational flow includes the changes in the scope, direction, and speed of communication because during the process of decision-making moving downwards and outwards, the communicational flow can be performed as extended, lateral, and flexible, rather than

the vertical one-way communication with centralization and control（Mintzberg, 1979; Burns and

Stalker, 1994), which allows more information resources that leaders may ignore or be unable to access can be accessed by the employees and involved into the team decision-making, therefore to increase the quality of team decision-making (Hempel et al., 2012).

In the organisation with a high decentralized level and formality that benefits the individual decision- making autonomy, the decision-making of team composing can be decided by the team leaders based on the task, and team boundaries or team members are more dynamic due to the larger range and more directions of communication.; while on the contract, the organisation with a low degree of decentralization and control-preference formality, the team composition might be decided by the top level, and the team composition might be more stable since the communicational flow might be more single direction and small scope.

###### Norms

Building the core norms that can guide the individual's action and establish the scope of team behaviors that can be tolerated (Hackman and Wageman, 2004). In detail, the decision about training and developing a team, sense making, and providing feedback need to be made (Morgeson et al., 2010). The appropriate norms can help to build psychological safety to advantage the team learning and team output (Edmondson, 1999), and decrease the misunderstanding to increase the efficiency of communication (Mathieu et al., 2019). Therefore, the appropriate establishment of norms can benefit the team's innovation but is affected by the organizational context as well. Unlike the above two factors, the team decision-making on norms establishment is mainly affected by the organizational culture. As a social control system, culture affects the way middle leaders implement and prefer power

through specific values and behavioral norms, especially the attitude of corporate culture toward failure and risk (Flynn, and Chatman, 2001). In an organisational culture that maintains a positive attitude towards failure and risk, middle leaders are more likely to develop leadership behaviors that encourage and support innovative ideas, such as providing resource support for employees' innovative behaviors (Amabile, 1996). However, if they are in an environment that values stability and control, middle leaders may pay more attention to compliance with rules and regulations to ensure stability, thereby limiting the use and decentralization of resources that they can control (Schein, 2010).

**Observation**

In conclusion, The main performance or phenomenon of team decision-making autonomy (empowerment of autonomy) can be observed from the structural perspective. From the structural perspective, the autonomy of empowerment is similar to the structural autonomy. According to Mintzberg (1989), structural empowerment is affected by the decentralization characteristics of organisational structure and the formalization characteristics of organisational structure-related decision-making. The consequences or representative of decentralization can be observed through the decision-making level and communicational flow. The performance of formality is considered in two different aspects, the scope of formality and orientation of formality in practice, which can affect or result in the decision-making autonomy of a team or individual on their work. Therefore, the final captured observation or phenomenon of organizational context in this research will be on the communication flow and decision making with happened level and autonomy of own work decision, to capture the degree of team autonomy (decentralization and formality).

###### Routines

The above discusses how to establish a starting structure to complete the task, which includes multiple levels of participants and the mutual constraints among them. In the actual implementation of team activities, there are complex interactions, balances, and coordination between these multi-level participants, so an entry point is needed to capture the dynamics and changes between these multi- level participants. Routine, as a collective phenomenon, includes a variety of participants across multiple levels (Becker, 2004). Under the constraints of organisational, temporal, social, physical, and cognitive structures, as well as in personal and organisational contexts, participants at multiple levels formulate or change their behaviors according to actual conditions, rather than fixed action patterns ( Feldman and Pentland, 2003; Howard-Grenville, 2005; Rerup and Feldman, 2011; Wright, 2016). Therefore, the routine perspective can not only capture the behavioral patterns of the

interactions of multiple participants in the process of task completion but also identify the changing dynamics of the process.

**Ostensive and performative aspects of routines:**

According to Feldman and Pentland (2003), the composition of organisational routines includes two aspects, the ostensive aspects, and performative aspects, where the ostensive refers to the abstract idea of routines and performative refers to actual performance practiced by the specific people in a specific place at a specific time (who, where, when and how). Those two aspects affect each other and transform mutual, and the manager practices as the agency during these processes. Managers can influence the external framework of routines, as known as the ostensive of routines, through the design of artifacts such as procedures, written regulations, and office space, but the ostensive part is not routine. The routine also includes the actual action patterns of routines formulated by the participants themselves.

Therefore, for managers, in addition to designing the external framework of routines, it is also necessary to guide the actual behavior of participants and design "ruts in the road" to ensure that the practice develops in the desired direction, which may involve the use of incentives or training. In addition, it is necessary to consider what response mode is suitable for specific participants, whether the new routine mode is consistent with other routines, whether it needs to be changed and how to change it; and identify similar or identical narrative templates (performative to ostensive) from multiple actions; finally, lock the routine at key points to ensure that the process can be promoted normally, while releasing a certain degree of flexibility in other routines (Feldman and Pentland, 2008).

The guidance of routine design seems not to provide a clear framework for managers to follow, but all of them require the involvement of managers in the routines to know what really happens and familiar with involvers, which can build the basement for managers to make decisions about what should be remained and changed at which time, and which group actions/patterns can transform to new ostensive of routines. Therefore, the covering of routines will include the leader's design of the external framework or artifact, the actual guidance or leading of the performance and implementation of the routine, and the decisions made related to changes in the routine (what can be retained and what can be changed, the identification of unified behavioral patterns of the group during task implementation and the promotion of new routines, and the identification of key routines at different task nodes).

It is worth mentioning that Feldman and Pentland (2005) reveal the different research perspectives on routines, including seeing routine as a black box, examining parts of routines (ostensive or performative), and examining the interaction of routines. For the purpose of observing the flexibility and stability of routines, this research took the angle of interaction of routine and mainly focused on the relationship between the ostensive and performative aspects of routines. It should be clarified that in the design of the routine ostensive framework or artifact mentioned in the previous paragraph, artifacts are limited to written rules or procedures, and do not involve broader concerns such as the office environment and layout; and the definition of the ostensive framework is the default rules or ideas, abstract concepts or operating scripts, which do not necessarily have to be presented in written form.

Under the background of innovation, innovation is basically seen as the recombination and creation of new knowledge, whereas knowledge sharing is the basement that supports the activities of recombination and creation of new knowledge. Therefore, we specifically focus on the communication or information processing routines in the team innovation.

For conclusion, the interview is expected to capture the organisational context, mainly about the degree of decentralization, which is performed as decision making level and communication flow in the team; and the characteristics that can influence the initial team setting and process, including the task design, team composition, norms and routine, which will be covered in the interview questions.

### Sampling, Data collection, analysis, and outcomes

For the sampling, the industry we focused is food industry since the main innovation in the food industry is towards the implementation of innovation.

On the macro or company level, innovation can be seen as 1) invention and development, and 2) market introduction and diffusion. In the food industry, the mainstream seems to be market-side, i.e., market introduction and diffusion, which does not involve extensive R&D development but focuses more on small innovations to intervene in the final innovation outcome for the market (Grunert et al., 1997). Although technological advancements, such as nanotechnology and 3D or 4D printing, have brought changes to the food industry, innovation in this sector remains primarily in the application of new technologies rather than R&D development, aimed at meeting customer needs or improving efficiency (Hassoun et al., 2024). Therefore, we can say that pure or initial tech development (R&D) might not be the mainstream in the food industry, making it suitable for studying the implementation of innovation.

In the food industry, the implementation of innovation can occur close to the market-end or production-end. The market-end focuses on development based on consumer opinions, including product innovation in formulation and raw materials, such as functional foods (Bigliardi & Galati, 2013), alternative proteins, and personalized nutrition (Hassoun et al., 2024); innovation in packaging and sustainability (intelligent and sustainable packaging, upcycling, and zero-waste food production) (Mahalik & Nambiar, 2010; Hassoun et al., 2024); and supply chain and distribution innovation, such as using blockchain for food traceability and 3D food printing technology (Hassoun et al., 2024). The production-end focuses on developing processes and manufacturing for efficiency, food safety, and automation, mainly by applying advanced processing technologies, such as High-Pressure Processing (HPP), Ultrasound, Cold Plasma, and Pulsed Electric Fields (PEF), and energy-efficient manufacturing (Mahalik & Nambiar, 2010; Hassoun et al., 2024); AI and IoT for automation; and improvement of production equipment (Hassoun et al., 2024), models, and processes (Mahalik & Nambiar, 2010; Naila et al., 2024).

In simple conclusion, the implementation of innovation in the food industry primarily involves changes in formulation or raw materials and packaging in final products, and the use of different technologies in final products and production processes. For innovations close to the market-end, food production and packaging seem to be the main sectors in the food industry.

In our research, we define innovation implementation broadly, referring to new output results (products and services) and the use of new models or methods to solve problems in the task process. However, we focus on cross-functional teams that implement innovations close to the market, i.e., the results of cross-functional team activities can be directly put into the market or close to the market- end.

We chose to focus on the UK food industry, and to find the general description of team leader of cross-functional team in food industry, we searched the job roles that fit our criteria (the team that requires people with different knowledge) on the LinkedIn:

**Job roles highly related to innovation teams and tasks:**

New Product Development (NPD) Manager/consultant/controller, senior innovation Director/Manager, Technical Innovation Manager, product developer, development lead/technologist, Director of Sparkling Innovation Ltd, process development manager, Head of Food NPD and innovation, R&D Director/Manager (innovation), customer innovation manager, head of innovation for bakery and dairy

**Job roles less related to innovation teams and tasks:**

Commercial Strategy Director, programme leader, Head of Customer Collaboration, Project Manager, Customer Collaboration Planning Manager, Business Unit Leader

fter identifying the main population, the sample of interviewees will be chosen using the snowball sampling method. We aim to target 15 to 30 interviewees, each participating in an approximately one- hour interview, which will be recorded in audio format. Upon completion of the interviews, the recordings will be transcribed, and thematic analysis and grounded theory will be used to develop the conceptual framework. We expect to identify the factors that influence how team leaders manage innovative tasks and to establish a general framework or taxonomy that describes how team leaders manage individuals with different knowledge backgrounds for innovation purposes within various organisational contexts.

To be more specific, the expected outcome is to discover the combination of structural and cultural practices of team leaders under different scenarios of organisational context (different degrees of decentralisation and organisational culture). This aims to capture how team leaders translate and break down organisational tasks into teams, balance and utilize the team's structural and cultural practices to meet the needs of different subtasks, and thus shift among subtasks to promote the completion of the overall task.

It is hoped that these findings will fill the research gap in the academic field regarding the lack of integration from the micro-perspective of organisational innovation and cross-level research perspectives. In terms of practical contributions, the research results aim to provide an optional guiding framework for leaders in different organisational cultural contexts to effectively manage team innovation. However, this research still faces limitations. Since the research focuses on a small number of qualitative studies, further validation through quantitative research is needed in the future.

### Ethical Considerations

For ethical considerations, the participant information sheet, consent form, and interview questions will be provided to interviewees in advance via email to ensure they fully understand the research and their rights, such as the right to withdraw. This will also help obtain their official consent. The data will be stored exclusively on the university’s devices and cloud accounts, accessible only to the researcher and supervisors. During data analysis, anonymization will be applied to all data, and all traceable paths will be destroyed. However, there will be a window of time before the data is fully

anonymized, which will be communicated to the interviewees to allow them the opportunity to withdraw their recordings.

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##### Progression paper for the conference: What is the impact of AI adoption on firm productivity? An empirical analysis for UK companies.

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1. Introduction

The adoption rate of advanced-digital technologies has increased dramatically, both at the country level and firm level. AI is one of the key technologies. Diffusion rate of Artificial Intelligence (AI) technology has increased because of the following reasons (Haefner et al., 2021). Firstly, technological advancements have reduced data storage cost and computational costs, leading to the rise of cloud computing and “Big Data” sets that were not previously available. AI systems can leverage vast amounts of data stored inexpensively on the cloud and perform complex computations more efficiently, enabling more businesses to adopt and integrate AI into their operations at a lower cost and with greater ease. Secondly, AI offers cost advantages and minimises the risk of human error, which helps firms adapt to competitive markets (Salehnejad & Proudlove, 2023). Overall, AI implementation become cheaper and more accessible than before, and firms need to invest to maintain competitive advantages.

Recent studies have investigated that increased investment in advanced digital technologies enhanced firm-level productivity (Wamba-Taguimdje et al., 2020; Damioli et al., 2021; Brynjolfsson et al., 2021; Yang, 2022; Czarnitzki et al., 2023; Zhai & Liu, 2023; Anderton et al., 2023). These studies mainly collected and used data from China, EU, and the U.S., and a very limited number of studies have contributed to the UK phenomenon. In addition, current literature mainly explores the impact of AI on productivity at the national level, with only a small portion exploring it at the firm level (Benassi et al., 2022; Massini et al., 2022; Lane et al., 2023). This is due to a lack of high-quality micro-level data (Seamans & Raj, 2018). Within this portion, some studies use qualitative approaches (Brooks et al., 2020; Wamba- Taguimdje et al., 2020), which indicates there is a growing need for quantitative analyses to measure the impacts of AI on economic outcomes at the firm level (growth and productivity). However, tech-pessimists have questioned the benefits of AI investment because “Digital economy” is still in the installation phase, infrastructures are not mature yet, and the success largely relies on tangible and intangible complementary assets, which leads to the rise of discussion of modern productivity paradox (AI advancements have not matched productivity growth) (Brynjolfsson et al., 2019). Some papers showed that actual statistical evidence clashes with the high productivity expectations associated with the new technology, for example, Brynjolfsson et al. (2019). This perspective leads us to consider the following: Can all companies benefit from AI investment? Could it depend on certain

factors, such as company size? Without investing in complementary assets, is investing in AI alone sufficient to ensure firms’ productivity gains?

The research aims to explore the impact of AI adoption on firm-level productivity, with the focus on the UK companies to contribute to this ongoing debate and provide empirical evidence about technology-driven productivity performance.

1. Literature review
   1. What is Artificial intelligence (AI)?

The term “AI” was originally coined in the 1950s and is the basic concept of machines displaying human-like intelligence (Jordan, 2019). Over time, the definition of AI has gradually evolved, and modern AI is often referred to as a general-purpose technology (Brynjolfsson et al., 2020; Tambe et al., 2020; Zhai & Liu, 2023). AI is considered a general-purpose technology because of its predictive capabilities. According to Taddy (2018), AI can be broken down into three important pieces: domain structure, data generation, and general-purpose machine learning (ML), which can explain AI’s prediction ability. Firstly, *domain structure* is provided by the business and economic domain expertise, and then a substantial amount of data is required to get the system up and running, along with a strategy for continual *data generation* to ensure the system can adapt and learn. Finally, *ML algorithms* identify patterns and make predictions from unstructured data. AI systems solve complex problems by breaking down the problem into many small and simple prediction tasks, each of which can be tackled by ML algorithms. ML algorithms build blocks of AI, which indicates that AI is a modular technology (Taddy, 2018).

In addition, Guo et al. (2023) believed that AI also is an enabling technology (ET). ET is usually for augmentation, enhancing the capabilities of existing systems or process; AI augments human capabilities by overcoming human limitations to allow individuals to achieve what was previously thought difficult, such as improving decision-making and optimising actions. For example, the predictive capabilities of AI algorithms allowed managers to make better decisions by reducing uncertainties (Enholm et al., 2021; Guo et al., 2023). Augmentation indicates that AI complements and supports humans instead of replacing them, so individuals remain crucial for generating value and maintaining leverage in labour markets as well as in political decision-making processes (Raisch & Krakowski, 2021; Brynjolfsson, 2022).

These economic properties of AI have the potential to bring economic growth. Therefore, AI is an intangible asset that firms can invest in and as an input to generate output through production function (Mihet & Philippon, 2019; Czarnitzki et al., 2023). Corrado, Hulten, and Sichel developed the Corrado-Hulten-Sichel (CHS) classification framework, which is used to categorise types of intangible assets into three main categories: computerized information, innovative property, and economic competencies. Based on the CHS classification framework, AI investments fit into the group of firms’ intangible assets: computerised (digitised) information (software and

databases) and innovative property (innovative output and patents) (Corrado et al., 2021).

* 1. Information technology (IT) and productivity
     1. The impact of IT adoption on productivity (national-level vs. firm-level) Technology is an internal driver of firms’ productivity (Syverson, 2011). Information technology is described as a general-purpose technology, initially called computerisation (Bresnahan & Trajtenberg, 1995). IT can be considered the old technology paradigm because traditional IT systems are primarily designed for data management and basic business functionalities, are being outpaced by more agile and integrated technologies such as cloud computing, big data, AI, and the Internet of Things (IoT) (Tapscott & Caston, 1994). Early studies in the 90s and early 00s examined its effects on productivity at the national and firm levels.

At the national level, it is believed that IT was the main reason for the productivity growth of the US in the mid-1990s because IT generally influenced productivity patterns across multiple industries and countries (Jorgenson et al., 2005; Oliner et al., 2008). In contrast, the productivity growth of the EU was slow over the same period; Van Ark et al. (2008) concluded that the gap between the US and the EU was mainly because of differences in IT capital investments instead of geography. The U.S. has embraced more aggressive IT investments and quicker adoption of new technologies, facilitated by a business environment that encourages innovation and risk-taking. In contrast, many EU countries have been more conservative in their IT spending, often due to stricter regulations, a focus on preserving existing industries rather than fostering new ones, and sometimes less flexible labour markets. Evidence from the UK showing the significance of IT capital for productivity is found in Faggio et al. (2010). The study indicated that sectors with the highest rise in productivity spread also witnessed the most significant growth in IT capital intensity. These studies support the positive relationship between IT investments and productivity by providing national evidence.

As this topic became more popular and data became more accessible, researchers started to explore the economic impact of IT at the firm level, especially focusing on its impacts on productivity, which is also the main focus of this PhD research proposal. Lehr & Lichtenberg (1999) found that computers contribute positively to total factor productivity (TFP) at the firm level during the period 1977-1993 and yield excess returns compared with other types of capital. Also, computers are complementary to skilled labour. These findings were also supported by Brynjolfsson and Hitt (1999, 2000), who demonstrated that spending on computer capital and labour of information systems (IS) significantly increased firm-level outputs. The mechanism can be explained by the impacts of IT adoption in firms. IT reduces costs, increases output quality, and enhances firms’ performance in intangible aspects, such as convenience, timeliness, quality, and variety, to increase productivity (Brynjolfsson & Hitt, 2000). Many studies analysed labour productivity instead of TFP and suggested that IT investments can increase labour productivity (Kelley, 1994; Gera et al., 1999; Aral et

al., 2007; Dedrick et al., 2013; Arvanitis & Loukis, 2009; Badescu & Garces-Ayerbe, 2009). Labour productivity, which measures the output per unit of labor, instead of TFP, which accounts for the outputs generated from all combined inputs, and suggested IT investments can increase efficiency with which labour is utilized without necessarily accounting for the overall efficiency of all resources employed. Aral et al. (2007), looking at US companies, found that the use of IT can make information workers more productive because workers can multitask more effectively with the help of a richer communication structure. This paper is relatively special because it examined the causality between IT and productivity for service sectors; most of the other studies mainly focused on manufacturing sectors. IT benefits multinational firms that require asynchronous, geographically dispersed communication forms (Aral et al., 2007). IT reduced uncertainties to improve resource allocations and decision-making and reduce delay costs to increase productivity (Cyert & March, 1963; Aral et al., 2007). One example is that accurate and detailed information can reduce time spent on unsuitable candidates to enhance the efficiency of executive recruiting processes (Fried & Gates, 2008).

* + 1. Roles of complementary assets on IT adoption

The literature discussing the link between IT and productivity has highlighted the importance of specific assets within a company that can modify the IT impacts on firm productivity. Among these, organisational and managerial practices, human resources, and infrastructure have been identified as the most significant factors.

Researchers also found that solely investing in IT was not enough for firms to increase their productivity performance from IT investments, and corresponding complementary assets are required (Brynjolfsson & Hitt, 1999). IT adoption changes the way firms conduct business, and complementary *organizational investments* (business processes and work practices) are the value sources of IT. If firms only invest in computers or changes in organizational practices, the benefits of computerization are more than outweighed by negative interactions with existing organizational practices (Hughes & Morton, 2006; Arvanitis & Loukis, 2009; Brynjolfsson & Hitt, 2000). This is consistent with the findings of Colombo et al. (2013). Colombo et al. (2013) found that Italian SMEs cannot gain significant productivity growth no matter which types of broadband applications they implement if they cannot introduce a wide range of complementary strategic and organizational changes, such as hierarchy adjustments, skills development of workers, and Re-engineering and rationalisation of internal processes .Adoption of broadband applications involves considerable learning costs; SMEs with high trial and error costs must ensure that the benefits they can obtain outweigh the investment (Ghobakhloo et al., 2011).

Another complementary asset is *human capital* because IT produces large quantities of data that can be utilised only by highly skilled workers and professionals who have the related literacy and competencies to use IT effectively. In addition, a good quality workforce is flexible to adapt to new technology and can deal with challenges to reduce

downtime and maximize technology’s potential benefits (Arvanitis & Loukis, 2009). Papers by Brynjolfsson and Hitt (1999), Lehr and Lichtenberg (1999) on the US firms, Benhabib and Spiegel (2005) on Europe, Ramlan and Ahmed (2009) on Malaysia, Siqueira and Fleury (2011) on Brazil, Dedrick et al. (2013) on developing countries and Tarutė and Gatautis (2014) on global scale support the argument that human capital is essential for the IT or information communication technology (ICT) development.

In addition, Dedrick et al. (2013) found that the availability of telecommunications *infrastructure* reduced telecommunications costs to increase access to the Internet and other networks to increase IT diffusion and productivity gains. Tarutė and Gatautis (2014) also claimed that certain infrastructures are necessary to achieve the best results of IT adoption. These three types of complementary assets are commonly discussed in the existing literature.

* + 1. Information Productivity Paradox

Not all researchers support the statement that an increase in IT investments will positively impact firm or country productivity – what is famously called “the IT productivity paradox”. The concept was highlighted by Robert Solow in 1987 when he famously remarked, “You can see computers everywhere except in the productivity statistics.” It means that investments in IT increased while there was no corresponding increase in productivity (Triplett, 1999). The paradox challenges the assumption that advancements in technology, particularly in IT, would naturally lead to greater efficiency and productivity in the workplace. Brynjolfsson (1993) found an unexplained residual drop in productivity in the early 1970s, which coincided with the rapid increase in the use of IT. IT productivity paradox was initially supported by many researchers, including Roach (1987) and Baily (1986) on the US; Dewan & Kraemer (1998) on the US, Japan, France, and Germany; and Hajli et al. (2015) on the 21-member nations of the OECD. For example, Hajli et al. (2015) provided evidence that productivity slowed down while expenditures on ICT had risen, which is consistent with the findings of Roach (1987). Roach (1987) found that despite the substantial growth in computing power for the service industry from 1970 to 1980, productivity measurements in this sector showed no corresponding increase. However, Brynjolfsson and Hitt (1993) used firm-level data on components of information systems (IS) spending for the period 1987-1991 to examine the contribution of IS to firm-level productivity. As a result, the productivity paradox disappeared by 1991, at least in this sample of firms. In addition, Lehr & Lichtenberg (1999) suggested that the traditional information productivity paradox was due to a measurement error, which will disappear with suitably detailed, firm-specific data. Therefore, the research results are inconclusive, and the literature cannot confirm or deny the existence of the information productivity paradox. The ambiguity of findings led to continuous discussion, which has evolved into discussing the modern productivity paradox. This will be detailed in the section 2.3.3.

* 1. AI as an advanced digital technology and productivity

Advanced digital technologies, including AI technology, are known as the new

paradigm of technology. Table 1 summarises various definitions of digital technologies. AI is a subset of advanced digital technologies and is the primary focus of the research proposal. AI encompasses a broad spectrum of technologies, applications, and methodologies. Section 2.1 explains the specific meanings of AI in the research proposal. IT lays the foundation of the digital universe, providing the infrastructure and data essential for AI (Turban et al., 2001). In other words, you do not have AI if you do not have IT. The technological evolution from the old paradigm of technology (IT) to the new paradigm of technology (AI) indicated that the literature on IT has laid a foundational framework upon which the literature on AI has been built. Section 2.3.1,

2.3.2 and 2.3.3 will review studies from the last decade to examine the relationship between adopting advanced digital technologies/AI and firm-level productivity.

|  |  |
| --- | --- |
| Author and  year | Classification |
| Bukht and Heeks, 2017 | refer to electronic tools, systems, devices, and resources that generate, store, or process data; varies in a wide range: AI, ML, cloud computing, IT, ICT, networking, big data, algorithmic  decision-making, etc. |
| OECD, 2017 | Categorized digital technologies into three broad types:   * Digital technology enablers: foundational infrastructure enabling the digital overhaul of industrial production, including big data, the Internet of Things (IoT), and cloud computing. * Digital systems integrators: includes simulations, AI, and cyber- physical systems) to facilitate digital transformation. * Application technologies: include 3D printing, autonomous machines, and human-machine integration. |
| Gomes et al. (2021) | Developed a taxonomy proposal of digital technology based on various characteristics, roles, impacts, and their participation in systems, digital platforms, and ecosystems.   * Complicated * Partially overlapped with the OECD (2017). |
| Nucci et al., 2023 | Categorized types of digital technologies in three domains:   * Internet-based technologies: refer to the optic-fibre ultra- broadband connection, mobility connection (4G and 5G) and IoT. * Areas of application of AI: includes investments in immersive technologies, big data, automatisation, robotics, and smart systems. * other technological areas: include 3D printing, simulation of   interconnected machines and cyber-security. |
| Dalmarco et al., 2019;  Parashar et | Advanced digital technologies include IoT, big data, cloud computing, AI, robotics, augmented reality, additive manufacturing  (3D printing), cyber-physical systems, cybersecurity, simulation, |

|  |  |
| --- | --- |
| al., 2023 | electric vehicles and system integration |

Table 1: classification

* + 1. The impact of advanced digital technologies on firm-level productivity

Recent empirical studies across various countries have explored the impact of advanced digital technologies on firm-level productivity. These investigations, conducted by researchers such as Zhai & Liu (2023) and Gao & Feng (2023) in China; Yang (2022) in Taiwan; Graetz & Michaels (2017), Kopka & Fornahl (2023), and Grashof & Kopka (2022) in the European Union; Qi et al. (2022) in the United States; Rodrigo (2021) in Brazil; Czarnitzki et al. (2023) and Roth et al. (2023) in Germany; Damioli et al. (2021) and Sharma et al. (2021) on a global scale; and Nucci et al. (2023) in Italy, consistently indicate a positive and statistically significant relationship between the adoption of digital technologies and productivity. For example, Gao and Feng (2023) found that a 1% increase in AI adoption could result in a 14.2% increase in the total factor of productivity. Czarnitzki et al. (2023) employed both cross-sectional and panel databases and covered all types of AI methods, technologies, and active use of AI within firms. They examined the productivity effects of AI use and AI intensity and suggested that AI adoption positively affects TFP. In addition, Rodrigo (2021) provided establishment- level evidence on the long-term dynamic effects of robot adoption on labour productivity. He found that overall estimated productivity gains are economically significant, while Qi et al. (2022) generated consistent results. The analysis of Qi et al. (2022) confirmed a positive association between robotics-related patents and overall productivity in the manufacturing industry from 1967 to 2013. The relationship is causal and remained significant after controlling for endogeneity. It is worth noting that different firms may experience various productivity gains from adopting advanced digital technologies, known as - (Brynjolfsson, 2017).

* + 1. Heterogeneity

This section explained heterogeneous factors of firm characteristics including firm age, firm size, market concentration, foreign direct investment (FDI), industry attributes, and initial productivity levels, which may influence the effectiveness of AI adoption on firm productivity. Table 2 summarises the relevant heterogeneous factors of firm characteristics that the literature shows influence in the relationship between technology and productivity, and the researchers' findings have similarities and differences. Czarnitzki et al. (2023), Yang (2022), and Nucci et al. (2023) suggested that older firms tend to experience higher productivity gains from AI investments. There are several explanations. Firstly, their accumulated experience and deep industry knowledge enable them to integrate new technologies more effectively into existing processes. Secondly, financially more stable, older firms also have the capacity to make comprehensive investments that go beyond mere technology acquisition to include employee training and system upgrades, enhancing the overall impact on productivity (Gopalakrishnan & Bierly, 2006; Semrau & Sigmund, 2012). However, Anderton et al. (2023) got the contradicted result. Younger firms are inherently agile, open to innovation, lack legacy systems, and are attractive to the digital workforce. This allows

firms to benefit more from investments in intangible capital and integrate cutting-edge technologies quickly (Borowiecki et al., 2021).

It is commonly acceptable that smaller firms may face more difficulties in adopting digital technologies due to limited resources and capabilities (Anderton et al., 2023; Zhai & Liu, 2023; Yang, 2022; Nucci et al., 2023). Instead, some literature says that SMEs benefit from less capital-intensive technologies (OECD, 2023). Borowiecki et al. (2021) used variables (investment in ICT hardware, high-speed broadband, software) to measure digital adoption and examined the impact on firm-level productivity in the Netherlands. Regression results suggested that medium-sized and large firms generally exhibit lower productivity growth than small firms. Kopka & Fornahl (2023) demonstrated that the impact of firm size on productivity gains depended on the types of AI patents.

Firms in industries with higher market concentration may experience lower productivity gain (Anderton et al., 2023), while Gao & Feng (2023) generate the opposite result. In environments where few firms dominate, the reduced competitive pressures discourage firms from adopting new technologies and optimising existing processes to enhance efficiency (Baumol, 1982; Scherer & Ross, 1990). However, stable market conditions encouraged strategic investments in productivity-enhancing technologies, and superstar firms have more significant financial resources and economies of scale that enable substantial investments in complementary assets and digital technologies (Aerts & Schmidt, 2008). In China, the government has strong power over firms and dominant companies are encouraged to invest in technology, aiming to boost productivity gains due to the government's strong emphasis on technological innovation. This could explain why the findings of Gao & Feng (2023) contradict Anderton et al. (2023).

Yang (2022) presented that firms experience higher productivity gains if they have higher FDI, which is consistent with Bloom et al. (2012) because of the spillover effects. In addition, Zhai & Liu (2023) showed that labour-intensive firms exhibit greater productivity improvements, aligning with the possibility that AI technology may replace repetitive labour tasks. This only applies when tasks are highly substitutable (Zhang & Liu, 2024). Gao & Feng (2023) and Nucci et al. (2023) have different findings because capital-intensive firms are heavily dependent on machinery and equipment; AI technologies increase capital allocation, enhance automation processes, optimise production lines, and enable predictive maintenance to reduce downtime and maintenance costs to increase productivity (Brynjolfsson & McAfee, 2014). In addition, firms’ initial productivity levels also need to be considered. Borowiecki et al. (2021), Anderton et al. (2023) and Liu et al. (2023) showed that previously productive firms experienced higher productivity growth after implementing AI technologies.

Other heterogeneous factors from Table 2, including liquidity, leverage, various industry attributes (such as digital vs. non-digital sectors, state-owned vs. non-state-

owned enterprises, and technology intensity), as well as export intensity, have only been discussed by a small portion of the literature, resulting in insufficient empirical evidence. These heterogenous factors will act as control variables in the regression model. Different research contexts, including other countries and methodologies, yield varying conclusions, which indicate the necessity of conducting the research in the UK context.

|  |  |  |  |
| --- | --- | --- | --- |
| Author | Country | Year | Heterogenous factors |
| Czarnitzki et al. | Germany | 2023 | 1. Firm age: higher productivity for older firms 2. 17 industry dummies: depend on the   specific industry |
| Zhai & Liu | China | 2023 | 1. Firm size: higher productivity for larger firms 2. State-owned enterprises: positive (gain more productivity from AI investments) 3. Labour-intensive industries: positive (gain more productivity from AI   investments) |
| Anderton et al. | EU | 2023 | 1. Firm size: higher productivity for larger firms 2. Firm age: lower productivity for older firms 3. Market concentration: negative (less productivity gains from AI investments) 4. Liquidity: negative (less productivity gains from AI investments) 5. Leverages: positive (more productivity gains from AI investments) 6. Digital sectors are more productive than non-digital sectors 7. Only the 30% of most productive   lagged firms can benefit from digitalisation |
| Kopka & Fornahl | EU | 2023 | 1. Types of AI patents: AI method patents vs. AI application patents    * AI methods: greater positive effects of frontier firms, larger firms    * AI applications: greater positive effect of latecomer firms, smaller   firms |

|  |  |  |  |
| --- | --- | --- | --- |
| Gao & Feng | China | 2023 | 8. Non-state-owned enterprises: positive (benefit more from technology investments)   1. Market concentration: higher productivity for higher market concentration 2. Capital-intensive: higher productivity for more capital- intensive firms. 3. Technology-intensive: higher productivity for more technology-   intensive firms. |
| Yang | Taiwan | 2022 | 1. Firm size: higher productivity for larger firms 2. Firm age: higher productivity for older firms 3. Foreign Direct Investment (FDI): engage in outward FDI, particularly through the establishment of foreign affiliates, tend to experience higher productivity gains. 4. Export intensity: higher proportion of firms’ sales coming from exports tend to benefit more from AI   investments. |
| Nucci et al. | Italy | 2023 | 1. Firm size: higher productivity for larger firms 2. Firm age: older firms are more likely to rely extensively on digital technologies. 3. More labour-intensive: negative (less productivity gains from technology   investments) |
| Borowiecki et al. | Netherlands | 2021 | 1. Initial productivity levels: positive (benefit more from technology investments) 2. Firm age: lower productivity for   larger firms |
| Li et al. | China | 2021 | 1. Operational efficiency (OE): measure OE using the stochastic frontier approach (SFA); Higher   productivity for higher OE. |

Table 2: heterogeneous factors

* + 1. Modern Productivity Paradox

Like in the era of information technology development, all researchers do not recognise the firm-level productivity growth brought by investments in advanced digital technologies. Productivity growth has fallen and stayed low over the past decade. This phenomenon was widespread in both developed and emerging economies. This is known as the “Modern productivity paradox” and is a redux of the “Information technology paradox” (Brynjolfsson et al., 2019; Capello et al., 2022;). Bloom et al. (2020) found that research productivity decreased across various sectors, goods, and companies, and Gutiérrez & Philippon (2019) found that the productivity growth of superstar firms decreased. The following are potential explanations for the paradox (Capello, 2022; Brynjolfsson et al., 2019):

* + - * False hopes: optimism about the potential transformative technologies may be unfounded.
      * Mismeasurement of output and productivity
      * Concentrated distribution and rent dissipation: gains from new technologies are already attainable but are concentrated among a relatively small fraction of the economy.
      * Implementation and restructuring lags
      * Reallocation effects

These explanations largely overlapped with reasons associated with the information technology paradox (Dewan & Kraemer, 1998; Triplett, 1999; Lehr & Lichtenberg, 1999; Bresnahan, 2002). Implementation and restructuring lags could be the primary reasons for the research to consider. Firstly, it requires time to generate positive impacts on productivity after the implementation. Rodrigo (2021) conducted event studies and found that it took five years after adopting robots to have significant productivity gains. This is supported by Brynjolfsson et al. (2021), who collaborated with the U.S. Census Bureau and surveyed over 30,000 manufacturing establishments to study predictive analytics and firm-level productivity. They concluded that the impact of AI on productivity may not be immediately observable after implementation but may require a period of lag due to the presence of intangible investments. However, Babina et al. (2022) used U.S. datasets to examine the effect of changes in AI investments (2010- 2014) on productivity growth through 2018. They found no significant positive effect, even with a lag of a few years, while employing a standard distribution lead-lag model. Secondly, investments in complementary assets are necessary to exploit the full benefits of AI technology. This explanation also is supported by Colombo et al. (2013), Dedrick et al. (2013), Tambe et al. (2020), Aitken (2021), Bronsoler et al. (2021), and Salehnejad and Proudlove (2023).

Through the discussion from the old to the new paradigm of technology, much literature has acknowledged the benefits of technology adoption for firm-level productivity. At the same time, studies have also questioned and raised the existence of a paradox. However, there has never been a definitive conclusion. In addition, the multiple conflicting conclusions about heterogeneous factors in section 2.3.2 indicate that new and further empirical evidence is required. Seamans & Raji (2018)

emphasised the extreme value of enhancing empirical evidence regarding AI adoption and its impacts on firms. The discussions about literature by country suggested that very few studies examine the UK context, possibly because it is challenging to collect firm-level data by running own survey to measure firms' AI adoption levels.

Secondary datasets are now available for the UK context. The literature discussed in section 2.3.1 mainly examined overall or average productivity growth, with very few studies considering how long it takes for the productivity gain to take place. For example, Brynjolfsson et al. (2021) only indicated a lag period but did not test how long it lasted because they focused on complementary assets roles. This further highlights the research gap in exploring the short vs long term productivity growth brought about by AI investments.

1. Dataset: Using web-content data to define AI

It is difficult to find reliable data at the micro level to analyse Artificial Intelligence (AI) activities and their impacts on firms. In particular, several sectors were analysed simultaneously, and recent data covered a few years. Seamans & Raj (2018) and Czarnitzki et al. (2023) believe there are highly likely no direct methods to measure the level of AI adoption within firms, and there is a lack of high-quality micro-level data. Meanwhile, existing literature explicitly indicated a growing need for quantitative analyses to measure the research question. In addition, current empirical work primarily collects and uses aggregated statistical data related to AI activities, categorised by industry and country. This significantly hindered in-depth research on topics associated with AI (Seamans & Raj, 2018). Therefore, discovering and creating a relevant micro- level database is of utmost importance. Many studies used “patent applications” to measure AI adoption, for example, Damioli et al. (2021), Zhai & Liu (2023), Kopka & Fornahl (2023), and Zhang et al. (2024).

However, this measure has faced significant criticism because patent data may offer an incomplete and biased view of AI’s potential impact on productivity. Firstly, not all AI methods are patented, and many firms may utilise AI technologies developed by third parties (Czarnitzki et al., 2023). Patent data is more commonly used to measure technological development than AI adoption. Secondly, approaches are required to define what an AI patent is, as there are no appropriate Cooperative Patent Classification (CPC) codes to capture it. International Patent Classification (IPC) also can be used to categorise patents based on the technology they cover, which has a similar drawback as CPC. In addition, IPC classes cannot be directly associated with specific industries, but many technologies overlap multiple sectors (Martinelli et al., 2021).

Martinelli et al. (2021) used IPC classes to analyse the technological domains of patents related to Industry 4.0, enabling technologies to study the technological revolutions of the Industry 4.0 paradigm instead of adopting technology. In addition, Hötte et al. (2022) conducted four different approaches to identify AI innovations in patents: keyword search, science citations, the World Intellectual Property Organisation (WIPO), and the

United States Patent and Trademark Office (USPTO). The paper aimed to measure AI innovations through patent analysis and study their economic impact. Therefore, these indicated that “Patent” was not an appropriate measure of AI adoption. Martinelli et al. (2021) also noted that there is a lack of systematic microdata on technology adoption, so conducting a comprehensive comparative analysis of firm adoption decisions and examining their impacts is challenging without longitudinal data.

Our paper aims to find a novel way to measure AI adoption and analyse its productivity impact at the firm level. The novelty of our paper resides in analysing the impact of AI on firm productivity by using a novel longitudinal dataset comprising firms involved in AI activities. Specifically, the dataset used in our analysis is constructed by The Data City (TDC), a commercial data creator company. The information provided by TDC is extracted from various data sources, including Company Website, Dealroom, Lightcast, Creditsafe, Companies House, Innovate UK, 360 Giving and more. TDC has several advantages over other micro datasets:

* Using real-time industrial classifications (RTICs) to classify the economy: traditional standard industrial classifications (SICs) approach to categorising companies by primary business activities has potential limitations. First, the SIC system hasn’t been updated since 2007 and failed to capture new sectors, like emerging advanced AI technology. Second, results might be inaccurate because pf a problematic assignment process and overly broad categories. RTICs could complement SICs’ disadvantages.
* The UK-based data provider originates from the UK, although it has gradually opened up to the global. Information pertinent to the UK context is more abundant and comprehensive than other global micro datasets.
* Large scope: encompasses over 400 proprietary classifications and provides insights into over 400 emerging economy sectors. It includes data on approximately

5.4 million companies.

Therefore, TDC is a potential and powerful dataset for our analysis. However, it is worth noting that it is not a perfect dataset for measuring AI activities and examining research questions. For instance, at this stage, it does not adequately distinguish between AI diffusers and AI adopters. However, it remains the optimal choice given the currently available resources.

The data information that TDC provides includes:

* Company information: company number, company name, country of origin, contact information, registered address, sector classification by RTICs, company size, incorporation date, etc.
* Fundamental financial information: income statements (gross value added, taxes, turnover, expenses, income, earnings, dividends, shareholder funds, etc.), assets, liabilities, cash flows, total funds, total innovative UK funding, persons with significant control, etc.

Other economic information, including the crucial information for this study:

employment, company growth trends (growth rates and company growth percentage per year), job postings (by software skill, specialised skill, certifications skill, common skill), innovation score, women-led stats, and R&D expenditures.

1. Methodologies to build dataset

There are two strategies that TDC used to build potential dataset: keywords filter strategy and machine learning algorithm strategy. For keywords filter strategy, two functions allow us to search over all website text: contains and does not contain. We put the selected keywords into these two functions by adding “ ” and \* and choosing between “all of these keywords” or “any of these keywords”. This option generated a broader set of results to ensure that we included all relevant AI adopters firms. Otherwise, no matching firms would be found by selecting “all of these keywords” when we put all keywords together at once. In this case, I have downloaded three datasets from TDC platform by filtering the keywords:

* Dataset 1: firms that are AI developers that belong to RTIC0004 and RTIC0095
* Dataset 2: firms that considered to be “AI adopters” with using “consult”\* to filter the list.
* Dataset 3: firms that considered to be “AI adopters” but without using “consult”\* to filter the list.

Dataset 1 is created by TDC platform automatically. One possible reason to separately create dataset 2 and 3 is to avoid biased results. Using the keyword “consult”\* would cause the number of companies sharply reduced from 33,086 to 10,242. This might exclude firms that meet qualifications of “AI adopters”, for example, Fresh Fridge Hire Limited provided consultancy services about refrigerated food distribution and courier, which adopted AI related technology. However, companies that develop AI technology often operate under the guise of consultancy to effectively commercialise their AI products and services. Consequently, applying a filter that does not contain “consult”\* would significantly remove “AI developers” from the company list. Therefore, it remains uncertain whether the use of the keyword “consult”**\*** is appropriate. To address this, two different datasets were downloaded for further data analysis to reach a well- founded conclusion.

By analysing dataset 1 & 2, we found that the number of overlapped companies is 268, which indicated that some firms fall into both categories: AI developers and AI adopters. They not only develop AI algorithms internally but also apply these algorithms within their own organizations. Diagram 1 shows the details. In fact, the TDC platform is a clear example—it has developed its own AI algorithms and incorporated them into the platform to help users search and build their datasets. Therefore, creating a binary variable distinguishing strictly between "AI developers" and "AI adopters" might be difficult.

However, we found that the keywords list and methods of filtering firms are problematic. Firstly, placing "AI" under the option "does contain any of these

keywords" means all AI-related firms are included, encompassing both developers and adopters. This term acts as a broad umbrella, capturing all keywords related to AI, and consequently preventing further effective differentiation. Specifically, adopter-related keywords such as "ai adoption"\* become redundant, as the broader keyword "AI" already covers all AI-related firms. Similarly, developer-specific keywords (e.g., "ai algorithms"\*) also become ineffective for distinguishing developer firms within such a broad scope.

For machine learning algorithm strategy, it helped to build a list of firms that meet our criteria (such as AI adopters) by providing good examples and bad examples of firms to train the AI algorithms. This is how it works:

* Firstly, find a set of companies that are good and bad representatives by inserting company numbers or use the keyword search engine.
* Secondly, start to train the algorithms by adding these companies to “included” and “excluded” functions to build our list.
* Thirdly, generate the list and check the classifier terms, which allow us to understand what positive and negative training terms are. So, we can know whether the generated list meet our qualifications or not.
* Fourthly, adding more firms to continuously train the list until we get the desired output. The more firms that you put, the more accurate results that you will get.

We tried this approach by including AI adopters and excluding AI developers to find the desired firm list of adopters. However, the results are unsatisfactory. This might be because AI is a general-purpose technology that spans numerous fields, involving a wide range of terms. Consequently, the algorithms struggle to distinguish precisely which firms match our intended criteria. Another issue is that AI developer firms also frequently use general AI-related terms such as "ai" and "smart technology." When we attempt to exclude developer firms by placing these terms into the "excluded" category, the algorithms interpret them as negative terms and exclude potentially relevant firms as well. Thus, the machine learning algorithm strategy has proven to be less effective compared to the keyword-based strategy.

1. Conclusion

The research presents significant theoretical and managerial implications. These findings can substantially enrich existing academic theories and offer practical guidance for business leaders aiming to harness AI's potential. Firstly, it contributes to a deeper understanding of technology-firm productivity relationships. It provides empirical evidence that AI, as a general-purpose technology, does not uniformly affect firm productivity but is heterogeneously influenced by firm-specific factors. This heterogeneity in AI impact aligns with and extends the technology diffusion theory (Fichman, 1992), which posits that technology adoption and benefits vary across different organizational contexts. This will help managers make better investment decisions and strategies by considering firms' unique attributes, which is especially essential for SMEs with insufficient resources and high trial-and-error costs (Kopka &

Fornahl, 2023). Secondly, the research indicates that complementary assets are crucial for firms to fully capitalize on their technological investments, supporting the RBV in the digital age. Therefore, managers understand the necessity of complementary assets and can evaluate the company's capital stock to ensure that the company will not face a crisis while increasing new investment because a large amount of money is required at the initial stage. Finally, the findings of this research have implications for policy- making (Zhai & Liu, 2023; Anderton et al., 2023). Policymakers could use this knowledge to design more effective support mechanisms for firms adopting AI technologies, such as incentives for AI research and development, subsidies for technology adoption, or grants for training programs. These policies could be tailored to the needs of different industries and firm sizes, enhancing the overall economic benefits of AI adoption across the UK.

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## Supply chain corruption: A taxonomy

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###### Abstract

Corruption in supply chains remains a recurring problem that has become a concern for economic development and organisational integrity. Recent major corruption cases highlight the scale of the issue and indicate how prevalent corruption is in supply chains. To address this, academics and practitioners tried to find solutions by defining anti- corruption strategies. However, current studies predominantly concentrate on specific issues and do not capture all dimensions of supply chain corruption. This research aims to fill the gap by developing a taxonomy that combines literature and empirical data. We synthesise findings from 83 academic articles and insights from 75 supply chain practitioners to develop a taxonomy of supply chain corruption. The proposed taxonomy builds on seven dimensions: form, sector, actor, stage, cause, motive, and impact, which collectively facilitate a better understanding of the complexities of supply chain corruption. The taxonomy provides a framework for academics and practitioners assessing supply chain vulnerability to corruption by identifying 11 forms of corruption in public and private sectors, along with the actors involved, underlying causes, personal motives, and impacts. This taxonomy is the first in the supply chain context, advancing knowledge by laying the groundwork for future research agendas and significantly contributing to combat corruption.

**Keywords:** Supply Chain, Corruption, Taxonomy

**Introduction**

The supply chain exists as a network of entities that are involved in a long chain of processes that must adhere to regulations and standards. Each entity has its own set of interests and perceptions when it comes to doing business, which can lead to opportunities for corrupt individuals and businesses to engage in corruption to advance their interests. Globally, the United Nations estimated the cost of corruption at 5% of the world’s Gross Domestic Product (Johnson, 2018). Using the world’s GDP for 2024 of US$ 102 trillion, this equates the cost of corruption to the global economy to US$ 5 trillion annually. Corruption has been a recurring problem that has become a concern for many countries and organisations, including the public and private sectors (Fan et al., 2021). In the most

recent major corruption case, United States prosecutors have accused an energy company of paying more than $250 million in bribes to government officials to secure energy supply contracts worth $2 billion in profits (Jones and Ellis-Petersen, 2024). Despite this, the subject of corruption in supply chains appears to be neglected and lacking from the literature (Kim and Wagner, 2021).

This increasing number of major corruption cases indicates how prevalent corruption is in supply chains, which encourages academics and industry practitioners to examine into why it occurs and the processes that allow it to continue. Academics have focused on researching anti-corruption strategies to address high-level corruption, such as the bending of explicit rules and principles for the benefit of closed networks (Fazekas et al., 2023). Moreover, institutionalised corruption is being practiced more actively, especially in public procurement, and it becomes a mere avenue for obtaining funds for political purposes (Lassou et al., 2023). Current research on corruption predominantly concentrates on specific issues, such as favouritism in government contracts (Fazekas et al., 2023), supply chain fraud including product quality fraud, and collusion in the procurement of infrastructure projects (Signor et al., 2022). Supply chain corruption may take various forms, and there are many other dimensions to consider in reducing its probabilities. Furthermore, different sectors may involve different actors, with corruption enablers increasing the potential for corruption at various stages. The consequences of corruption can also vary for the company and its affiliated entities. To fill this critical gap, our research examines all of the dimensions that must be considered when addressing supply chain corruption.

Furthermore, to gain a better understanding of supply chain corruption, we also identify and analyse the characteristics of each dimension. The terms “dimensions” and “characteristics” are taken from the component of a taxonomy by Nickerson et al. (2013). Characteristics are positioned one level under dimensions that provide the available options for each dimension. For example, in the dimension of form, common characteristics include bribery, kickback, and fraud (Bahoo et al., 2020). However, the current studies are focusing on specific issues, and it will be difficult to know what the forms of supply chain corruption are. Similarly, there are many potential corruption enablers, but we must be aware of all possible enablers in the supply chain. This is an essential gap for understanding supply chain corruption, and we aim to address this by defining the characteristics of each dimension found.

The dimensions and characteristics of supply chain corruption form the fundamental of the taxonomy developed in this research. This taxonomy will guide the user both academics and practitioners in better understand the issue. Corruption in supply chain is not only impacting the financial aspect of the organisation but also damage to trust, reputation, and disrupt business operations. Addressing this issue will be more easier using the developed taxonomy as it covers all aspects related to supply chain corruption. Academics can use the taxonomy to explore new research agenda and identify emerging area for future research. Supply chain practitioners can apply the taxonomy to better assess their supply chain vulnerabilities from corruption and develop mitigation strategies to reduce the occurrence of corruption. This research seeks to answer the following research questions:

RQ1. What dimensions of supply chain corruption should be considered?

RQ2. What characteristics distinguish each dimension of supply chain corruption?

To answer these questions, we employ the taxonomy development method by Nickerson et al. (2013) to develop a taxonomy of supply chain corruption that consists of

its dimensions and characteristics. Taxonomy is chosen because of its capability in fully capture the issue by defining all possible dimensions and characteristics, which answer our research questions. Moreover, this method combines the inductive and deductive approach iteratively from all relevant sources including literature and empirical data. These approaches are important because the taxonomy aimed to combine the knowledge from all relevant literatures with the empirical data collected from supply chain practitioners. Through a multi-stage qualitative study, this research consists of two iterations of inductive approach based on literature review to and one deductive iteration on the data collected from supply chain practitioners anonymously via Prolific. This approach will gather the required qualitative data and develop the taxonomy.

Our research makes several contributions theoretically and practically. The theoretical contribution of this research is the development of a taxonomy of supply chain corruption that allows academia and practitioners to better understand the dimensions and characteristics of this issue. The taxonomy broadens the knowledge of the supply chain, particularly the corruption risks, and provides a groundwork for future studies in analysing more of each dimension. This research also contributes practically as the actionable insights that could guide practitioner to strengthen their operations with the aim to mitigate the corruption from occurring and minimise its impact.

**Literature Review**

*Corruption*

Corruption has been extensively studied by academics from a variety of fields, including law, finance, economics, accounting, and international business, with an emphasis on the different forms and implications of corruption in each of these fields. Corruption is defined as “the abuse of entrusted power for private gain,” highlighting its flexible and hidden characteristics (Transparency International, 2024). Synthesizing the literature, Bahoo et al. (2020) define corruption by highlighting three key characteristics: the individuals or entities involved in illegal activities, the misuse of power or authority, and the underlying motives to derive personal benefits. Their research on corruption is broad and covers the actors (individuals or firms), forms (bribery, fraud, financial crimes, abuse, falsification, favouritism, nepotism, manipulation, etc.), motives (personal or financial gains), sectors (public and private), causes (demand-side and supply-side factors), and impacts (negatively affects trade, business operations, and firms' performance).

There are two types of corruption that have been specified in the literature, public and private corruption. Public corruption is frequently used to describe the exploitation of public power and resources for private gain, or the abuse of official positions for non- official purposes (Cuervo-Cazurra, 2016; Getz and Volkema, 2001; Mikkelsen, 2013). Additionally, public corruption can vary in scale, classified as either low-level or grand corruption depending on the scale, involved parties, and impact of the corruption. Low- level corruption involves small favours or gifts, while grand corruption involves large- scale abuses, such as the illicit acquisition of state property (Pashev, 2011). On the other hand, private corruption typically entails private individuals or entities providing bribes, like gifts or information trades, to obtain personal advantages (Argandoña, 2003). Our corruption analysis will include both the public and private sectors.

Corruption typically involves two opposing parties, where one party demands or accepts bribes and the other party offers them (Getz, 2006). Ashforth et al. (2008) emphasise that examining both sides is essential to fully understand corruption. In this research, we include all possible corruption actors who may engage in various forms and processes. From the literature review, we conclude that each study focuses on specific dimensions or characteristics of corruption. To address this gap, this study will develop a

taxonomy of supply chain corruption by looking at a broader range of dimensions and characteristics that will help academics and practitioners develop better anti-corruption strategies in their supply chain.

*Supply Chain Corruption*

Kim and Wagner (2021) propose a supply chain-orientated perspective of corruption, highlighting the upstream (suppliers, suppliers’ suppliers) and downstream (customers, customers’ customers) sides of corruption, aligning with the SCOR model. This viewpoint is crucial for understanding the supply chain, as it expands the conventional focus on the focal firm to capture a broader view of interconnected supply chain entities. This concept of supply chain corruption has been extended in another research study, for example, Wang et al. (2023) who analysed the effects of supply chain corruption on stock returns. Their findings highlighted the importance of robust anti-corruption strategies to reduce financial impacts of supply chain corruption. However, research on supply chain corruption remains fragmented, highlighting the existing gap for a systematic classification of its various dimensions and characteristics. Supply chain corruption occurs when supply chain entities engage in illegal activities, which can happen in the public and private sectors or even both in public-private partnerships. (Iossa and Martimort, 2016). In this research, all entities, including upstream, focal firms, and downstream partners, are analysed for potential corruption instances. It is crucial to understand the underlying causes of this corruption, especially in the upstream and downstream sides of the supply chain.

All industries faced the corruption problem in their supply chain including manufacturing, energy, utilities, resources, technology, media, telecommunications, healthcare, finance, and consumer markets. This highlights the widely concerned problem of corruption that requires more research to discover the specific dimensions of characteristics of supply chain corruption in each industry. However, most studies are too focused on the sourcing stage, specifically procurement. For instance, Fazekas et al. (2023) noticed favouritism throughout the procurement process, from planning to contract execution. Procurement corruption often arises when agents, acting on behalf of buyers, use their authority to select non-deserving suppliers in exchange for bribes, exploiting the buyer’s limited insight into purchase details (Singh, 2017). The supply side of corruption in procurement cases is when suppliers bribe buyers to obtain a competitive advantage, while the demand side of corruption is whereas buyers request bribes in return for a favour or disclose confidential information (Wang et al., 2023). One of the real- world case is the Milan Expo scandal, where Italian politicians, entrepreneurs, and businessmen were arrested on suspicion of engaging in a network of bribes to secure contracts (Sargiacomo et al., 2015). This case shows how corruption become systemic and can involve multiple actors.

This research considers both the supply and demand sides of corruption, all potential forms, and relevant instances to provide a comprehensive understanding of supply chain corruption. In line with the literature, we indicate two points to explain the term of supply chain corruption. First, the form of corruption activity includes bribery, kickback, collusion, favouritism, and all other forms. Second, the actors involved in corruption (individual or organisation) misuse their position, power or authority in breaches of existing rules and regulations to benefit themselves (financially or otherwise) instead of the greater good. These definitions conform with broader corruption theories while tailoring them to the specific dimensions of supply chains. These points of supply chain corruption provide clear boundaries for the research, ensuring all relevant instances are captured, both conceptual and empirical, from literature and data collection involving

supply chain practitioners across sectors. This research allows academics and practitioners to systematically classify the dimensions and characteristics of supply chain corruption.

*Taxonomy*

In developing a classification system, several processes could be used, including typologies or taxonomies as the form of conceptual knowledge that identify the research territory and their relationships (Iivari, 2007). Various classifications often represented as taxonomies, frameworks, or typologies (Limaj and Bernroider, 2022). The process of classification development could be done at a distinguished level of conceptual and empirical (Bailey, 1994). At the conceptual level, the researcher derives the classification from a theoretical foundation deductively in the form of typology, while the empirical level begins with the data and derives the classification from the data analysis in the result of taxonomy (Nickerson et al., 2013). Both typology and taxonomy can be referred to, and this research uses taxonomy because it is initially developed through inductive approaches based on literature and empirical data. Taxonomy is important to advance the knowledge as it allows researchers to generalise, communicate, and apply research findings. The taxonomy development method by Nickerson et al. (2013) is applied in this research because it allows researchers to combine the conceptual and empirical levels when developing the taxonomy, resulting in a comprehensive taxonomy that includes both literature and empirical instances.

**Methodology**

This study develops a taxonomy of supply chain corruption using the Nickerson et al. (2013) taxonomy development method. A taxonomy is a set of dimensions that each consist of a set of mutually exclusive and collectively exhaustive characteristics whereby an object under consideration (in this case, an instance of supply chain corruption) can have one characteristic and only one characteristic for each dimension. The Nickerson method starts by defining meta-characteristics; this high-level definition provides the scope of the taxonomy, identifying the phenomena being studied and defining how users will apply it. Here we set the meta-characteristics according to the taxonomy's objective, to identify a comprehensive set of dimensions and characteristics of supply chain corruption as a basis to identify new research directions and inform practitioners of areas for focus in tackling corruption.

Next, we define the ending conditions for the development of the taxonomy. Nickerson et al. (2013) advocates employing both subjective and objective ending conditions. For subjective ending conditions, we analyse whether the taxonomy at each iteration is concise, robust, comprehensive, extendable, and explanatory (Nickerson et al., 2013). Conciseness evaluates the clarity of object definitions, robustness assesses the distinctness of objects, comprehensiveness guarantees the classification of all objects, extendibility facilitates the incorporation of new information, and explanatory improves understanding. For objective ending conditions, we adopt those defined by Nickerson et al. (2013) whether a representative sample has been examined, no new dimensions or characteristics emerge in the last iteration, no further merges or splits occur, and each dimension and characteristic is unique. At the end of each iteration, all subjective and objective ending conditions are jointly applied.

With these two prior decisions taken, the methodology can consider how to develop the dimensions and characteristics of the taxonomy. This was done over three iterations of the taxonomy. The iterative process moves between conceptual development and empirical data and analysis. The iterations finish when the pre-defined ending conditions

have been met. This study required three iterations to develop the taxonomy before reaching the ending criteria. Iteration 1 used data from a systematic literature review to identify the overall dimensions of the taxonomy; Iteration 2 developed the characteristics of supply chain corruption within the dimensions; Iteration 3 collected data from supply chain professionals to validate both the dimensions and characteristics.

*Iteration 1 – Developing Initial Taxonomy Dimensions*

Iteration 1 focused on developing the different dimensions of the taxonomy through a systematic literature review. The SLR inductively defined the dimensions essential for understanding supply chain corruption. The literature review followed the method by Tranfield et al. (2003). Gusenbauer (2022) identified Scopus, Web of Science Core Collection, and ABI/INFORM Global as the top bibliographic databases for business and management fields. Relevant literature was collected from these sources using the comprehensive search string outlined in Table 1, the string was defined based on the meta- characteristics of this study. Filters restricted results to English journal articles published from 2009 to 2023, yielding 4,364 results. Further, to maintain quality only articles published in CABS Rank 3, 4, and 4\* journals was applied, yielding 415 articles.

**Table 1 - Search String**

Topic Keywords

Supply Chain Management

"Supply Chain Management" OR "SCM" OR "Logistics” OR "Procurement” OR "Operations” OR "Inventory” OR "Distribution” OR "Vendor Management" OR "Supplier Management”

Corruption "Corruption" OR "Fraud" OR "Bribery" OR "Embezzlement" OR "Kickbacks" OR "Misconduct" OR "Illicit Practices" OR "Corrupt Practices" OR "Ethic\*" OR "Malpractice" OR "Abuse of Power" OR "Conflict of Interest" OR "Transparency Issues" OR "Nepotism" OR "Collusion" OR "Blackmail" OR "Extortion" OR "Favouritism" OR

"Corporate Fraud" OR "Corruption Risk"

The screening of titles and abstracts reduced the number to 120 articles, and subsequent full-text reviews resulted in 83 final articles. The articles were evaluated against the pre-defined meta-characteristics of the research. The conceptualisation process emphasised the definition of corruption and supply chain corruption, as examined in recent years, resulting in seven dimensions for the initial taxonomy. Additional iterations were required to define the characteristics.

*Iteration 2 – Defining Initial Taxonomy Characteristics*

Iteration 2 focused on deriving mutually exclusive and comprehensive characteristics within each dimension. The data set was the 83 articles identified in the SLR from Iteration 1. After the initial data familiarisation, comprehensive reviews of the full texts were performed to ascertain the forms, actors, sectors, stages, causes, motives, and impacts of corruption. Open coding identified 639 segments, which were classified into initial codes using MAXQDA software. The codes were refined through careful analysis and axial coding to identify patterns and categorise similarities conceptually. For instance, both the offering and soliciting of bribes are classified as acts of bribery. Axial coding ensured that all characteristics were comprehensive and clearly defined. The second iteration identified 46 characteristics across the seven dimensions defined in the first iteration. Gioia et al. (2013) qualitative coding analysis was used in this iteration in alignment with inductive theory development. Despite meeting the requirements of most

ending conditions, a final iteration was required to validate characteristics using different data sources.

*Iteration 3 – Validation of Taxonomy from Empirical Data of 78 Instances*

Iteration 3 focused on testing and validating the taxonomy developed through the first two iterations with real empirical data of instances of supply chain corruption collected from 75 supply chain professionals. Participants were globally recruited through Prolific, an online platform known for its strict control measures and procedures to ensure high- quality data (Kapoor et al., 2022; Kim et al., 2023). Prolific maintains the anonymity of participants, meaning they were more able to talk freely about supply chain corruption without compromising their position. Participants also had frequent reminders in each question not to disclose any information about them, other people, or the organisations associated with the instance of supply chain corruption they were describing. There were no cases where anonymity was breached by participants.

To maintain data quality, a screening survey was sent to 500 participants. As we set a maximum number of respondents to keep costs capped, we found that the survey was typically only available for a few hours before the maximum number of responses was gathered. Therefore, we deployed the screening survey in three batches, one to capture participants in Europe, one in North America, and one for the Global South. To be eligible for the primary study, participants needed to have knowledge of supply chain corruption. The survey identified 128 eligible participants who were invited to complete the primary survey. The primary survey offered participants a chance to give detailed descriptions of instances of corruption through open questions. We ensured that all seven dimensions from the taxonomy were represented in the survey, but with the opportunity for participants to give descriptions of other areas so as not to constrain their responses. Participants were able to give more than one instance of supply chain corruption if they had more than one to share. Of the eligible 128 participants, 75 completed the primary survey and provided a total of 78 instances of supply chain corruption. Open coding revealed 694 unique subcodes from 78 instances. The subcodes were compared with the

46 characteristics from the second iteration, confirming their alignment. One characteristic within the "form" dimension lacked empirical validation, while all others were supported. The specified ending conditions were satisfied, with no new dimensions or characteristics introduced, and no mergers or splits necessary. The refined taxonomy was completed after meeting all subjective and objective conditions.

**Findings**

Ending conditions (objective and subjective) is analysed after each of the three iterations to determine whether the taxonomy developed has met all conditions. We jointly analyse the objective and subjective conditions as detailed in the Table 2. Once the objective ending conditions have met then we evaluate the subjective ending conditions.

**Table 2 - Ending Conditions by Iteration**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Iteration 1 (Inductive) | Iteration 2 (Inductive) | Iteration 3 (Deductive) |
| **Objective ending conditions**  - Representative sample have been examined | - | - |  |
| - No new dimensions or characteristics emerge | - | - |  |
| - No new merge or split of dimensions or | - | - |  |

characteristics

|  |  |  |  |
| --- | --- | --- | --- |
|  | Iteration 1 (Inductive) | Iteration 2 (Inductive) | Iteration 3 (Deductive) |
| - Each dimension and characteristic was unique |  |  |  |
| **Subjective ending conditions** |  |  |  |
| - Concise |  |  |  |
| - Robust |  |  |  |
| - Comprehensive |  |  |  |
| - Extendable |  |  |  |
| - Explanatory |  |  |  |

In the first iteration, we continued on the main debates highlighted in literature review that corruption in supply chain occurred in many forms, being done by various actors, happens in both public and private sectors, might happen in all stage of supply chain, caused by wide range of institutional and organisational factors, motivated by personal or financial gains, and impacting supply chain. These initial understanding of supply chain corruption are used as the starting point in doing a thorough literature review for the first iteration. In the first iteration, we inductively define seven dimensions of supply chain corruption includes form, sector, actor, stage, cause, motive, and impact*.* These seven dimensions serve as the result of the initial taxonomy.

**Table 3 - Taxonomy of Supply Chain Corruption**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **FORM** | Bribery | Kickback | | | Collusion | | Favouritism | | Manipulation of Tendering and Awarding Process | | | Non- competitive or Restricted Procedures |
| Abuse of Authority | | Fraud and Misconduct | | | Contract Violation | | Illegal and Unethical Practices | | | Conflict of Interest and Cronyism | |
| **SECTOR** | Public | | | | | | Private | | | | | |
| **ACTOR** | Politician | | | | Public Officials | | | | Business Entities | | | |
| Management | | | | Procurement Officer | | | | Retailers | | | |
| **STAGE** | Plan | | | Source | | | Make | | | Deliver | | |
| **CAUSE** | Market Uncertainty | | | | Political Pressure | | | | Bureaucratic Pressure | | | |
| Organisational Weaknesses | | | | High Discretionary Power | | | | Secure Competitive Advantages | | | |
| **MOTIVE** | Financial Gain | | | | Personal Gain | | | | Political Needs | | | |
| **IMPACT** | Financial Loss | | | | Reputational Damage | | | | Disruption | | | |
| Decrease in Quality | | | | Damage to Trust | | | | Inadequate Competition | | | |

After having the detailed explanation of each dimension, the second iteration using the inductive approach led to the identification of characteristics for each dimension. The third iteration validated the developed taxonomy by deductively analysing the empirical data of real-world instances to the dimensions and characteristics of supply chain

corruption. The final taxonomy of supply chain corruption is shown in Table 3. It comprises of 38 characteristics grouped into seven dimensions. The explanation of each dimension and characteristic is detailed as follows.

*Dimensions of Supply Chain Corruption*

First, we identified form as the specific illegal activities committed by perpetrators in the context of corruption. A wide range of such activities has been highlighted in recent academic studies. For instance, Bahoo et al. (2020), focusing on corruption in international business, identified various forms of corruption, including bribery, fraud, financial crimes, and favouritism. This dimension is critical to the research because recognising the different forms of corruption is necessary for understanding the wide range of corrupt practices that might occur.

The next dimension is sector, focusing on the specific area of transaction within the supply chain, which includes the public sector that may involve a private party and the private sector in the form of private-to-private corruption. Vast majority of academia focuses their study of corruption on public corruption due to more attention from the society and the openly discussed topics. In contrast, private-to-private corruption has been relatively neglected even that most corruption cases involve a private party (Argandoña, 2003).

The third dimension is actor, defined as the individuals or supply chain entities involved in committing acts of corruption. The literature highlights that the actor is the individual or entity initiating and engaging in corruption. For example, Sargiacomo et al. (2015) identified multiple actors in corruption and fraud cases, including politicians, business entities, and bureaucrats. In public corruption settings, business employees are typically the actors of active bribery, while public officials are more often the actors of passive bribery. Understanding who the actors are in a corruption setting is critical, as different actors influence the outcomes of corruption.

Next, we identified stages of supply chain including both upstream and downstream following SCOR model that organised into plan, source, make, and deliver (APICS, 2017). In this research, the SCOR model will be applied to analyse each supply chain process, incorporating entities such as the focal firm, suppliers, customers, and their respective upstream and downstream partners. Examining the complete supply chain cycle enables this research to identify potential corruption issues across each stage.

The fifth dimension is cause, which are the circumstantial factors that contribute to the occurrence of corruption. Causes in this research focusing on organisational-level circumstances and factors responsible for enabling corruption. For instance, Padhi et al. (2016) identified the main causes of corruptive activities in bidding as the monopoly power of certain bidders and lack of participation in auctions. These causes primarily focus on organisational-level factors explaining why bidders collude during the bidding stages. The causes that create opportunities for such potentially unethical activities are therefore essential components in the occurrence of corruption (Pendse, 2012).

Further, we identified motives as the personal reasons individuals choose to engage in corrupt acts. It focuses on the individual-level reasoning behind engaging in or refraining from such illegal activities. Personal moral judgment, social influence, and individual perceptions of corruption are the three key motives highlighted by Gorsira et al. (2018). Moral obligation varies between individuals, with the decision to engage in corruption being deeply personal. As a result, corruption may be seen as acceptable by some but unethical by others, depending on their attitudes and perceptions of the act (Powpaka, 2002).

The last dimension is impact, which is defined as the results arising from corrupt activities that vary depending on the actors involved and the sectors in which it occurs. Corruption involves illegal activities that pose significant risks to organisations, resulting in a wide range of adverse consequences. Damage to a firm’s reputation is one of the most common organisational-level impacts (Kim and Wagner, 2021). Its effects can severely undermine economic development, particularly in the procurement of state-funded projects, and cause broader social harm (Halter et al., 2009).

*Characteristics of the First Dimension: Form*

Bribery is one of the characteristics under form, defined as the solicitation, offering, and acceptance of a bribe by public officials (Arnold et al., 2012). An indicative example from the literature is when bidders initiate the provision of bribes in exchange for the benefits obtained (Fan et al., 2021). From the empirical data, we identified some instances, including a supplier who bribed to pass inspection on falsified documentation and bribed a contract manager to approve incomplete work.

The next characteristic is kickback, which is comprised of fixed and proportional kickback provided by the supplier to the official. A fixed amount kickback typically occurs when a company bribes a public official who successfully influences the tender in their favour (Ntayi et al., 2013). Regarding proportional kickback, it is calculated as a fraction of the revenue that must be allocated to the corrupt individual (Fan et al., 2021). A real-world instance provided by one of the participants is the supply of PPE during the pandemic, for which contracts were given to suppliers who were selected based on how much kickback was given afterwards.

The third characteristic is collusion within the supply chain that may establish an agreement on a predetermined winner, exampled by pre-bidding collusive agreements aimed at maximising profit (Padhi et al., 2016) or giving the appearance of competition for a project that conceals a predetermined winner (Barrus and Scott, 2020) This form was also observed in an empirical case where open competition occurred, but it was later revealed that the winner had been predetermined.

We identified favouritism as the fourth characteristic, defined as the manipulation of regulations and principles to award a contract to a preferred bidder (Fazekas et al., 2023). Favouritism grants preferential treatment to a specific bidder, including informal advantages for bid preparation and advance notifications to the favoured bidder (Thomann et al., 2023). Favouring a particular supplier is also confirmed in one of the real-world instances where the senior executives assure a particular company that is owned by their relatives to win the tender.

The subsequent form identified is the manipulation of tendering and awarding processes, characterised by intentional influence during procurement stages to obtain advantages for specific bidders. This form includes altering the quality assessment to advantage a particular bidder (Wang, 2020; Xu and Li, 2019) and distorting technical specifications designed for a preferred bidder (Thomann et al., 2023). In certain cases, the tender process was extremely tailored to a specific supplier’s capabilities, which was confirmed from one of the real-world instances collected.

The next characteristic is non-competitive or restricted procedures that occurs when actors deliberately limit or remove competition, particularly in the procurement process. This includes single bidding, wherein only one bid is obtained in a competitive market due to the deliberate exclusion of other prospective bidders (Fazekas et al., 2023). Deterrence of illegal entry is also evident in scenarios with minimal competition, as competitors have been deterred through intimidation and threats (Clark et al., 2018).

The seventh characteristic is abuse of authority that involves the exploitation of influence and power for personal benefit (Neu et al., 2015), which includes bureaucratic corruption and the minor corruption associated with the everyday misuse of entrusted power (Jiménez et al., 2022). Furthermore, one of the real-world instances provides the corruption case where an executive used the influence and power to buy low-quality items in return for money given by the supplier.

Fraud and misconduct are identified as the next forms of supply chain corruption. Fraud is defined using illegal activities to illicitly gain personal benefit while causing losses to others, while misconduct entails a breach of legal, regulatory, or ethical standards that must be upheld (Mu and Carroll, 2016). Misconduct encompasses irresponsible practices such as excessive working hours, the employment of child labour, and substandard wage rates (Wu et al., 2017). One example from empirical data is an upstream supplier that manipulated quality certification to pass off substandard raw materials which compromised the product’s integrity.

The ninth characteristics of form is contract violations that may occur when the contracted supplier fails to perform or deliver as specified in the contract in terms of cost, production, and execution (Gallego et al., 2021). In particular situations, this violation pertains to bribery, wherein companies offer bribes to not supply the goods or services stipulated in the contract (Colonnelli et al., 2022). Contract violation can also occur when a supplier sent inferior products that did not meet the specifications defined in the contract as captured in one of the real-world instances provided.

The next characteristic is illegal and unethical practices that occur when there are unjustified or overpriced payments for goods and services, or when payments exceed the winning bid amount (Zamboni and Litschig, 2018). Some indicative instances exist where manufacturers obtain information via informal channels, colluding with retailers to establish a cartel, resulting in inflated wholesale prices (Shamir, 2017). The empirical data gathered from Prolific covers the illicit sale of counterfeit goods, discarded property, and spare pallets within shipping containers.

The last characteristic is conflict of interest. The accelerated awarding of contracts was identified as a source of accountability issues concerning PPE contracts during Covid-19 in the UK, where a high-priority lane was utilised to fast-track contracts for firms with strong connections to government officials (Sian and Smyth, 2022). Personal connections affecting the selection process were also identified in one of the empirical instances, which leads to higher costs and poor quality.

*Characteristics of the Second Dimension: Sector*

In defining the sector of corruption, Arnold et al. (2012) recognise the bribery of or by public officials and bribery in the private sector as the corruption, which provides us the initial understanding of these two sectors. Public corruption occurs when government officials and bureaucrats exploit their positions to arbitrarily alter regulations and policies for corrupt purposes (Sartor and Beamish, 2020). The empirical data show some instances of price fixing for construction contracts between six companies to win government contracts.

The second characteristic of sector is private sector corruption that refers to private- to-private corruption, demonstrated by companies providing gifts in return for illicit information exchange for personal or corporate advantage (Halter et al., 2009). The real- world instances of private corruption include a supplier who bribes a purchasing manager to secure a contract and collusion between a supplier and one of the staff of a private company.

*Characteristics of the Third Dimension: Actor*

Understanding potential actors in supply chain corruption is necessary because different forms of corruption may involve different supply chain entities. The first actor is a politician that is found to be the actor for the occurrence of political corruption in public procurement, where they utilise their hierarchical position to obtain their interest by embezzling the money from the contracting firm (Chiappinelli, 2020). Politicians often use their position in the market, exploiting the mutually interdependent needs where business entities need favourable policies and government contracts while they need financial resources for electoral success (Neu et al., 2015).

The second actor identified is a public official, who may initiate corruption in the public sector without political pressure, exploiting their positions for personal gain (Gauthier et al., 2021). A public procurement officer may manipulate the technical specifications of a project to accommodate the interests of affiliated companies, thereby permitting the briber to influence the design phase of procurement in return for a bribe (Caillaud and Lambert-Mogiliansky, 2021). The corrupt bureaucrats may use their authority to ensure the company that bribes them gets chosen as the bid winner, as explained in one of the empirical data collected.

The third actor is business entities that may be found in both public-to-private and private-to-private corruption. Bribery is employed by enterprises to secure contracts (Gauthier et al., 2021), by suppliers conceal materials to create scarcity and inflate prices (Simangunsong et al., 2016) or by bidders collaborate to form cartels that elevate prices (Padhi and Mohapatra, 2011). From the real-world instances, we highlighted some cases where vendors conspired with internal staff to manipulate invoices and inflate costs.

The next actor is the management of the private sector, which is susceptible to corruption because of the presence of corrupt relationships, potentially resulting in unethical practices within the organisation. Managers may use their discretionary authority to prioritise suppliers to the detriment of the company (Bowman, 2020). Moreover, empirical evidence substantiated the involvement of various management figures in corrupt practices, including logistics company owners who conspire to inflate prices, corporate executives who offer bribes to officials for the export of illicit goods, and directors who procure services from firms owned by relatives.

Procurement officers in the private sector identified as the next actor that possess the potential for corruption; for example, a buyer at a technology company exploited his position to accept bribes from a supplier (Wang et al., 2023). The compromised procurement officer will contact the successful bidder to permit them to modify the bid, enabling them to secure a more profitable agreement (Fan et al., 2021). The empirical data provide some instances where the officers order more stock from a particular company because they could get personal benefits instead of contracting with other companies.

Retailers also engage in corruption, as they may form cartels through anticompetitive agreements that enable them to secure greater profits (Lin et al., 2021).Retailers may initially seek to collude, potentially forming a buying alliance; for example, in the electronics sector, several OEMs may delegate component procurement to a shared contract manufacturer (Kemahlioǧlu-Ziya and Bartholdi Iii, 2011).

*Characteristics of the Fourth Dimension: Stage*

Upstream corruption occurs when a company commits corrupt practices with its suppliers, while downstream corruption transpires when a company engages in corrupt practices with its customers (Kim and Wagner, 2021). The indicative example from literature is that corruption may arise during the planning phase when favouritism

influences the selection of project requirements and specifications (Caillaud and Lambert- Mogiliansky, 2021). Some of the real-world instances collected show the upstream stage, including a supplier that bribes to pass falsified documentation and a company owner who bribes to get first preference.

The next characteristic is source including pre-bidding phase, the bidding phase, and the post-bidding phase (Dávid-Barrett and Fazekas, 2020). In the pre-bidding phase, a corrupt politician seeks to establish a monopoly or resource dependence, favouring the contributing bidder (client) by, for instance, specifying excessively particular products for procurement (Fazekas et al., 2023). The real-world instances confirmed the corruption in the source stage, including certain vendors conspiring with internal staff to approve inflated contracts by circumventing normal procurement procedures in return for bribes. The third stage is make, where corruption may happen during the production phase, encompassing possible misconduct throughout the production process (Wu et al., 2017). Moreover, fraud may transpire at any stage of the production process (Mu and Carroll, 2016). In the contract execution phase, a corrupt politician would seek to achieve relaxed quality assessments or alter the contract to their advantage (Fazekas et al., 2023). During the implementation phase, corruption can arise when a signed contract lacks

comprehensiveness (Iossa and Martimort, 2016).

The fourth stage is deliver, where downstream corruption happens if the parties involved are downstream of the target firm, referring to situations where the target firms give a bribe/kickback to their customers (Kim and Wagner, 2021). The empirical data show that in many retail markets, such as gasoline and retail pharmacies, collusion exists. The real-world corruption instances may also occur during the delivery stage, including bringing illegal items, sending damaged goods, or bribing to fasten the process.

*Characteristics of the Fifth Dimension: Cause*

One cause that contributes to supply chain corruption is market uncertainty, which frequently encourages bidder collusion. Sharing information and networking with vendors can lead to collusion, impacting fair competition (Padhi et al., 2016). When competition is disrupted, it becomes challenging to secure competitive bidding. Monopoly on a particular material by some suppliers is highlighted in the empirical data as one real-world instance of market uncertainty that may occur.

The next characteristic is political pressure, which presents an important cause contributing to supply chain corruption, often driven by the presence of individuals with political connections in crucial procurement roles. Having these individuals positioned at various levels, from senior oversight to procurement management, allows them to influence procurement resources and decision-making (Lassou et al., 2023). The empirical data provide an instance where high-ranking officials create procurement as avenues of and directing funds to their proxies.

An increase in the amount of bureaucratic pressure on the supply chain may result in instances of corruption. This corruption may take place during procurement, on the production stage, or during the logistics and distribution process. In the sector of public procurement, the significant share of government budgets makes public contracts a tempting opportunity for corrupt individuals to syphon off financial resources from the state (Lassou et al., 2023). The vast scale of procurement activities also indicates a heightened risk of corruption.

Weaknesses within an organisation play a significant role in facilitating supply chain corruption, resulting from a range of structural and operational deficiencies. A crucial element is the insufficient oversight, which occurs when key control institutions are denied the necessary resources to operate effectively, hindering their ability to carry out

their monitoring responsibilities (Lassou et al., 2023). Limited resources increase organisational vulnerabilities; when procurement officers encounter unfulfilled basic needs and insufficient social welfare, their capacity to resist moral temptations declines (Ntayi et al., 2013). Procedural inefficiencies also facilitate corruption, which is highlighted by the empirical data that lack of transparency resulted in favouritism, which eventually affected project budgets.

High discretionary power in decision-making is a significant cause of supply chain corruption. Political agents frequently bypass regulations or laws, heavily depending on their discretion to enable corrupt practices (Dong et al., 2022). Procurement officials possessing significant discretion, particularly within constrained procurement frameworks, are more prone to misusing their authority for personal benefit (Zamboni and Litschig, 2018). A real-world instance includes how officials can directly influence the decision to award tenders to companies who owned by their family members.

A significant cause of supply chain corruption at the organisational level is the pursuit of competitive advantage, as firms frequently use unethical practices to outperform competitors. Firms that provide bribes seek to secure a competitive advantage over their rivals by tilting procurement choices to benefit themselves (Gauthier et al., 2021). In real- world instances provided, we found several cases where companies offered bribes in exchange for information that would gain them a competitive advantage in tenders.

*Characteristics of the Sixth Dimension: Motives*

Financial gain appears as a primary motive for corruption within supply chains, often driven by personal goals and objectives. Several actors in supply chains engage in corrupt practices to enhance profitability; for instance, collusion facilitates monopolistic control, which secures elevated profit margins by restricting fair competition (Lin et al., 2021). In a real-world case of collusion between companies in government tenders, the collective objectives are to fix prices above market values that would allow them to gain more profits.

The second characteristic is personal benefit, where corruption in supply chains frequently arises from individuals pursuing these advantages. For instance, a corrupt purchaser might take advantage of their role to secure personal gains, like accepting bribes in return for altering procurement results (Lennerfors, 2009). There are real-world instances from the empirical data where public servants may disrupt the provision of public services to gain personal benefits, frequently compromising the integrity of the organisation.

Political needs are the third characteristic that can drive supply chain corruption, especially when financial resources are required to maintain or expand political power. In relationships where both parties rely on each other, political figures often need financial support to achieve electoral success, whereas businesses aim to secure government contracts and advantageous policies. The exchange of influence within procurement processes often satisfies these needs (Neu et al., 2015).

*Characteristics of the Seventh Dimension: Impact*

Financial loss is a significant impact of supply chain corruption, as it results in increasing costs, rising retail prices, uplifted winning bid prices, misallocation of public funds, and damaging the economy. Aryal and Gabrielli (2013) discovered that costs increase as the result of bid rigging, which decreases the potential revenue. Similarly, the increasing expenditures were also found in the real-world instance of allegedly colluding companies that drive up the costs.

The second characteristic of impact is reputational damage where corruption in the supply chain adversely affects organisational reputation, encompassing significant financial, legal, social, and ethical implications that must be acknowledged. Ensuring compliance and ethical practices is a priority for companies to fulfil customer expectations; however, corruption harms this effort by normalising unethical behaviour, thereby damaging the organisation's reputation (Halter et al., 2009). This impact was also confirmed in the real-world instances where the company ended up losing the clients and affecting the reputation of the company.

The next characteristic is disruption that also has the impact of impairing governance, increasing risks, and lowering operational efficiency. Corruption frequently leads to a decline in governance capacity, as decision-makers neglect to implement democratic controls, thereby sustaining a detrimental cycle of corruption (Grossi and Pianezzi, 2018). Moreover, it worsens business uncertainties by heightening risks in volatile environments, consequently destabilising the supply chain (Khieu et al., 2023). The empirical data show that corruption may disrupt the production and result in a backlog of duties that need to be done.

Decrease in quality is the next impact of corruption, where the quality of the goods and services is being compromised. For example, collusion lowers the quality of products that are purchased, frequently failing to meet public expectations (Signor et al., 2022). Corruption-driven misconduct results in detrimental products, exploitative labour practices, and environmentally harmful business models, intensifying social injustices (Skilton and Bernardes, 2022). In real-world instances, the deficiency in quality assurance is exploited by greedy actors to increase profits by sacrificing quality.

Damage to trust is the negative impact of corruption on both the public and private sectors, and it contributes to widespread distrust between a company and its customers and suppliers. Collusion further erodes public trust by reducing the perceived fairness of competitive bidding procedures and the integrity of procurement authorities (Signor et al., 2023). The absence of transparency intensifies this problem, as institutional complexity cultivates environmental unpredictability and hinders accountability (Sartor and Beamish, 2020). One of the fraud instances from empirical data shows the loss of credibility as a result of the corruption.

The last characteristic is inadequate competition that may be done by distorting market dynamics and hindering suppliers from providing high-quality goods and services (Xu and Li, 2019). Collusive practices among various suppliers, whether affiliated or not, commonly affect competition by diminishing bid variance and creating distribution asymmetries (Huber and Imhof, 2019; Lin et al., 2021). Bribery is one of the real-world instances that may impact the supply chain by creating unequal market access for other suppliers.

**Discussion**

This research presents a comprehensive taxonomy of supply chain corruption by synthesising results from a thorough literature review with empirical data. The taxonomy consists of seven distinct dimensions: form, sector, actor, stage, cause, motive, and impact. We have refined each dimension through iterative analysis, enabling a comprehensive understanding of the aspects of supply chain corruption. We specified 38 characteristics to improve the conceptual clarity of the taxonomy, allowing for the analysis of diverse instances of supply chain corruption and the mitigation of their occurrence. The process involved three iterations, commencing with a literature review and concluding with the anonymous empirical data collection from 75 practitioners via Prolific. We created a taxonomy that integrates emerging code segments from academic

articles and real-world instances, facilitating the identification of conceptually developed and empirically validated dimensions and characteristics of supply chain corruption. Current research on corruption emphasises specific characteristics, which results in individual explanations for each study. Our taxonomy offers a comprehensive perspective on supply chain corruption, covering all potential forms in both the public and private sectors; the various actors involved; every stage of the supply chain; underlying causes; personal motives; and significant impacts. The development of our taxonomy integrates conceptual and empirical approaches, commencing with literature review as the foundation for the initial taxonomy, subsequently enhanced by an extensive literature review and the validation from 78 practical real-world instances.

*Theoretical Implications*

The taxonomy contributes to the knowledge of supply chain by offering a structured framework to analyse the complexity of supply chain corruption. Existing literature often examines corruption in isolated contexts, focusing on specific forms such as bribery or sectors like public procurement. The identification of seven dimensions allows for a holistic examination of corruption. For instance, the “form” dimension reveals the various forms of corruption, from bribery and kickbacks to fraud and misconduct. This highlights the necessity for future research to explore the distinct mechanisms behind each form. Likewise, the “sector” solidifies the clear distinction between sectors, wherein the public sector engages in public-to-private corruption, while the private sector concentrates on private-to-private corruption within the supply chain. Furthermore, the taxonomy addresses a critical gap in the literature by distinguishing individual-level motives and organisational-level causes. Managing the impact is essential for resilience in such circumstances, and our taxonomy provides a theoretical framework for potential impact scenarios.

The performance of supply chains is another emerging area that could be examined by academics in future research. Including corruption as one of the performance indicators in the organisation is important, as organisations need to work together to remove the corruption from the supply chain. The next research agenda includes how to have better strategies in response to disruption, for example, a pandemic. Disruptions will result in higher uncertainty, which is creating a prone area for corruption. Future research may examine how these disruptions influence the mitigation strategies of corruption. Digital supply chain is the next emerging area identified from the taxonomy, as retailers and consumers might give a new type of corruption in the supply chain. Understanding the corruption risks in e-commerce and e-procurement will help organisations to adopt the newest technology while safeguarded from corruption. Lastly, investigating the role of ethics training and organisational culture might help in addressing supply chain corruption. By strengthening the ethical awareness of procurement officials, staff, or management, we can collectively reduce the occurrence of corruption in our supply chain. The developed taxonomy can be used to identify and analyse these eight emerging areas for future research.

*Practical Implications*

The findings hold considerable significance for practitioners aiming to reduce corruption in supply chains. The taxonomy serves as a tool for organisations to identify and mitigate vulnerabilities in their operations. For example, identifying procurement officers as important players in corruption allows for focused interventions like improved training and ethical supervision. Likewise, recognising the “impact” aspect highlights the necessity for robust anti-corruption measures to protect organisational integrity. The

“sector” dimension underscores the importance of context-specific strategies. Organisations in the private sector should adopt tailored measures to address unique challenges, such as collusion. Moreover, the taxonomy’s emphasis on “stages” provides actionable insights for designing anti-corruption interventions. For example, introducing transparency measures during the pre-bidding phase. By aligning these strategies with the identified dimensions, organisations can develop comprehensive anti-corruption frameworks.

**Conclusion**

Corruption will continue to persist as a substantial issue across all industries, including supply chain management. Numerous studies on supply chain corruption exhibit considerable diversity regarding the various dimensions examined, the explanations of characteristics, the types of entities investigated, the methodologies employed, the contributions made, and the theoretical implications derived. This study advances our knowledge of supply chain corruption by creating an extensive taxonomy that integrates theoretical viewpoints with empirical data. By delineating seven dimensions of form, sector, actor, stage, cause, motive, and impact, it provides a comprehensive framework for analysing all aspects of supply chain corruption. The findings reveal the pervasive existence of corruption in both public and private sectors, highlighting its detrimental effects on organisational performance and societal welfare.

This research tackles the lack of studies on supply chain corruption from both conceptual and empirical viewpoints by employing the hybrid method established by Nickerson et al. (2013) to develop a taxonomy. We integrate the conceptual classification knowledge from the literature with empirical data derived from both literature and practitioner questionnaires. For each of the seven dimensions, we have organised the characteristics that enable academics and practitioners to comprehend the diverse forms of corruption, including the contributing factors, causes, and motives that may heighten the likelihood of occurrence. We identify a total of eleven forms of corruption that encompass various activities, including bribery, kickbacks, collusion, favouritism, manipulation of the tendering and awarding processes, non-competitive or restricted procedures, abuse of authority, fraud and misconduct, contract violations, illegal and unethical practices, as well as conflicts of interest and cronyism.

Understanding these eleven potential forms of corruption will assist institutions, organisations, and individuals in preventing them from occurring. This research enhances the literature and suggests practical strategies to address corruption in global supply chains. In developing the taxonomy, we have captured various dimensions and characteristics both from literature and empirical data to assure its usability for academics and practitioners in better understanding supply chain corruption. The taxonomy will not only be able to help in analysing and developing the necessary mitigation strategies for corruption but also serve as the groundwork for future research. We have identified eight research areas for future studies that can use the taxonomy as their reference. Ultimately, promoting transparency and accountability in supply chains is both a moral responsibility and an essential driver for resilient economic development.

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**An Interpretable Machine Learning Approach for Forecasting Extreme Price Occurrences in the Day-Ahead Electricity Market**

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**Abstract**

In recent years, the frequency and magnitude of extreme electricity prices have increased due to the rising share of renewable energy and external market dynamics, exposing market participants to signiﬁcant price risks. Accurately forecasting extreme price occurrences is essential for enhancing market stability and supporting informed decision-making in price risk management. To address this challenge, this paper introduces an adaptive, dynamic weighted threshold (DWT) method for identifying ex- treme prices under varying market conditions. Furthermore, it proposes a weighted-XGBoost (W-XGB) classiﬁcation model to forecast extreme price occurrences in the context of imbalanced data. Comparative analysis across various experiments demon- strates the proposed method’s superior forecasting performance and stronger discriminatory power compared to other baseline models. To enhance the model’s interpretability, SHAP (SHapley Additive exPlanations) is applied to analyze the relative con- tributions of different features. The analytical results reveal that extremely high prices are inﬂuenced by multiple interrelated factors, including supply-demand conditions, fossil fuel price volatility, and historical market behaviours, making their forecast more complex. In contrast, extremely low prices are predominantly driven by forecasted residual load, indicating a more de- terministic relationship with supply-demand conditions. Additionally, while geopolitical risk is considered, it exhibits minimal direct impact on extreme price occurrences. By incorporating SHAP-based interpretability analysis, this study provides a deeper understanding of extreme electricity price dynamics. The proposed solution is adaptable to various electricity markets, offering valuable insights for market operators and participants seeking to enhance risk management strategies and improve forecasting accuracy in volatile electricity markets.

1. **INTRODUCTION**

With the deregulation of European electricity markets in the late 20th century, market participants became increas- ingly exposed to signiﬁcant price risks. Unlike traditional commodities, electricity cannot be efﬁciently stored, and its transmission is constrained by the physical limitations of the grid ([Souhir et al.](#_bookmark150) [2019](#_bookmark150)). Consequently, electricity spot prices exhibit higher volatility than other commodities and are char- acterized by extreme price behaviours, including sharp price spikes and even negative prices.

Furthermore, the growing adoption of renewable energy re- sources in recent years has caused electricity price volatility in Europe to surge, and the frequency of extreme price events has also increased signiﬁcantly. More speciﬁcally, renewable energy resources such as wind power and photovoltaic power are intermittent because their production depends on uncer- tain weather conditions. This leads to an imbalance between electricity supply and demand, resulting in price volatility and the occurrence of extreme prices ([Ketterer](#_bookmark119) [2014](#_bookmark119), [Maniatis and](#_bookmark156) [Milonas](#_bookmark156) [2022](#_bookmark156)). Furthermore, geopolitical events have a signif- icant impact on the energy sector ([Su et al.](#_bookmark158) [2021](#_bookmark158), [Zhang et al.](#_bookmark177) [2022](#_bookmark177), [Martin-Valmayor et al.](#_bookmark121) [2023](#_bookmark121)), especially on electricity spot prices. For instance, the stability of oil and gas supplies used for electricity generation has been signiﬁcantly affected since the outbreak of the Russian-Ukrainian war. The interrup- tion of these commodities may lead to electricity shortages, which results in price volatilities and extreme prices ([Saâdaoui](#_bookmark141) [and Jabeur](#_bookmark141) [2023](#_bookmark141)). As a result, the need for managing electric- ity price risks has become even more urgent in increasingly complex electricity markets.

Various methods have been employed for the electricity mar-

ket to manage price risks, mainly including hedging and fore- casting ([Deng and Oren](#_bookmark96) [2006](#_bookmark96), [Conejo et al.](#_bookmark86) [2010](#_bookmark86), [Çanakog˘lu](#_bookmark87) [and Adıyeke](#_bookmark87) [2020](#_bookmark87), [Janczura and Wójcik](#_bookmark115) [2022](#_bookmark115)). However, in many regions, particularly in emerging countries, ﬁnancial derivatives such as futures and options that are commonly used for hedging price risks are either underdeveloped or unavail- able ([Avci Surucu et al.](#_bookmark107) [2018](#_bookmark107)). As a result, electricity price forecasting (EPF) has become the primary tool for market participants to manage price risks. Given its importance, sub- stantial research has focused on accurate EPF, with two broad categories of methods: statistical methods and machine learn- ing methods ([Nowotarski and Weron](#_bookmark131) [2018](#_bookmark131), [Loi and Le Ng](#_bookmark143) [2018](#_bookmark143), [Chang et al.](#_bookmark88) [2019](#_bookmark88), [Lago et al.](#_bookmark125) [2018](#_bookmark125), [Tschora et al.](#_bookmark164) [2022a](#_bookmark164)). However, accurately forecasting extreme price occur- rences remains a signiﬁcant challenge. Extreme price events are rare, often occur suddenly with large magnitudes, and are typically treated as outliers during data processing. This rarity and unpredictability make them particularly difﬁcult to model effectively ([He et al.](#_bookmark108) [2015](#_bookmark108), [Tafakori et al.](#_bookmark159) [2018](#_bookmark159)).

In practice, both market participants and operators need accurate forecasting of extreme price occurrences to address operational challenges arising from price risks in the mar- ket ([Christensen et al.](#_bookmark89) [2012](#_bookmark89), [Clements et al.](#_bookmark90) [2013](#_bookmark90)). This is because when spot prices exceed or fall below a certain thresh- old, their trading and operational decisions should be adjusted accordingly. For instance, generators on the sell-side need to avoid underpricing or incurring losses during periods of extremely low prices, while retailers or consumers on the buy- side need to mitigate the risk of overpaying during periods of extremely high prices ([Ullah et al.](#_bookmark167) [2018](#_bookmark167)). Moreover, market operators depend on accurate extreme price forecasts to reduce the costs associated with daily operations, such as managing supply-demand imbalances and monitoring potential instances of market power abuse by participants ([Westgaard et al.](#_bookmark170) [2021](#_bookmark170)).

Therefore, accurately forecasting extreme price occurrences

is essential for managers handling risk management and oper- ations, as well as for regulators overseeing the market in such circumstances.

* 1. **Deﬁnition and occurrences of extreme price**

The occurrence of extreme prices can be regarded as binary events, and forecasting the occurrence of extreme prices can be formulated as a binary classiﬁcation problem ([Hagfors et al.](#_bookmark102) [2016](#_bookmark102)). Extreme prices can usually be ﬁltered out from normal prices through a threshold, and exceeding the threshold indi- cates the occurrence of extreme prices. Since extreme prices are not readily observable, the ﬁrst step is to determine the threshold for differentiating normal and extreme prices. In gen- eral, there are two ways in the literature to pre-determine price thresholds: ﬁxed price threshold and variable price threshold. Fixed price threshold means to determine a ﬁxed price value such as 100 Eur/MWh, 120 Eur/MWh or 150 Eur/MWh as threshold ([Herrera and González](#_bookmark111) [2014](#_bookmark111), [He and Chen](#_bookmark105) [2016](#_bookmark105), [Clements et al.](#_bookmark91) [2015](#_bookmark91), [Manner et al.](#_bookmark116) [2016](#_bookmark116), [Galarneau-Vincent](#_bookmark103) [et al.](#_bookmark103) [2023](#_bookmark103)), whereas variable price threshold determines a cer- tain percentage of the highest (e.g., 99%, 95%, 90%) and the lowest (e.g., 1%, 5%, 10%) prices ([Trueck et al.](#_bookmark163) [2007](#_bookmark163), [Sandhu](#_bookmark144) [et al.](#_bookmark144) [2016](#_bookmark144), [Liu et al.](#_bookmark137) [2022a](#_bookmark137)). Variable thresholds provide more ﬂexibility than ﬁxed thresholds as they can change with the dynamics of market prices.

However, while variable thresholds introduce adaptability,

they rely on a static percentile computed over the entire dataset, which limits their responsiveness to evolving market dynam- ics. A threshold derived from global statistics fails to capture temporal variations, particularly those induced by signiﬁcant external shocks. For instance, geopolitical conﬂicts, extreme weather events, and policy shifts can drive substantial price ﬂuctuations in certain periods while leaving other timeframes

relatively stable. This imbalance skews extreme price classi- ﬁcation toward those affected years, potentially overlooking relatively high prices during normal periods.

Thus, given the increasing complexity of renewable electric- ity markets and the heightened inﬂuence of geopolitical events in Europe, existing thresholding methods struggle to deﬁne extreme prices effectively. This necessitates a more adaptive approach to identify extreme price occurrences accurately.

* 1. **Methods for forecasting extreme price occurrences**

In the literature, many approaches have been studied to fore- cast the occurrence of extreme prices. Traditionally, statistical approaches, such as autoregressive models and logistic regres- sion models, have been widely employed to model and fore- cast extreme price occurrences ([Eichler et al.](#_bookmark97) [2014](#_bookmark97), [Manner](#_bookmark116) [et al.](#_bookmark116) [2016](#_bookmark116), [Maryniak and Weron](#_bookmark123) [2019](#_bookmark123), [Liu et al.](#_bookmark137) [2022a](#_bookmark137), [Ad-](#_bookmark104) [line and Ikeda](#_bookmark104) [2023](#_bookmark104)). However, these econometric approaches often face challenges in capturing the non-linear relation- ships and complex interactions between features inherent in electricity markets.

Over the past decades, machine learning methods have demonstrated superior performance in handling non-linear re- lationships and incorporating a large number of predictors ([Galarneau-Vincent et al.](#_bookmark103) [2023](#_bookmark103)), making them more suitable for complex electricity market price data. Thus, scholars have increasingly applied machine learning models to forecast ex- treme price occurrences, achieving notable improvements in forecasting performance. Various machine learning models have been studied in the literature, including random forest (RF) ([Datta and Datta](#_bookmark98) [2016](#_bookmark98), [He and Chen](#_bookmark105) [2016](#_bookmark105), [Galarneau-](#_bookmark103) [Vincent et al.](#_bookmark103) [2023](#_bookmark103)), deep neural networks (DNNs) ([Yamada](#_bookmark171) [and Mori](#_bookmark171) [2021](#_bookmark171), [Liu et al.](#_bookmark140) [2022b](#_bookmark140)) and gradient boosting de- cision tree (GBDT) ([Stathakis et al.](#_bookmark154) [2021](#_bookmark154), [Galarneau-Vincent](#_bookmark103) [et al.](#_bookmark103) [2023](#_bookmark103), [Zamudio López et al.](#_bookmark174) [2024](#_bookmark174)).

Among these machine learning methods, boosting ensem- ble approaches, particularly Extreme Gradient Boosting (XG- Boost) ([Chen and Guestrin](#_bookmark92) [2016](#_bookmark92)), have emerged as state-of- the-art techniques in various predictive tasks. Due to its fast training speed and high predictive accuracy, XGBoost has become a widely preferred model across diverse application domains ([Ma et al.](#_bookmark151) [2021](#_bookmark151), [Rawson et al.](#_bookmark135) [2022](#_bookmark135), [Hunt et al.](#_bookmark112) [2022](#_bookmark112), [Zhang et al.](#_bookmark176) [2023](#_bookmark176), [Asselman et al.](#_bookmark106) [2023](#_bookmark106), [Niazkar et al.](#_bookmark128) [2024](#_bookmark128), [Yao et al.](#_bookmark173) [2024](#_bookmark173)). While XGBoost has been applied to normal electricity price forecasting ([Galarneau-Vincent et al.](#_bookmark103) [2023](#_bookmark103)), research speciﬁcally focusing on forecasting extreme price occurrences remains limited.

* 1. **Challenges on classiﬁcation of imbal- anced data and its interpretability**

In practice, occurrences of extremely high or low prices are relatively rare, making them signiﬁcantly less frequent than normal price events and resulting in a highly imbalanced class dataset. However, standard machine learning algorithms are not inherently optimized for imbalanced datasets in classiﬁca- tion problems. In many cases, these models have struggled to deliver satisfactory results when classifying imbalanced data ([Ruisen et al.](#_bookmark138) [2018](#_bookmark138), [Averro et al.](#_bookmark109) [2023](#_bookmark109)). Therefore, addressing the class imbalance is critical for achieving effective model performance.

In recent years, several approaches have been proposed to enhance the performance in handling class imbalance. These methods can be broadly categorized into two groups: data- level methods and algorithm-level methods ([Tanha et al.](#_bookmark160) [2020](#_bookmark160)). Data-level approaches aim to rebalance the data distribu- tion through resampling techniques, such as random over- sampling, random under-sampling, and the Synthetic Minority Over-sampling Technique (SMOTE) ([Del Rio et al.](#_bookmark99) [2015](#_bookmark99), [Dhankhad et al.](#_bookmark100) [2018](#_bookmark100), [Varmedja et al.](#_bookmark168) [2019](#_bookmark168)). However, these methods alter the original data distribution, potentially degrad- ing data quality and leading to overﬁtting or underﬁtting issues ([Liu et al.](#_bookmark142) [2022c](#_bookmark142)).

Algorithm-level methods primarily adjust the learning pro- cess to mitigate bias toward majority classes ([Tanha et al.](#_bookmark160) [2020](#_bookmark160), [Wang et al.](#_bookmark169) [2020](#_bookmark169)). A common approach is cost-sensitive learning, where the model adjusts the misclassiﬁcation cost for different classes, assigning a higher penalty to errors in the minority class. This encourages the model to focus more on correctly classifying minority class instances while still consid- ering majority class performance ([Ling and Sheng](#_bookmark136) [2008](#_bookmark136)). The goal is to minimize the overall misclassiﬁcation cost across the training dataset. However, determining appropriate cost values is challenging, as it requires balancing multiple factors with trade-offs ([Tanha et al.](#_bookmark160) [2020](#_bookmark160)).

In contrast to cost-sensitive learning, some machine learn- ing frameworks have integrated class-weighting mechanisms into their algorithms, making them more practical and accessi- ble. Models such as Logistic Regression with class weighting, Random Forest with class weighting, and Weighted-XGBoost ([Averro et al.](#_bookmark109) [2023](#_bookmark109)) offer built-in solutions that can effectively handle class imbalance with minimal parameter adjustments.

Given the stringent timeliness and accuracy require- ments for forecasting extreme electricity price occurrences, weighted-XGBoost emerges as a particularly suitable choice ([Averro et al.](#_bookmark109) [2023](#_bookmark109)). Nevertheless, limited research has explic- itly addressed the class imbalance issue in forecasting extreme electricity price occurrences, highlighting an overlooked gap in the literature.

In addition, as machine learning models become more accu- rate in forecasting the occurrence of extreme prices, they also become less interpretable and are often regarded as black-box models ([Machlev et al.](#_bookmark152) [2022](#_bookmark152)). This poses a signiﬁcant disad- vantage for market stakeholders, as they are not only interested in accurately forecasting extreme price occurrences but also in understanding the driving factors behind them. Such insights are crucial for supporting effective price risk management and informed decision-making.

Explainable Artiﬁcial Intelligence (xAI) has gained consid- erable attention due to the increasing demand for interpretabil- ity of remarkable black-box models ([Molnar](#_bookmark129) [2020](#_bookmark129), [Burkart](#_bookmark114) [and Huber](#_bookmark114) [2021](#_bookmark114)). It is a branch of machine learning research that focuses on designing human-understandable models and providing post-modeling explanations for black-box models ([Tjoa and Guan](#_bookmark161) [2020](#_bookmark161)). An important subﬁeld of xAI explores the predictability of desired labels or values based on the input features ([Lundberg et al.](#_bookmark145) [2020](#_bookmark145)). In this context, SHAP values (SHapley Additive exPlanations) have emerged as a widely used approach to quantify the contribution of each input fea- ture to the output of machine learning models ([Lundberg and](#_bookmark149) [Lee](#_bookmark149) [2017](#_bookmark149)).

SHAP values have been successfully applied in electricity system research to identify drivers and assess risks related to power grid frequency stability ([Kruse et al.](#_bookmark122) [2021a](#_bookmark122)[b](#_bookmark124)), ex- plain load forecasting ([Lee et al.](#_bookmark127) [2020](#_bookmark127)), gain insights into PV power generation forecasting ([Chang et al.](#_bookmark93) [2020](#_bookmark93), [Mitrentsis](#_bookmark126) [and Lens](#_bookmark126) [2022](#_bookmark126)), and assess the forecastability of electricity prices ([Tschora et al.](#_bookmark165) [2022b](#_bookmark165), [Trebbien et al.](#_bookmark162) [2023](#_bookmark162), [Cramer et al.](#_bookmark95) [2023](#_bookmark95)). SHAP values have been extensively utilized in the elec- tricity system, however, the speciﬁc challenge of explaining the occurrences of extreme electricity price forecasts has yet to be addressed.

* 1. **Research aims and contributions**

To ﬁll the gaps, this research aims to develop an inter- pretable machine learning framework to forecast imbalanced extreme electricity price occurrences and analyze the contri- bution of different input features. To achieve this, this study introduces a dynamic weighted threshold method to identify extreme electricity prices, and weighted-XGBoost serves as the primary forecasting model. The framework benchmarks its performance against Logistic Regression and Random Forest models with class weighting. It incorporates historical electric- ity prices, market characteristics (such as load and generation), fuel prices, and a geopolitical indicator as forecasting features. Finally, it applies SHapley Additive exPlanations (SHAP) to assess feature contributions and identify key drivers of extreme price occurrences.

The key contributions of this paper can be summarised as follows.

* Introduces a dynamic weighted threshold method to iden- tify extreme electricity prices, dynamically adapting to market conditions. Unlike static thresholds, this method en- sures robust identiﬁcation of extreme prices in both crises and stable periods.
* Incorporates the Geopolitical Risk Index as a novel fea-

ture in extreme electricity price forecasting, examining its potential impact in the context of geopolitical dynamics.

* Employs a weighted-XGBoost model to improve the fore-

casting accuracy of rare extreme price events, overcoming the limitations of standard machine learning models in handling imbalanced data.

* Applies SHAP-based explainability to decompose model

results and assess feature importance. This provides valu- able insights into the mechanisms driving extreme price occurrences, supporting more informed risk management strategies.

The remainder of the paper is organized as follows. Section [2](#_bookmark51) describes the data and methodological development, includ- ing the proposed dynamic weighted threshold and weighted- XGBoost model. Section [3](#_bookmark68) presents results and discussion, including extreme electricity price forecasts, comparative per- formance analysis against baseline models, and feature con- tribution analysis based on SHAP values. Finally, Section [4](#_bookmark82) provides a summary of the paper along with conclusions.

1. **DATA AND METHODOLOGY**

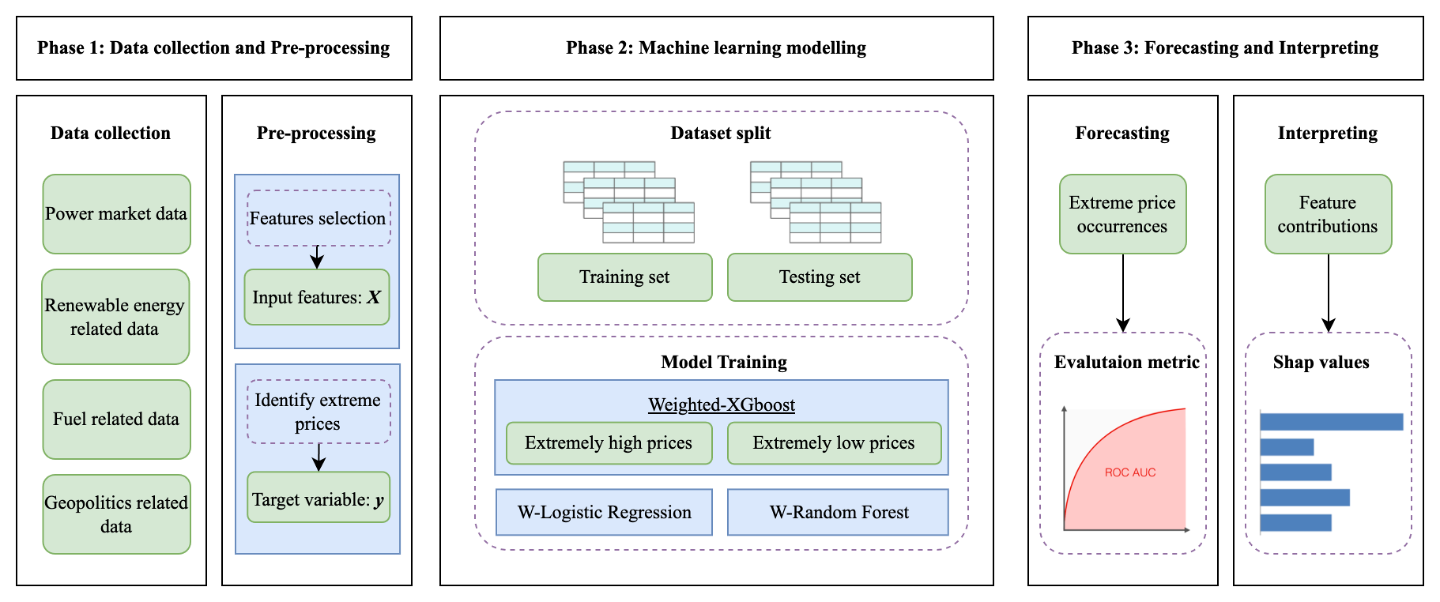
This section consists of three phases, as illustrated in Figure

[1](#_bookmark53). The ﬁrst phase covers data collection and pre-processing, detailed in Sections [2.1](#_bookmark52), [2.2](#_bookmark54), and [2.3](#_bookmark56). The second phase fo- cuses on machine learning modelling, discussed in Section

[2.4](#_bookmark59). The last phase covers methods of forecast evaluation and interpreting analysis, presented in Sections [2.5](#_bookmark66) and [2.6](#_bookmark69).

* 1. **Data**

This research focuses primarily on the European electric- ity spot market. Five years of data from January 1, 2019, to December 31, 2023, are chosen as this period primarily encompasses the European energy crisis. In addition, since Germany’s day-ahead electricity market is one of the most actively traded spot markets with a high penetration of renew- able energy resources in Europe ([Lehna et al.](#_bookmark130) [2022](#_bookmark130)), German data is selected for research. For power market data, day- ahead electricity prices, residual load forecasts, total load



**F I G U R E 1** Proposed methodology for forecasting and interpreting extreme electricity prices.

forecasts, and total generation forecasts in the German mar- ket are obtained from the publicly available German Federal Network Agencys SMARD platform ([SMARD.de](#_bookmark146) [2024](#_bookmark146)), as well as renewable energy-related input variables: wind and photovoltaics generation forecasts.

Although renewable energy resources already account for more than half of Germany’s electricity production, coal- and natural gas-based power generation continues to be a crucial complement to intermittent generation ([Madadkhani and Ikon-](#_bookmark155) [nikova](#_bookmark155) [2024](#_bookmark155)). Therefore, EGIX (European Gas Index) and API2 (ARA coal price) indexes are considered in this research. To capture the inﬂuence of carbon pricing, EUA (European Union Allowance) carbon prices are further included in the set of variables. These daily data are obtained from [Reﬁnitiv](#_bookmark139) ([2024](#_bookmark139)). Since the market closed on weekends, missing obser- vations are calculated by interpolating the values from the forward-ﬁlled approach (i.e., Friday’s data) ([Mankoff et al.](#_bookmark117) [2020](#_bookmark117)).

Furthermore, this study takes into account the geopolitical impact conditions. Even though the geopolitical impact may already be transmitted to electricity prices through commodity prices, we still include a geopolitical risk index in the model to better understand its impact on the occurrence of extreme electricity prices. This is due to their impact on electricity prices may also be direct and independent. Prior research has suggested that geopolitical risks can signiﬁcantly affect Euro- pean electricity prices ([Saâdaoui and Jabeur](#_bookmark141) [2023](#_bookmark141), [Abdullah](#_bookmark101) [et al.](#_bookmark101) [2023](#_bookmark101)). Thus, the daily geopolitical risk index proposed by [Caldara and Iacoviello](#_bookmark94) ([2022](#_bookmark94)) is considered in this research.

The lower-frequency daily data is converted to hourly data using a forward-ﬁll approach to align it with hourly obser- vations ([Mankoff et al.](#_bookmark117) [2020](#_bookmark117)). This method ensures that all

24 hourly values within the same day remain identical after the conversion. As a result, we obtained 43824 hourly values for the DA electricity price and each variable, corresponding to 1826 days of data (5 years), with 24 observations per day. Table [1](#_bookmark55) reports the descriptions of the model variables and data sources, and Figure [2](#_bookmark57) shows plots of the time-dependent data.

* 1. **Input features**

To ensure the feasibility of our forecasting approach, all input features must be available at the time of the forecast. Speciﬁ- cally, we forecast extremely high and low electricity prices for a given hour on day *d*, using only information accessible by the previous day (*d* – 1). This ensures that the model remains applicable to real-world forecasting scenarios.

Electricity prices exhibit strong daily and weekly patterns due to ﬂuctuations in supply and demand dynamics ([Liu et al.](#_bookmark137) [2022a](#_bookmark137)). Accordingly, historical prices from *d*–1, which capture short-term daily cyclicality, and *d* – 7, which reﬂect recurring weekly trends, are incorporated as key forecasting features. Additionally, market forecasts such as electricity load and generation forecasts, published on *d* – 1, provide essential forward-looking information on expected market conditions. Furthermore, fuel prices and geopolitical indicators are in- cluded using the most recent available data (*d* – 1), as they offer valuable insights into broader economic and political factors affecting electricity markets. The selected features are categorized as follows:

* **Historical prices:** Day-ahead electricity prices and one week earlier (*Pτ*,*d*–7).

**T A B L E 1** Descriptions of the model variables and data sources.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Data** | **Units** | **Frequency** | **Description** | **Data sources** |
| ***Power market data***  Day-ahead prices | EUR/MWh | Hourly | Electricity prices in the day-ahead market. | [SMARD.de](#_bookmark146) ([2024](#_bookmark146)) |
| Load forecast | MWh | Hourly | Forecasted total electricity demand in the power system. | [SMARD.de](#_bookmark146) ([2024](#_bookmark146)) |
| Generation forecast | MWh | Hourly | Forecasted total electricity generation in the power system. | [SMARD.de](#_bookmark146) ([2024](#_bookmark146)) |
| Residual load forecast | MWh | Hourly | Forecasted remaining demand that renewable energy cannot cover. | [SMARD.de](#_bookmark146) ([2024](#_bookmark146)) |
| ***Renewable energy-related data*** | | | | |
| Wind generation forecast | MWh | Hourly | Forecasted electricity generation from wind power sources. | [SMARD.de](#_bookmark146) ([2024](#_bookmark146)) |
| PV generation forecast | MWh | Hourly | Forecasted electricity generation from photovoltaic solar panels. | [SMARD.de](#_bookmark146) ([2024](#_bookmark146)) |
| ***Fuel-related data***  Gas prices | EUR/MWh | Daily | European Gas Index (EGIX), representing natural gas prices. | [Reﬁnitiv](#_bookmark139) ([2024](#_bookmark139)) |
| Coal prices | EUR/MWh | Daily | API2 (ARA coal price) index, representing coal prices. | [Reﬁnitiv](#_bookmark139) ([2024](#_bookmark139)) |
| Carbon prices | EUR/tCO2 | Daily | EUA carbon prices, representing the cost of carbon emissions. | [Reﬁnitiv](#_bookmark139) ([2024](#_bookmark139)) |
| ***Geopolitics-related data***  Geopolitical risk index | Point | Daily | A measure of adverse geopolitical events and associated risks. | [Caldara and Iacoviello](#_bookmark94) ([2022](#_bookmark94)) |

* **Load forecasts:** Day-ahead forecasts for total load (*X*Load) and residual load (*X*Res) at hour *τ* on day *d*.

*τ* ,*d*

*τ* ,*d*

* **Generation forecasts:** Day-ahead forecasts for total gen-

eration (*X*Gen), wind generation (*X*Wind), and photovoltaic

This approach, inspired by applications of rolling quantile in risk management, volatility forecasting, and trading strategy optimization ([Marshall et al.](#_bookmark120) [2017](#_bookmark120), [Packham et al.](#_bookmark133) [2017](#_bookmark133), [Jiang](#_bookmark118) [et al.](#_bookmark118) [2019](#_bookmark118)), ensures more responsive classiﬁcation compared

*τ* ,*d τ* ,*d*

(PV) generation (*X*PV ) at hour *τ* on day *d*.

*τ* ,*d*

* **Fuel-related prices:** Closing prices of key fuel at hour

*τ* on the previous day, including Carbon (*X*Carbon), Gas

*τ* ,*d*–1

*τ* ,*d*–1

to static quantile methods.

To formalize this method, we deﬁne a rolling window *P*(*r*)

*τ* ,*d*

over the price time series *P*. The rolling window at hour *τ* on

Gas

(*X*

*τ* ,*d*–1

), and Coal (*X*Coal ).

day *d* is deﬁned as:

* **Geopolitical indicators:** Geopolitical Risk Index at hour

(*r*)

′

*τ* on the previous day (*X*GPR ).

*τ* ,*d*–1

*Pτ* ,*d* = {*pτ ′*,*d′* | *d*

*∈* [*d* – *r* + 1, *d*], *τ* ′

*∈* [0, 23]}, (1)

Here, *τ* represents the hour of the day, taking values from 0 to 23, and *d* represents the day, ranging from 1 (January 1,

2019) to 1826 (December 31, 2023). *d*–1 refers to the previous day and *d* – 7 corresponds to the one week earlier.

* 1. **Indentifying extreme prices**

With the input features established, the next step is to deﬁne the target variable for forecasting extreme electricity prices. This study formulates the task as a supervised binary classiﬁca- tion problem. Traditional approaches often rely on a static per- centile computed over the entire dataset, which fails to adapt to periods of high volatility. To enhance extreme price identi- ﬁcation, we propose an adaptive, dynamic weighted threshold (DWT) method, integrating static global quantiles (capturing overall market trends) with rolling local quantiles (reﬂecting

*τ* ,*d*

where *r* denotes the window length in days. The set *P*(*r*) there- fore contains all historical hourly prices over the past *r* days, including every hour *τ* ′ of each day *d*′. This construction en- sures that the rolling window captures a complete sequence of past hourly prices across *r* consecutive days, covering all 24 hours per day.

Extreme price thresholds are determined using both global and local quantiles. Global quantiles capture long-term trends by computing quantiles over the entire time series *P*:

*τ* ,*d*

*θG*(*α*) = inf{*p* : *F*(*p*) *≥ α*},

*θG*(1 – *α*) = sup{*p* : *F*(*p*) *≤* 1 – *α*}, (2)

where *F*(*p*) is the cumulative distribution function (CDF) of *P*, and *α* is the quantile level, restricted to *α ∈* (0, 1).

Local quantiles, in contrast, adapt to short-term ﬂuctuations

by computing quantiles within the rolling window *P*(*r*) :

*τ* ,*d*

short-term ﬂuctuations). The weights are dynamically adjusted

*τ* ,*d*

*L*

*τ* ,*d*

*θ*

(*α*) = inf{*p* : *F*(*r*) (*p*) *≥ α*},

(3)

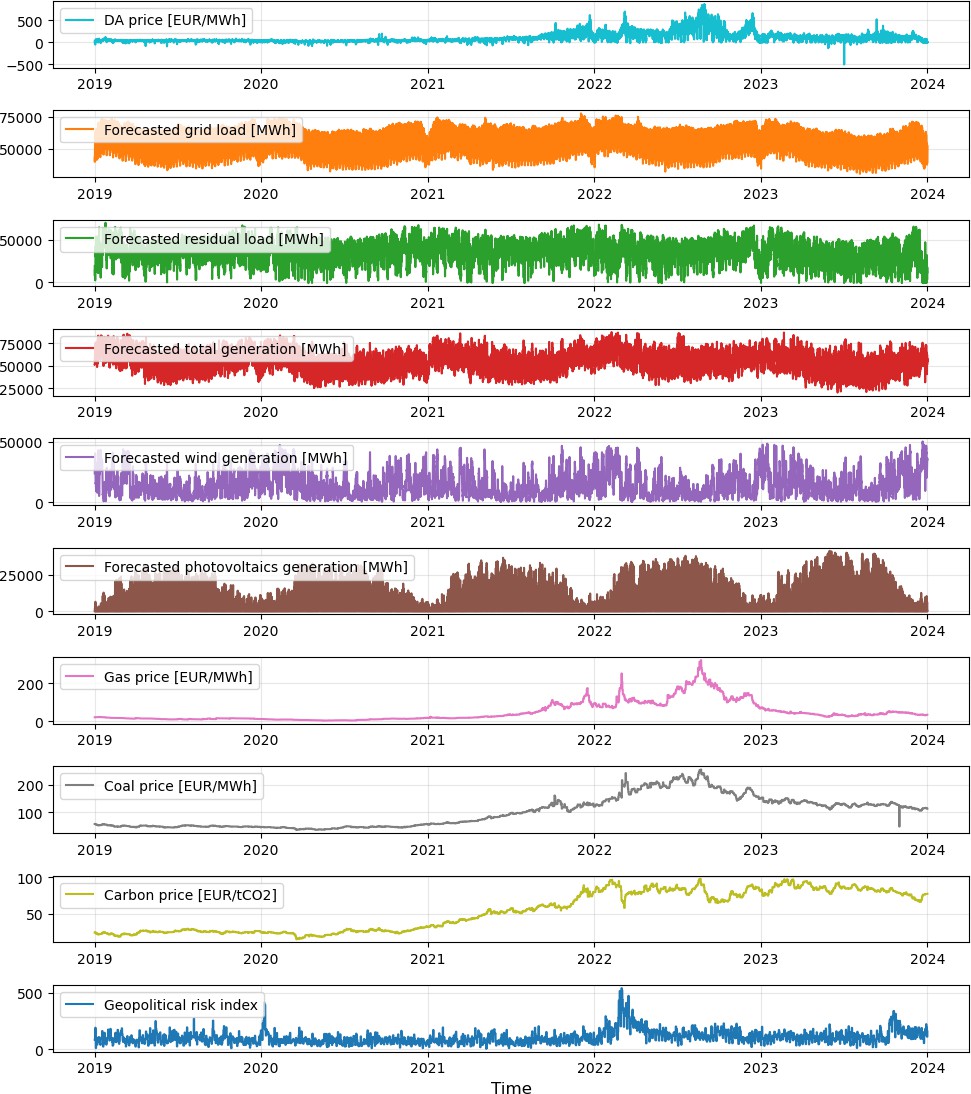
based on market volatility, allowing the thresholds to adapt effectively to price variations.

*L*

*τ* ,*d*

*θ*

(1 – *α*) = sup{*p* : *F*(*r*) (*p*) *≤* 1 – *α*},



**F I G U R E 2** Time series plots of the considered data.

where *F*(*r*) (*p*) is the CDF of the price set in the rolling window

*τ* ,*d*

To ensure consistency, *στ*,*d* is normalized between 0 and 1:

(*r*)

*P* .

*τ* ,*d*

*σ*norm =  *στ*,*d* – min(*σ*) . (5)

Volatility is a key indicator of market conditions and struc-

tural market changes ([Lin and Wesseh Jr](#_bookmark132) [2013](#_bookmark132), [Hernandez](#_bookmark110)

*τ* ,*d*

max(*σ*) – min(*σ*)

[et al.](#_bookmark110) [2022](#_bookmark110)). Therefore, we employ it as an adaptive weight- ing factor to dynamically adjust the balance between global

Finally, the dynamic weighted thresholds for extreme price classiﬁcation are computed as:

and local quantiles. The local volatility *στ*,*d* is computed as the

*Dτ*,*d*(*α*) = *σ*norm*θG*(*α*) + (1 – *σ*norm)*θL*

(*α*),

standard deviation of prices within *P*(*r*) :

*τ* ,*d*

*τ* ,*d*

*τ* ,*d*

(6)

*τ* ,*d*

*Dτ*,*d*(1 – *α*) = *σ*norm*θG*(1 – *α*) + (1 – *σ*norm)*θL*

(1 – *α*).

*τ* ,*d*

= I 1

*τ* ,*d*

*τ* ,*d*

*στ* ,*d*

1t *r ·* 24

(*p* – *µ*

L

(*r*)

*p*∈*P*

*τ* ,*d*

*τ* ,*d*

)2, *µ*

*τ* ,*d*

= 1

*r ·* 24

*p*∈L*P*(*r*)

*p*. (4)

*τ* ,*d*

This adaptive weighting scheme follows an intuitive princi- ple: global quantiles are weighted more for threshold stability when local volatility is high, since local price information

is ﬂuctuating and unstable. Conversely, local quantiles are weighted more for better threshold responsiveness when local volatility is low, since local price information is more reliable. This mechanism ensures that threshold values adjust dy- namically without excessive ﬂuctuations, making them more effective for real-world decision-making in risk management. The approach effectively balances stability and adaptability, ensuring that extreme price thresholds remain useful in both

calm and volatile market conditions.

Figure [3](#_bookmark60) illustrates the effectiveness of the DWT method, us- ing a 30-day rolling window as an example, compared to static quantile-based thresholds. The static thresholds (dashed lines) remain ﬁxed at the 90th and 10th quantiles over the entire dataset, failing to adapt to evolving market conditions.

In contrast, the dynamic weighted thresholds (solid lines) adjust in response to market ﬂuctuations. Notably, during peri- ods of extreme market shocks (e.g., post-COVID energy crisis and the Russia-Ukraine war), the dynamic weighted threshold adapts to the changing market while maintaining stability. This adaptive behaviour is essential for extreme price forecasting, ensuring that classiﬁcation thresholds remain relevant even as market conditions evolve.

Using the dynamic weighted thresholds, we deﬁne extreme price occurrences as follows:

window sizes *±*15 days, resulting in three window lengths: 15 *×* 24 = 360, 30 *×* 24 = 720, and 45 *×* 24 = 1080 hourly

observations. With these thresholds established, extreme price occurrences, serving as the target variables for classiﬁcation, can be determined. Table [2](#_bookmark58) summarizes the counts of extreme price occurrences identiﬁed using this method.

**T A B L E 2** Overview of extreme price occurrence counts.

**Type of experiments Type of prices Time window**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | **15-day** | **30-day** | **45-day** |
| Extremely high | Extreme prices | 4213 | 4376 | 4373 |
|  | Normal prices | 39611 | 39448 | 39451 |
| Extremely low | Extreme prices | 4047 | 4053 | 3995 |
|  | Normal prices | 39777 | 39771 | 39829 |

* 1. **Weighted-XGBoost classiﬁer**

Weighted-XGBoost is an enhanced version of XGBoost de- signed to address class imbalance issues ([Averro et al.](#_bookmark109) [2023](#_bookmark109)).

*y*high = (1, *pτ* ,*d* > *Dτ* ,*d* (*α*)

(7)

It is integrated into the XGBoost package and can be acti-

*τ* ,*d*

0, otherwise

vated by setting the parameter *scale*\_*pos*\_*weight* during model

where *y*high = 1 indicates that *P*

is classiﬁed as an extremely

training ([Chen and Guestrin](#_bookmark92) [2016](#_bookmark92)). In this study, this method

*τ* ,*d*

*τ* ,*d*

is tailored to forecast extreme electricity price occurrences,

high price at hour *τ* on day *d*, while *y*high = 0 denotes a non- extreme price.

*τ* ,*d*

Similarly, extremely low prices are labelled as:

which occur much less frequently than normal prices, lead- ing to a highly imbalanced dataset. This section describes how weighted-XGBoost is employed to forecast extreme price

*y*low =

(1, *pτ*,*d*

< *Dτ* ,*d*

(1 – *α*)

(8)

occurrences and elaborates on its mathematical foundation.

*τ* ,*d*

0, otherwise

* + 1. **Feature Representation and Tempo-**

where *y*low = 1 indicates that *pτ*,*d* is classiﬁed as an extremely low price at hour *τ* on day *d*, and *y*low = 0 denotes a non- extreme price.

*τ* ,*d*

*τ* ,*d*

In this paper, extremely high and low prices are classiﬁed separately to facilitate targeted forecasting and to examine the distinct mechanisms driving these price extremes. Fur- thermore, typical values for *α* are set to 0.9, enabling the identiﬁcation of the top and bottom prices based on DWT, respectively.

Since the DWT approach integrates both global and local information, it is crucial to use a relatively short window *r* to effectively capture immediate ﬂuctuations. Given this, we set the window size *r* to 30 days, corresponding to 30 *×* 24 =

**ral Indexing**

Weighted-XGBoost is implemented as a binary classiﬁcation model to forecast the occurrence of extremely high and low electricity prices. The dataset *D* = {(**x***i*, *yi*)} consists of *n* hourly observations recorded in strict chronological order, where **x***i ∈* R*M* is the feature vector , with *M* denoting the number of input features, and *yi ∈* {0, 1} is the binary target variable. Each sample, indexed by *i*, corresponds to an obser- vation at hour *τ* on day *d* is represented as (**x***i*, *yi*). The feature vector **x***i* includes the following components as determined in Section [2.2](#_bookmark54):

**x***i* = {*pτ* ,*d*–1, *p* ,*d*–7, *x*Load, *x*Res, *x*Gen, *x*Wind, *x*PV , *x*Carbon,

720 hourly observations. In practice, decision-makers may

*τ τ* ,*d τ* ,*d*

*τ* ,*d*

*τ* ,*d*

*τ* ,*d*

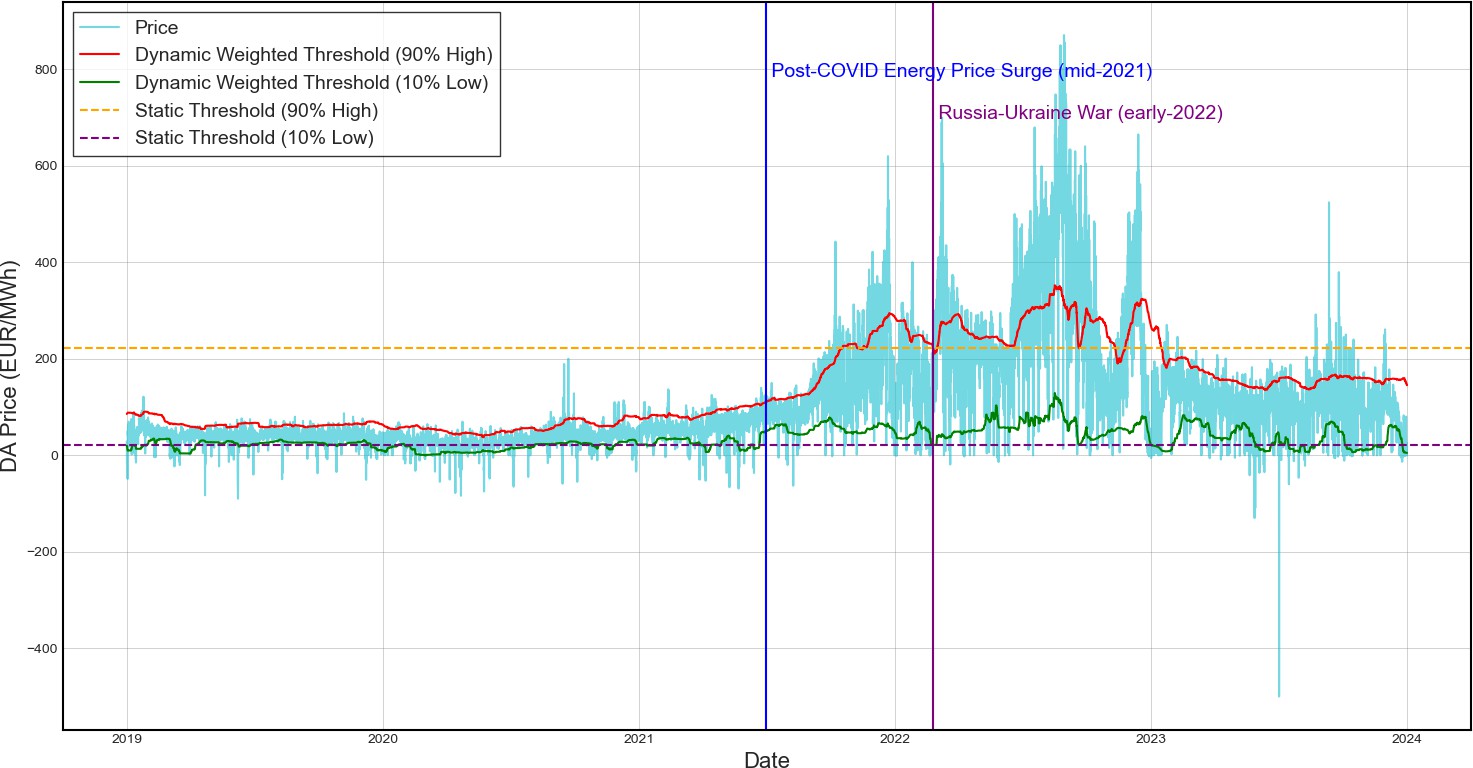
*τ* ,*d*–1

(9)

*x*Gas , *x*Coal , *x*GPR }.

consider different time window sizes to capture recent infor- mation. Therefore, we also evaluate the method using varying

*τ* ,*d*–1 *τ* ,*d*–1 *τ* ,*d*–1



**F I G U R E 3** Comparison of dynamic weighted thresholds and static thresholds.

The target variable *yi ∈* {0, 1} represents whether an ex- treme price event occurs at the corresponding time. In this

while Ω (*f* ) represents the regularization term on decision trees to prevent overﬁtting:

study, two separate weighted-XGBoost models are trained for forecasting extreme price occurrences: one for extremely high

(*y*high) and another for extremely low (*y*low), as detailed in

1 2

Ω (*f* ) = *γT* + 2 *λ ∥w∥*

, (13)

*τ* ,*d*

Section [2.3](#_bookmark56).

*τ* ,*d*

where *γT* is a structural complexity penalty, with *T* repre- senting the number of leaf nodes in the tree and *γ* being a regularization parameter that speciﬁes the minimum loss re-

* + 1. **Regularized learning objective**

duction required to make a further partition on a leaf node. The second term, 1 *λ ∥w∥*2, applies *l*2 regularization on the leaf

In this setup, (**x***i*, *yi*) represents a data pair, the model’s ﬁnal

2

weights *w*, where *λ*

controls the strength of the regularization.

forecast for the *i*-th sample, denoted ˆ*yi*, can be expressed as shown in Eq. ([10](#_bookmark61)):

*K*

L

ˆ*yi* = *fk* (**x***i*) , *fk ∈ F*, (10)

*k*=1

where *K* denotes the number of trees and *F* represents the space of trees utilized in boosting. Each *fk* corresponds to an independent tree structure *q* and leaf weights *w*. The set of functions *fk* can be learned by minimizing the regularized objective function *L*, as shown in Eq. ([11](#_bookmark63)):

This formulation ensures the model does not grow excessively complex while maintaining good generalization performance.

* + 1. **Gradient tree boosting**

Gradient boosting trees adopt an additive modeling approach, where at the *t*-th iteration, a new decision tree *ft* is added to im- prove the model’s forecast ˆ*y*(*t*) by minimizing the loss function, as formulated in Eq. ([14](#_bookmark62)):

*i*

*n*

L L *L*(*t*) = L *l*(*yi*, ˆ*y*(*t*–1) + *ft*(**x***i*)) + Ω(*ft*). (14)

*n*

*K*

*i*

*L* =

*i*=1

*l* (ˆ*yi*, *yi*) +

*k*=1

*n*

Ω (*fk*) , (11)

*i*=1

To enable efﬁcient optimization of the objective function,

where *l* (ˆ*yi*, *yi*) represents the binary classiﬁcation loss function,

which quantiﬁes the deviation between the forecasted value ˆ*yi* and the observed value *yi*. In classiﬁcation trees, this loss is

*i*

*t*

2

the Taylor expansion is applied, resulting in the following expression:

typically deﬁned using the logistic loss function, formulated as:

*l* (ˆ*yi*, *yi*) = *yi* ln (1 + *e*–ˆ*yi* ) + (1 – *yi*) ln (1 + *e*ˆ*yi* ) , (12)

*L*(*t*) ⋍

L*i*=1

r*l*

*yi*, ˆ*y*(*t*–1)

+ *gift* (**x***i*) +

1 *hif* 2 (**x***i*)L

+ Ω (*ft*) ,

(15)

where *g* = *∂y*(*t*–1) *l y* , ˆ*y*(*t*–1) and *h* = *∂*2 *l y* , ˆ*y*(*t*–1) rep- resent ﬁrst- and second- order gradient statistics on the loss function, respectively. The constant term *l yi*, ˆ*yt*–1 can be re- moved to simplify the objective function at step *t*, shown as follows:

*i*

*i*

( )

*n*

*i*

ˆ*i*

*i*

*i*

*i*

ˆ*y*(*t*–1)

*i*

*i*

* + 1. **Hyperparameter optimization**

Furthermore, some parameters cannot be determined through the training process above and must be speciﬁed in advance. Machine learning commonly uses hyperparameter optimiza- tion techniques to set these parameters in order to achieve the

*t*

*L*˜(*t*) =

L*i*=1

r*gift* (**x***i*) +

1 *hif* 2 (**x***i*)L

+ Ω (*ft*) . (16)

best forecasting performance. Common approaches include grid search, random search, and Bayesian optimization ([Yang](#_bookmark172) [and Shami](#_bookmark172) [2020](#_bookmark172), [Srinivas and Katarya](#_bookmark153) [2022](#_bookmark153), [Bischl et al.](#_bookmark113)

Let *Ij* = {*i q*(**x***i*) = *j*} represent the sample set of leaf *j*. Sub-

1

2

stituting the expanded form of Ω into the Eq. ([16](#_bookmark64)), we obtain the following expression after simplifying:

[2023](#_bookmark113)). Grid and random search exhaustively explore the entire parameter space, while Bayesian optimization uses prior infor- mation to guide a more efﬁcient search process. By leveraging

*n T* probabilistic modelling, Bayesian optimization can identify

*L*˜(*t*) = L r*gift* (**x***i*) + 1 *hif* 2 (**x***i*)L + *γT* + 1 *λ* L *w*2 optimal hyperparameters with fewer evaluations ([Turner et al.](#_bookmark166)

*j*

*i*=1

L

*T*

2

L 

*t*

1 L

2 *j*=1

 2

(17)

[2021](#_bookmark166), [Stuke et al.](#_bookmark157) [2021](#_bookmark157), [Lindauer et al.](#_bookmark134) [2022](#_bookmark134)). Therefore, this study adopts Bayesian optimization for hyperparameter tun-

=

*j*=1

 *i*∈*Ij*

*gi* *wj* + 2 

*i*∈*Ij*

*hi* + *λ* *wj*  + *γT*,

ing. Several key hyperparameters are selected for optimizing

weighted-XGBoost in this study, including the following:

where *wj* represents the weight of the leaf node *j*.

The optimal weight *w*∗ of leaf *j* in a ﬁxed structure *q*(**x**) can be calculated as following:

*j*

*w*∗ = – LL*i*∈*Ij gi* , (18)

*j*

*i*∈*Ij hi* + *λ*

1. max\_depth: Deﬁnes the maximum depth of each tree, controlling the models complexity.
2. learning rate (*η*): Determines the step size during opti-

mization, affecting model convergence.

(3) n\_estimators: Speciﬁes the number of boosting rounds, balancing model accuracy and computational cost.

and the corresponding optimal value of the objective function

can be found:

1. gamma (*γ*): A regularization term that controls tree com- plexity by setting a minimum loss reduction required for

*L*˜(*t*)(*q*) = – 1

2

*i*∈*Ij hi* + *λ*

L

L*T* L

*j*=1

2

*i*∈*Ij i*

*g*

+ *γT*. (19)

a split.

1. lambda (*λ*): Applies an *l*2 penalty on leaf weights to

prevent overﬁtting and improve generalization.

(6) scale\_pos\_weight: Adjusts the penalty for the minor-

Eq. ([19](#_bookmark65)) can be used to measure the quality of a tree structure *q*.

However, enumerating all possible tree structures *q* is com- putationally infeasible. Instead, a greedy algorithm that itera- tively expands the tree by adding branches is employed. At each step, the model evaluates candidate splits and selects the

one that maximizes the loss reduction. Given a node contain- ing instance set *I* = *IL ∪ IR*, splitting it into left and right nodes, *IL* and *IR*, respectively, results in the following loss reduction:

1 " (L *gi*)2 (L *gi*)2 (L *gi*)2 #

=

– *γ*.

ity class, enhancing model performance on imbalanced datasets.

* 1. **Model evaluation**

For this study’s objective of forecasting the occurrence of ex- treme prices, traditional metrics like Accuracy, Precision, Re- call and F1-score provide general insights into overall model performance. However, due to the inherent class imbalance in the data, additional metrics, the geometric mean (G-Mean) and

*L*split

2 L*i*∈*IL*

*hi* + *λ*

L*i*∈*IR*

*hi* + *λ*

L*i*∈*I*

*hi* + *λ*

(20)

Area Under the Curve (AUC), are particularly critical.

The confusion matrix shown in Table [3](#_bookmark67) is crucial, and many

If the reduction in loss is positive (*L*split > 0), the split is considered beneﬁcial, and the model proceeds with the parti- tion. Otherwise, the split is discarded to prevent unnecessary complexity.

*i*∈*IL* + *i*∈*IR* – *i*∈*I*

Overall, the proposed tree structure of weighted-XGboost can be established based on the loss function mentioned above.

evaluation metrics are derived from it. It contains the summary of forecasting results of all instances of the dataset used for testing.

Accuracy is the ratio of correctly classiﬁed samples to the total number of samples. Precision indicates the proportion of samples predicted as positive by the model that are actually positive. Recall represents the proportion of all actual positive

**T A B L E 3** Confusion matrix.

feature to a models predictions. It quantiﬁes the marginal im- pact of a feature by analyzing the changes in model output when the feature is included or excluded.

Formally, the Shapley value *ϕm* for feature *m* is deﬁned as:

*ϕm* =

L

|  |  |  |
| --- | --- | --- |
| **Conditions for each sector** | **Predicted values**  Positive | Negative |
| **Actual values** Positive | True positive (TP) | False negative (FN) |
| Negative | False positive (FP) | True negative (TN) |

**x***S* ⊆**x**\{*m*}

|**x***S*|!(|**x**| – |**x***S*| – 1)!

|**x**|! *f***x**

(

*S∪*{*m*}

(**x***S*∪{*m*}) – *f***x***S* (**x***S*)] ,

samples that are correctly identiﬁed by the model. The F1- score is the harmonic mean of precision and recall. These are shown as:

*Accuracy* = *TP* + *TN* , (21)

*TP* + *FP* + *TN* + *FN*

(28)

where **x** represents the complete set of input features, and **x***S* denotes a subset that excludes feature *m*. The term *f***x***S∪*{*m*} refers to the model trained with feature *m*, while *f***x***S* corresponds to the model trained without it. Thus, *f***x***S∪*{*m*} (**x***S*∪{*m*}) represents the model output when feature *m* is included, whereas *f***x***S* (**x***S*) represents the output when it is omitted.

*Precision* = *TP*

*TP* + *FP*

*TP*

, (22)

However, computing the exact Shapley values is compu- tationally expensive due to the combinatorial complexity in- volved in estimating all possible feature contributions. To

*Recall* = *TP* + *FN* , (23)

*F*1 – *score* =  *Recall × Precision ×* 2 . (24)

*Recall* + *Precision*

In addition, G-Mean balances sensitivity (recall for the mi- nority class) and speciﬁcity (recall for the majority class), ensuring that the model performs well across both classes ([Zhang et al.](#_bookmark175) [2018](#_bookmark175)). A high G-Mean value indicates that the model is effective in identifying minority class instances without sacriﬁcing accuracy for the majority class.

*G* – *Mean* = )  *TP · TN* . (25)

*TP* + *FN*

*TN* + *FP*

Furthermore, AUC of the Receiver Operating Characteris- tic (ROC) is an effective metric for evaluating imbalanced binary classiﬁers ([Zou et al.](#_bookmark178) [2016](#_bookmark178)). ROC curve plots True Pos- itive Rate (TPR) versus False Positive Rate (FPR) at different classiﬁcation thresholds ([Sokolova et al.](#_bookmark148) [2006](#_bookmark148)).

address this, [Lundberg and Lee](#_bookmark149) ([2017](#_bookmark149)) introduced SHAP as an efﬁcient approximation, leveraging a linear additive explana- tion model to express feature contributions:

*M*

*g*(*z* ) = *ϕ*0 + L *ϕmz* , (29)

′ ′

*m*

*m*=1

where *M* denotes the number of features, as previously de- ﬁned. *z*′ is a binary indicator function that equals 1 if feature *m* is present and 0 otherwise. The term *ϕ*0 represents the ex- pected model output when all features are omitted, serving as a baseline prediction.

*m*

By employing SHAP, this study aims to provide a more

transparent understanding of how individual features con- tribute to extreme electricity price occurrences, thereby en- hancing the interpretability of the weighted-XGBoost models.

1. **RESULTS AND DISCUSSION**

TPR = *TP TP* + *FN*

FPR = *FP TN* + *FP*

, (26)

. (27)

The results on extremely high and extremely low prices with different window sizes *r* are reported in Section [3.1](#_bookmark70). A compar- ative analysis of various machine learning models is presented in Section [3.2](#_bookmark71). The SHAP-based contribution of various fea-

AUC values range from 0 to 1, with higher values indicating

stronger discriminatory power for both minority and majority classes.

**2.6 SHapley Additive exPlanations (SHAP)**

SHAP ([Lundberg and Lee](#_bookmark149) [2017](#_bookmark149)) is employed in this study to interpret the predictive model’s output. Prior to SHAP, the Shapley value was developed based on game theory ([Shapley](#_bookmark147) [et al.](#_bookmark147) [1953](#_bookmark147)) as a method for evaluating the contribution of each

tures is discussed in Section [3.3.2](#_bookmark81).

* 1. **Results on extreme price forecasts**

Two types of experiments are conducted to forecast extreme electricity price occurrences, focusing separately on extremely high prices and extremely low prices across various time win- dows. To evaluate the performance of the machine learning model, the dataset is divided into a training set (75%) and a test set (25%). In both experiments, forecasting is performed

using the proposed weighted-XGBoost with Bayesian opti- mization. During the hyperparameter optimization phase, the Bayesian optimization algorithm explored different combina- tions of weighted-XGBoost parameters to maximize the mean AUC score through 10-fold time series cross-validation. Af- ter completing the iterative process, the algorithm identiﬁes an optimal set of parameters. The hyperparameter tuning ranges and the optimal parameter results for both experiments are summarized in Table [4](#_bookmark72). The forecasting results are reported as follows.

The performance of weighted-XGBoost in forecasting ex- treme electricity prices is summarized in Fig. [4](#_bookmark73) and Fig. [5](#_bookmark74), as well as in Table [5](#_bookmark75) and Table [6](#_bookmark76), which present the confusion matrices and evaluation metrics across the 15-day, 30-day, and 45-day time windows. The results indicate that the model effec- tively distinguishes between normal and extreme prices while maintaining a reasonable balance between false positives and false negatives.

For extremely high prices, the model maintains strong classiﬁcation performance across all time windows. The test Accuracy averages 0.877, while Precision and Recall reach 0.942 and 0.877, respectively, resulting in an average F1-score of 0.898. Furthermore, G-Mean (0.880) and AUC (0.957) con- ﬁrm the models robustness in handling class imbalance. The ROC curves in Fig. [6](#_bookmark77) show consistently high test AUC values above 0.95, with scores of 0.954, 0.955, and 0.961 for the 15- day, 30-day, and 45-day windows, respectively. These results demonstrate the strong discriminatory power of weighted- XGBoost in forecasting extremely high price occurrences.

Similarly, for extremely low prices, the model exhibits re- liable classiﬁcation performance. The test Accuracy averages 0.876, with Precision, Recall, and F1-score reaching 0.937, 0.876, and 0.893, respectively. G-Mean (0.908) and AUC (0.968) further validate the models effectiveness in handling class imbalance while maintaining reliable forecasting. As illustrated in the ROC curves in Fig. [7](#_bookmark78), the AUC values re- main consistently high across different time windows, with test AUCs of 0.968, 0.967, and 0.969. Notably, the model exhibits a tiny training-test AUC gap, which remains below 0.02 across all time windows. This suggests that extremely low prices fol- low clear underlying patterns, making them effective for the model to generalize.

In comparison, a key observation from the results is that forecasting extremely high prices is more challenging than forecasting extremely low prices. This is reﬂected in the larger discrepancy between training and test AUC scores for ex- tremely high prices, suggesting a higher degree of overﬁtting. For instance, in the 30-day window, the test AUC for extremely high prices is 0.955, while the training AUC reaches 0.994, re- sulting in a gap of 0.039. In contrast, for extremely low prices, the gap in the same window is only 0.019. This indicates that

extremely low prices exhibit more stable and predictable pat- terns, whereas extremely high prices may be subject to more volatile external factors, such as supply shortages, demand surges, and geopolitical events.

Despite these challenges, weighted-XGBoost consistently demonstrates strong and reliable performance in forecasting both extremely high and low prices. Across all time windows, test AUC values exceed 0.95, conﬁrming the models robust- ness. The combination of traditional classiﬁcation metrics and imbalance-sensitive measures (G-Mean and AUC) ensures a comprehensive evaluation of its capability in handling rare ex- treme price occurrences. This highlights the models potential as a valuable tool for electricity market participants to man- age price risks and improve decision-making in volatile market conditions.

* 1. **Comparative analysis**

To evaluate the advantages of weighted-XGBoost in fore- casting imbalanced extreme electricity prices, the proposed model’s performance is compared with two widely used base- line models: Logistic Regression with class weighting (W-LR) and Random Forest with class weighting (W-RF). All models are trained on the same dataset under identical experimental conditions, including the feature set, hyperparameter optimiza- tion framework, and evaluation metrics. This ensures that observed performance differences can be attributed to the mod- els’ inherent capabilities in handling class imbalance. Two imbalance-sensitive metrics, AUC and G-Mean, are selected to compare the models. AUC provides an overall evaluation of the models discriminatory power, and G-Mean accounts for the balance between sensitivity and speciﬁcity, making them well-suited for comparing different models on imbalanced datasets.

The comparative performance of weighted-XGBoost

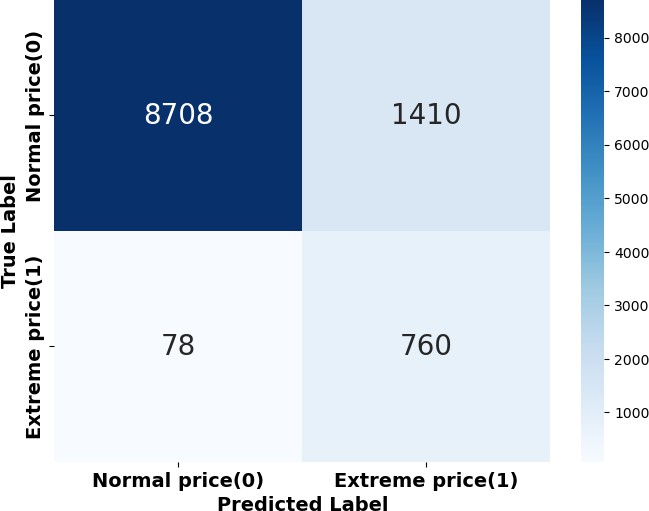
against W-LR and W-RF in forecasting extremely high and low electricity prices is summarized in Table [7](#_bookmark79) and Table [8](#_bookmark80), respectively. The results consistently demonstrate the superi- ority of weighted-XGBoost across all time windows in both AUC and G-Mean metrics for forecasting extremely high and low electricity prices.

For extremely high prices, weighted-XGBoost consistently outperforms the baseline models. It achieves the highest aver- age test AUC of 0.957, compared to 0.941 for W-LR and 0.950 for W-RF. Across different time windows, the test AUC val- ues for weighted-XGBoost remain stable, with scores of 0.954, 0.955, and 0.961 for the 15-day, 30-day, and 45-day windows, respectively. These results highlight the models ability to effec- tively distinguish between normal and extremely high prices across varying time windows. Similarly, in terms of G-Mean, weighted-XGBoost achieves the highest average test score of

**T A B L E 4** Hyperparameters tuning for proposed weighted-XGboost in this study.

**Hyperparameter Search range Type Optimal value (extremely high prices) Optimal value (extremely low prices)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | **15-day window** | **30-day window** | **45-day window** |  | **15-day window** | **30-day windw** | **45-day window** |
| learning\_rate | [0.005, 0.1] | Real | 0.05 | 0.08 | 0.05 |  | 0.05 | 0.05 | 0.08 |
| max\_depth | [2, 5] | Integer | 4 | 5 | 4 |  | 4 | 4 | 3 |
| n\_estimators | [50, 200] | Integer | 158 | 139 | 158 |  | 158 | 158 | 91 |
| reg\_alpha | [5, 50] | Real | 24.09 | 34.19 | 24.09 |  | 24.09 | 24.09 | 19.08 |
| reg\_lambda | [5, 50] | Real | 34.26 | 23.99 | 34.26 |  | 34.26 | 34.26 | 11.87 |
| gamma | [1, 10] | Real | 8.20 | 6.55 | 8.20 |  | 8.20 | 8.20 | 1.03 |
| subsample | [0.5, 1] | Real | 0.83 | 0.82 | 0.83 |  | 0.83 | 0.83 | 0.91 |
| min\_child\_weight | [5, 15] | Integer | 14 | 11 | 14 |  | 14 | 14 | 11 |
| max\_dalta\_step | [5, 10] | Integer | 8 | 7 | 8 |  | 8 | 8 | 9 |
| scale\_pos\_weight | [5, 30] | Real | 13.83 | 23.35 | 13.83 |  | 13.83 | 13.83 | 27.35 |

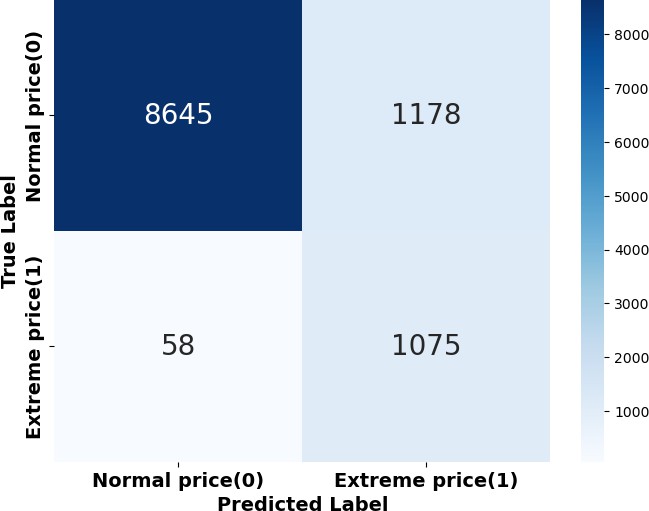
****

**(a)** 15-day window **(b)** 30-day window **(c)** 45-day window

**F I G U R E 4** Confusion matrix for forecasting extremely high prices across different time windows.

0.880, outperforming W-LR (0.793) and W-RF (0.875). The model consistently balances sensitivity and speciﬁcity, with test G-Means of 0.883, 0.870, and 0.888 for the 15-day, 30-day, and 45-day windows, respectively.

For extremely low prices, weighted-XGBoost also demon- strates superior performance, achieving the highest scores in both AUC and G-Mean. The model attains an average test AUC of 0.968, surpassing W-LR (0.959) and W-RF (0.962).

**(a)** 15-day window **(b)** 30-day window **(c)** 45-day window

**F I G U R E 5** Confusion matrix for forecasting extremely low prices across different time windows.

**T A B L E 5** Evaluation metric for forecasting extremely high prices using weighted XGBoost across different time windows.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Time window Data set** | **Accuracy** | **Precision** | **Recall** | **F1-score** | **G-Mean** | **ROC-AUC** |
| Training  15-day | 0.919 | 0.953 | 0.919 | 0.928 | 0.945 | 0.989 |
| Test | 0.864 | 0.942 | 0.864 | 0.890 | 0.883 | 0.954 |
| Training  30-day | 0.923 | 0.955 | 0.923 | 0.931 | 0.953 | 0.994 |
| Test | 0.885 | 0.939 | 0.885 | 0.902 | 0.870 | 0.955 |
| Training  45-day | 0.925 | 0.954 | 0.925 | 0.933 | 0.950 | 0.991 |
| Test | 0.881 | 0.945 | 0.881 | 0.902 | 0.888 | 0.961 |
| Training  Average | 0.922 | 0.954 | 0.922 | 0.931 | 0.949 | 0.991 |
| Test | 0.877 | 0.942 | 0.877 | 0.898 | 0.880 | 0.957 |

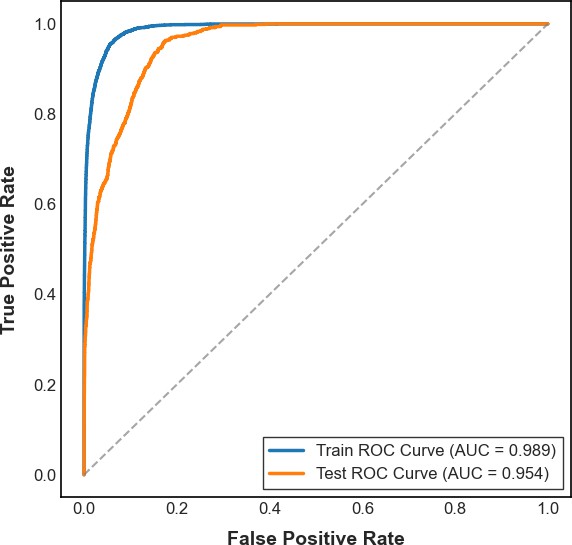
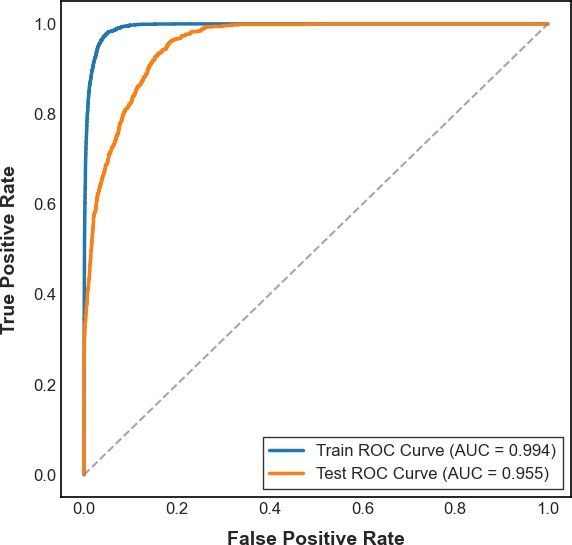
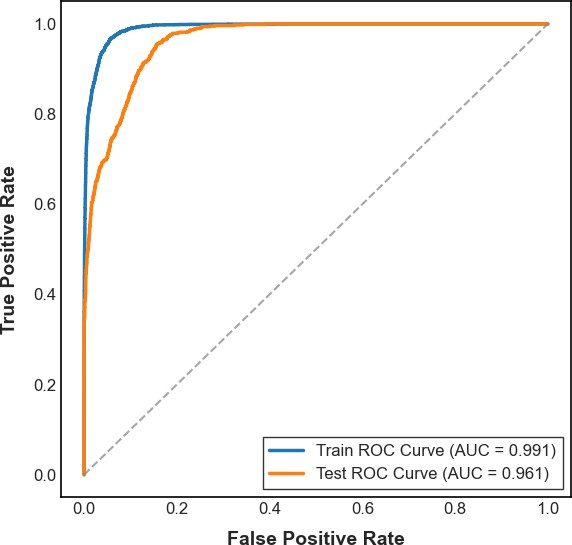
**T A B L E 6** Evaluation metric for forecasting extremely low prices using weighted XGBoost across different time windows.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Time window** | **Data set** | **Accuracy** | **Precision** | **Recall** | **F1-score** | **G-Mean** | **ROC-AUC** |
| 15-day | Training | 0.898 | 0.950 | 0.898 | 0.913 | 0.934 | 0.982 |
|  | Test | 0.887 | 0.940 | 0.887 | 0.902 | 0.914 | 0.968 |
| 30-day | Training | 0.915 | 0.955 | 0.915 | 0.926 | 0.945 | 0.986 |
|  | Test | 0.873 | 0.934 | 0.873 | 0.891 | 0.902 | 0.967 |
| 45-day | Training | 0.891 | 0.951 | 0.891 | 0.908 | 0.935 | 0.986 |
|  | Test | 0.867 | 0.937 | 0.867 | 0.887 | 0.909 | 0.969 |
| Average | Training | 0.901 | 0.952 | 0.901 | 0.916 | 0.938 | 0.985 |
|  | Test | 0.876 | 0.937 | 0.876 | 0.893 | 0.908 | 0.968 |

Across the 15-day, 30-day, and 45-day windows, the test AUC values for weighted-XGBoost are 0.968, 0.967, and 0.969, respectively, further conﬁrming its robustness in distinguish- ing normal and extremely low prices. In terms of G-Mean, weighted-XGBoost again outperforms the baselines, achieving an average test score of 0.908 compared to 0.849 for W-LR and 0.902 for W-RF. For individual time windows, the model

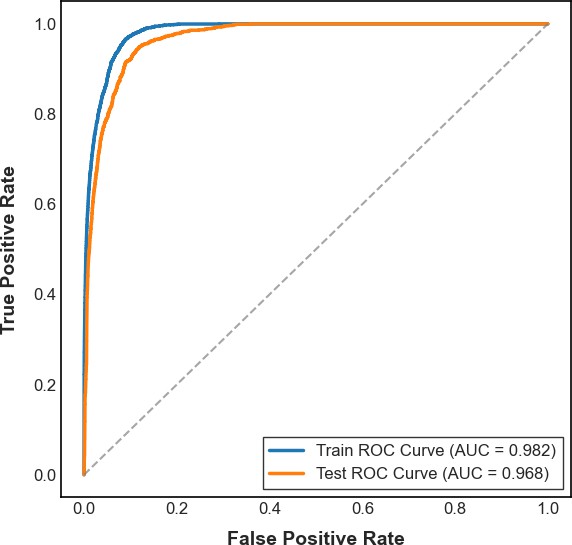
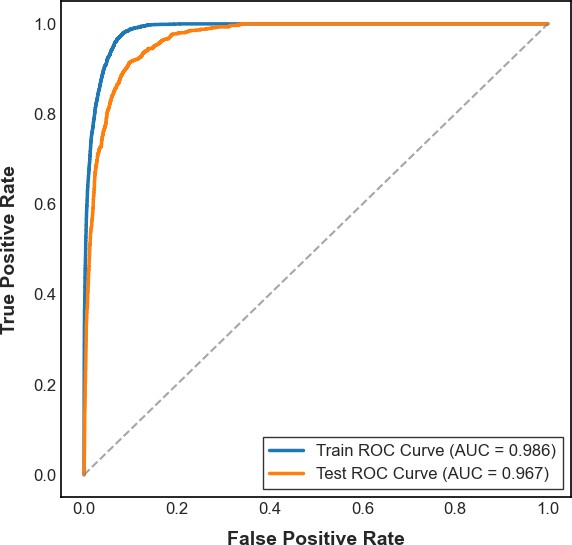
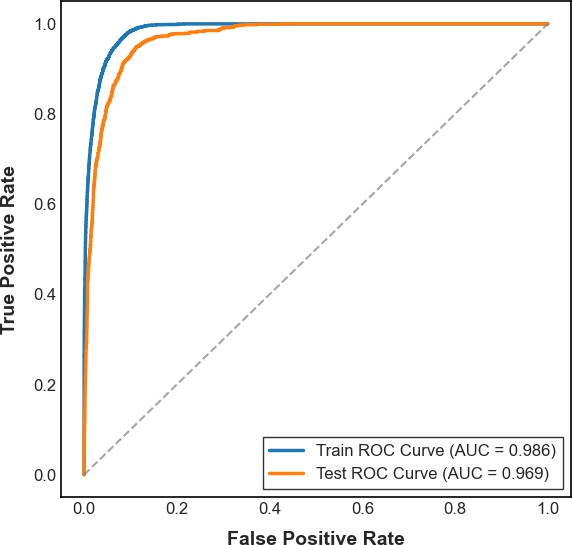
attains test G-Means of 0.914, 0.902, and 0.909 for the 15-day, 30-day, and 45-day windows, respectively.

Overall, the results indicate that weighted-XGBoost pro- vides more reliable and accurate forecasts of both extremely high and low prices compared to the baseline models. The consistently higher AUC and G-Mean values suggest that weighted-XGBoost is better suited for handling imbalanced

**(a)** 15-day window **(b)** 30-day window **(c)** 45-day window

**F I G U R E 6** ROC curves for forecasting extremely high prices across different time windows.

**(a)** 15-day window **(b)** 30-day window **(c)** 45-day window

**F I G U R E 7** ROC curves for forecasting extremely low prices across different time windows.

classiﬁcation tasks in extreme electricity price forecasting. These ﬁndings underscore its potential as a robust and effective tool for market participants seeking to manage price risks and improve forecasting accuracy in volatile electricity markets.

* 1. **Model interpretation**

Interpreting the features driving the model’s forecasts is es- sential for validating its effectiveness and ensuring practical applicability, which is crucial for effective price risk man- agement in electricity markets. While performance metrics provide an overall evaluation, they lack insight into the speciﬁc contributions of individual features. SHAP (SHapley Addi- tive exPlanations) is employed to address this, offering a transparent view of how features inﬂuence the model’s output. SHAP-based analysis can be conducted at both global and local levels to provide a comprehensive understanding of the models decision-making process. The global analysis exam- ines the overall impact of each feature on the model’s forecasts by aggregating SHAP values across the entire dataset ([Lund-](#_bookmark149) [berg and Lee](#_bookmark149) [2017](#_bookmark149)). This is typically visualized using SHAP summary plots, which rank features by their average contribu- tion to the forecasted outcome. These plots help identify which factors are most inﬂuential in determining extreme electricity

prices.

In contrast, the local analysis focuses on explaining indi- vidual forecasts by illustrating how speciﬁc feature values contribute to a particular forecast ([Lundberg et al.](#_bookmark145) [2020](#_bookmark145)). This is achieved through SHAP force plots, which show how differ- ent features push a single forecast higher or lower relative to a baseline value, which is the model’s expected output before considering any feature inﬂuences. These plots offer a detailed breakdown of feature contributions, helping to verify whether extreme price forecasts are driven by meaningful factors.

The following sections present global and local SHAP- based analyses for forecasting extremely high and low elec- tricity prices, highlighting key features and their roles across different time windows.

* + 1. **Global feature interpretation**

The SHAP summary plots in Fig. [8](#_bookmark83) and Fig. [9](#_bookmark83) illustrate the global feature importance for forecasting extremely high and low electricity prices across different time windows. These plots provide insights into how individual features inﬂuence model forecasts, highlighting the factors that drive extreme price events.

For extremely high prices, multiple interrelated market factors contribute signiﬁcantly to price surges. Forecasted residual load consistently emerges as the most inﬂuential fea- ture across all time windows, reﬂecting its strong correlation with supply-demand imbalances. High residual load, reﬂect- ing unmet demand by renewables and reliance on expensive dispatchable sources, often leads to price spikes under the merit order principle ([Trebbien et al.](#_bookmark162) [2023](#_bookmark162)). Fuel-related fea- tures, such as coal prices and gas prices, also play a crucial role in shaping high-price occurrences, highlighting the impact of fossil fuel cost ﬂuctuations on electricity markets. Addi- tionally, historical electricity price patterns over daily and weekly periods exhibit signiﬁcant importance, suggesting that past market trends provide valuable forecasting signals for ex- tremely high prices. The results conﬁrm that extremely high price occurrences are inﬂuenced by a combination of supply- demand conditions, fuel price volatility, and historical market behaviours, making their forecasting more challenging and sensitive to external shocks.

For extremely low prices, forecasted residual load exhibits

the dominant SHAP values across all time windows, highlight- ing its central role in driving extreme price decreases. Low

**T A B L E 7** Comparative analysis for forecasting extremely high prices.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type of experiment Model Data set** | **Time window** |  | | |
|  | **15-day** | **30-day** | **45-day** | **Average** |
| Training  W-LR | 0.960 | 0.965 | 0.965 | 0.963 |
| Test | 0.926 | 0.942 | 0.954 | 0.941 |
| Training  AUC W-RF | 0.978 | 0.978 | 0.979 | 0.978 |
| Test | 0.941 | 0.954 | 0.956 | 0.950 |
| Traning  W-XGB | **0.989** | **0.994** | **0.991** | **0.991** |
| Test | **0.954** | **0.955** | **0.961** | **0.957** |
| Training  W-LR | 0.892 | 0.901 | 0.900 | 0.898 |
| Test | 0.772 | 0.788 | 0.819 | 0.793 |
| Training  G-Mean W-RF | 0.922 | 0.925 | 0.927 | 0.925 |
| Test | 0.861 | **0.884** | 0.880 | 0.875 |
| Training  W-XGB | **0.945** | **0.953** | **0.950** | **0.949** |
| Test | **0.883** | 0.870 | **0.888** | **0.880** |

Abbreviations: W-LR = Logistic Regression with class weighting; W-RF = Random Forest with class weighting; W-XGB = Proposed weighted-XGboost.

**T A B L E 8** Comparative analysis for forecasting extremely low prices.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type of experiment Model Data set** | **Time window** |  | | |
|  | **15-day** | **30-day** | **45-day** | **Average** |
| Training  W-LR | 0.940 | 0.973 | 0.958 | 0.957 |
| Test | 0.954 | 0.966 | 0.957 | 0.959 |
| Training  AUC W-RF | 0.967 | 0.979 | 0.982 | 0.976 |
| Test | 0.961 | 0.963 | 0.963 | 0.962 |
| Traning  W-XGB | **0.982** | **0.986** | **0.986** | **0.985** |
| Test | **0.968** | **0.967** | **0.969** | **0.968** |
| Training  W-LR | 0.856 | 0.913 | 0.883 | 0.884 |
| Test | 0.846 | 0.860 | 0.841 | 0.849 |
| Training  G-Mean W-RF | 0.906 | 0.925 | 0.933 | 0.921 |
| Test | 0.902 | 0.899 | 0.905 | 0.902 |
| Training  W-XGB | **0.934** | **0.945** | **0.935** | **0.938** |
| Test | **0.914** | **0.902** | **0.909** | **0.908** |

Abbreviations: W-LR = Logistic Regression with class weighting; W-RF = Random Forest with class weighting; W-XGB = Proposed weighted-XGboost.

or even negative residual load suggests that renewable genera- tion nearly satisﬁes or exceeds total demand, often reﬂecting a system-wide oversupply condition. This leads to market- clearing price collapses under the merit-order mechanism. While secondary features, such as carbon price, coal price, and forecasted total generation, also inﬂuence forecasts, their SHAP values remain considerably lower compared to the fore- casted residual load. Additionally, renewable energy sources,

particularly high forecasted wind generation, are observed to exert a downward pressure on electricity prices, reinforcing the role of renewables in shaping price ﬂuctuations. Thus, ex- tremely low prices follow a straightforward and deterministic pattern, primarily governed by supply-demand conditions.

Overall, the comparison between extremely high and low price interpretations reveals notable disparities. Extremely high prices are inﬂuenced by a diverse set of factors, including

fuel price volatility, historical price trends, and grid conditions, making them more susceptible to external shocks. In contrast, extremely low prices are largely dictated by forecasted resid- ual load, suggesting a more deterministic relationship between supply-demand conditions and price drops. This distinction also inﬂuences the model’s generalization ability: forecasts of extremely low prices exhibit greater stability, as indicated by the dominance of a single feature, whereas extremely high price forecasts are more volatile due to the interplay of multiple driving forces.

Additionally, fossil fuel prices exhibit an asymmetric inﬂu- ence on extreme prices. While coal, gas, and carbon prices signiﬁcantly impact extremely high prices, their effect on ex- tremely low prices is relatively minor. This indicates that high prices are more sensitive to fuel price ﬂuctuations and external market events, such as supply shortages or geopolitical dis- ruptions, whereas low prices primarily result from foreseeable system-wide oversupply conditions.

These insights offer valuable implications for electricity market participants for effective market risk management. The complexity of extremely high prices necessitates dynamic market monitoring and rapid-response strategies to mitigate unexpected price spikes. Meanwhile, the strong forecastability of extremely low prices suggests that system participants can proactively mitigate the impact of electricity oversupply on market stability. By understanding the distinct driving forces behind extreme electricity prices, stakeholders can develop more effective forecasting strategies and market interventions to minimize risks and optimize decision-making.

* + 1. **Local feature interpretation**

While global SHAP analysis provides an overall ranking of feature importance, local SHAP force plots offer case-speciﬁc explanations, illustrating how individual feature values con- tribute to extreme price forecasts. Fig. [10](#_bookmark84) and Fig. [11](#_bookmark85) present these force plots for forecasting extremely high and low prices across the 15-day, 30-day, and 45-day time windows. To better understand the models decision-making process, we randomly select instances forecasted as extreme prices and analyze their feature contributions. Each force plot includes a tabular sum- mary displaying four key features that have consistently shown signiﬁcant inﬂuence across different time windows. These fea- tures visually depict how different factors push forecasts above or below the base value, ultimately determining whether an extreme price event is forecasted.

The SHAP force plots in Fig. [10](#_bookmark84) highlight the dynamic inter- actions between multiple market factors that collectively push forecasts beyond the base value, signaling a higher probabil-

ity of extremely high price occurrences. In the 15-day window example, high forecasted residual load (4.698 *×* 104 MWh)

plays a dominant role in increasing the models forecasted prob- ability of extreme prices. Coal price and forecasted grid load further reinforce this effect, while lower gas price and day- ahead price exert a negative inﬂuence, though to a lesser extent. Similarly, in the 30-day window example, high forecasted residual load (6.112 *×* 104 MWh), weekly historical price, gas price, and carbon price emerge as key contributors, highlight- ing the combined effect of past electricity market trends and fossil fuel price ﬂuctuations. In the 45-day window example, high forecasted residual load (5.655 *×* 104 MWh), forecasted wind generation and electricity price trends gain cole promi- nence, reinforcing the idea that extremely high price is affected by multiple market factors.

Conversely, the SHAP force plots in Fig. [11](#_bookmark85) demonstrate a signiﬁcantly different pattern for forecasting extremely low prices. Across all time windows, low forecasted residual load is consistently the strongest driver of extremely low price oc- currences. In the 15-day window example, a drop in residual

load (1.188 *×* 104 MWh) has the greatest positive impact on

pushing the models forecast above the base value, indicating a high probability of price dips. While factors such as coal price, carbon price, and gas price exhibit some inﬂuence, their impact remains minor. This trend continues in the 30-day and 45-day window examples, where low forecasted residual load

remains the primary determining factor (0.9423 *×* 104 MWh

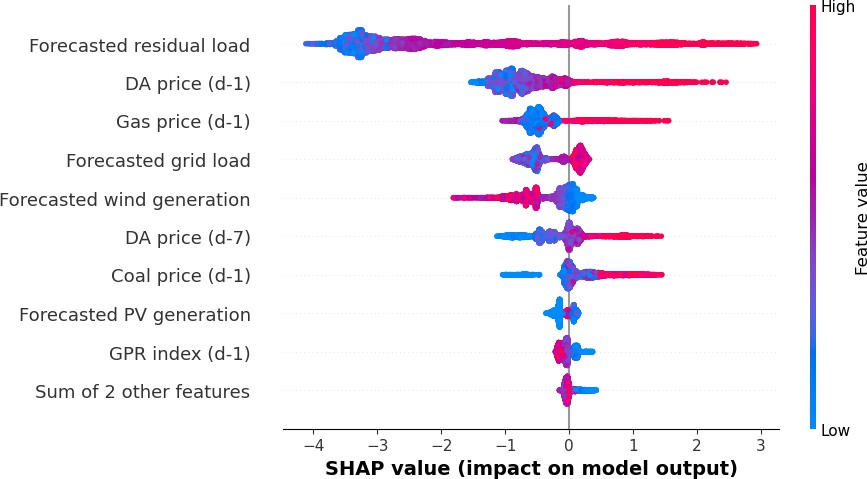
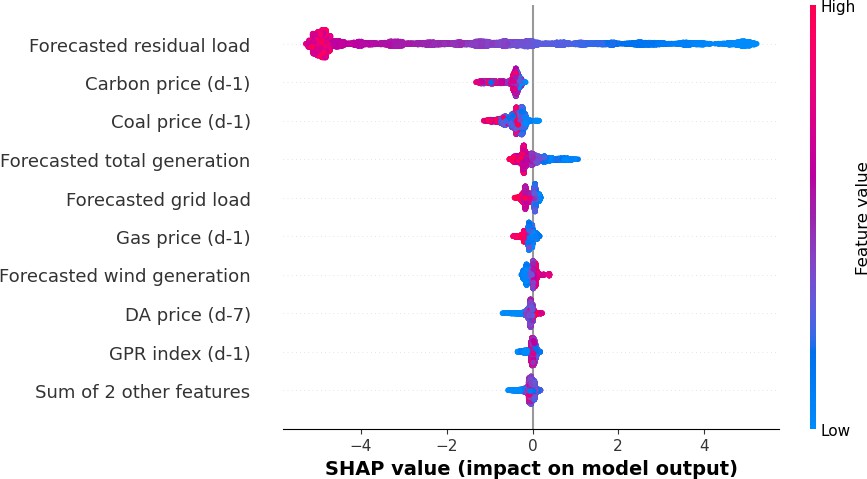
and 1.4830 *×* 104 MWh), with high wind generation becoming more prominent as a secondary inﬂuence.

Overall, the local SHAP force plots reveal a fundamental distinction between extremely high and low price occurrences. Extremely high prices are driven by a broader set of market factors, including fossil fuel prices, historical market trends, and grid load ﬂuctuations, making them more complex and sensitive to external shocks. In contrast, extremely low prices are predominantly dictated by a single factor, forecasted resid- ual load, suggesting that their occurrence follows a more predictable pattern based on supply-demand imbalances.

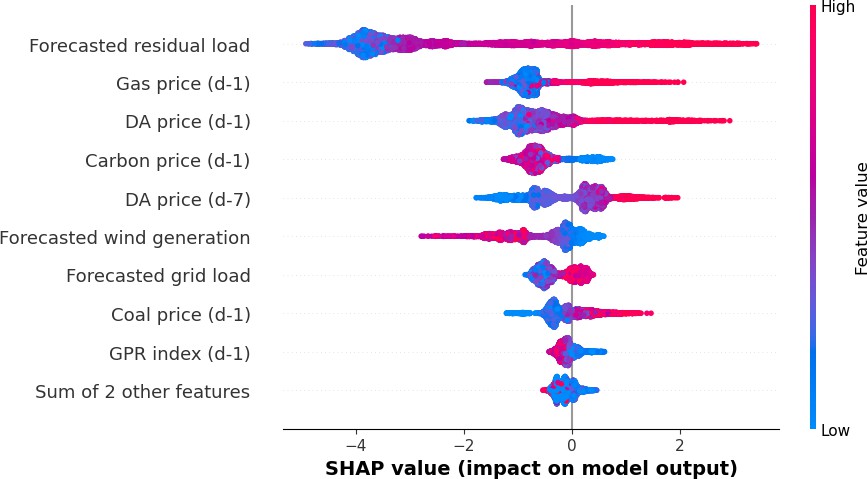
These insights reinforce the importance of feature-speciﬁc risk monitoring in electricity markets. While high prices re- quire tracking multiple economic and operational indicators, low price risks can be primarily managed through real-time monitoring of residual load and renewable energy forecasts.

1. **CONCLUSION**

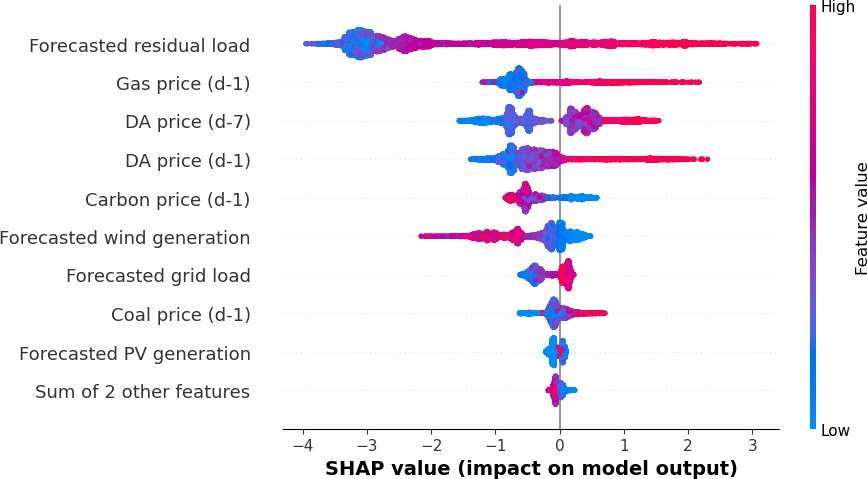
This study explored the application of weighted-XGBoost for forecasting extreme electricity prices in the context of imbal- anced data, focusing on both extremely high and low price occurrences. The experimental results demonstrated the ro- bustness and effectiveness of the proposed approach across different time windows, with consistently strong performance

1. 15-day window



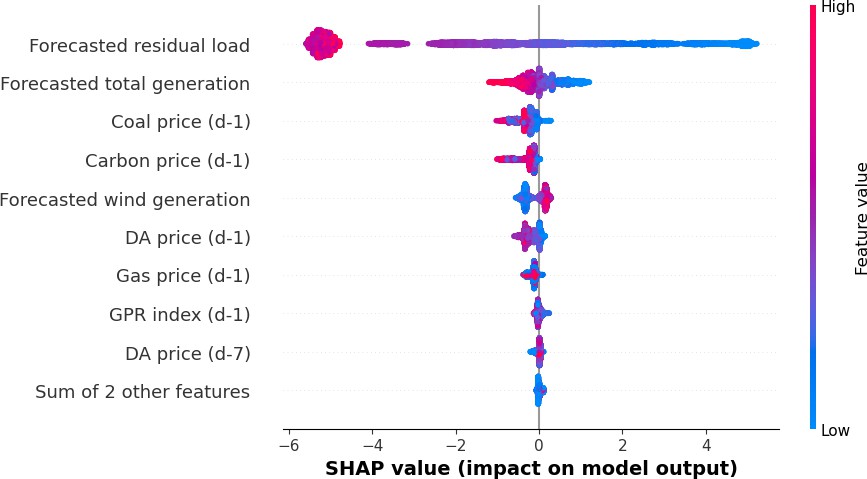
1. 30-day window



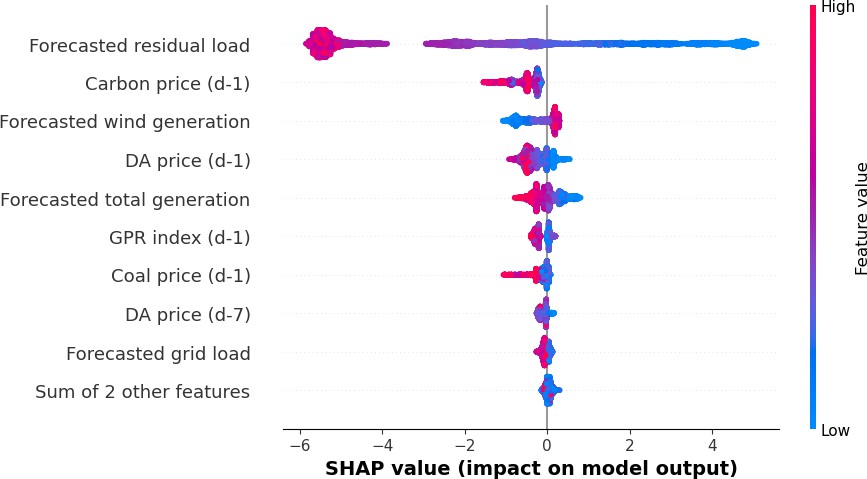
1. 45-day window

**F I G U R E 8** SHAP summary plots for extremely high prices across different time windows.

1. 15-day window



1. 30-day window



1. 45-day window

**F I G U R E 9** SHAP summary plots for extremely low prices across different time windows.

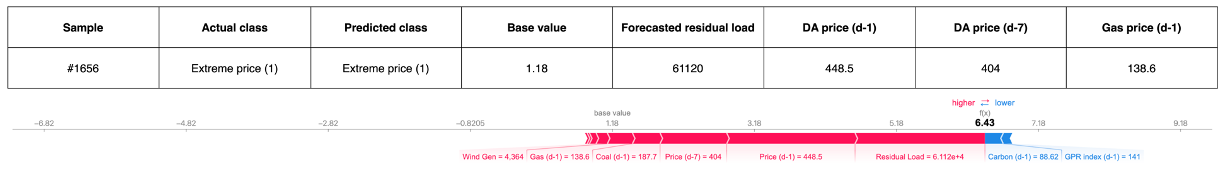
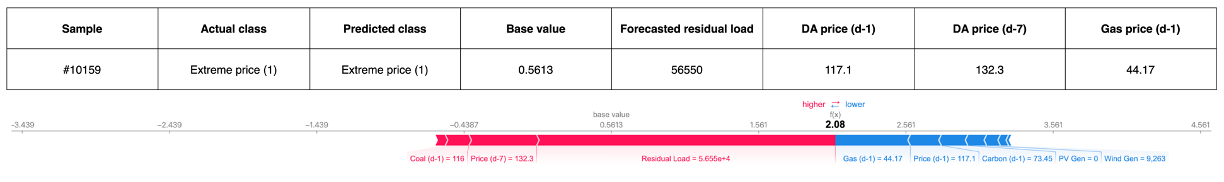
in key metrics such as accuracy, precision, recall, F1-score, G-Mean, and AUC.

The G-Mean and ROC-AUC metrics conﬁrmed the models ability to effectively distinguish between extreme and normal prices despite the inherent class imbalance. AUC values con- sistently exceeded 0.95 across training and test datasets, un- derscoring the models high classiﬁcation quality. Furthermore, compared to baseline models, weighted-XGBoost achieved superior performance, demonstrating higher forecasting accu- racy and better robustness in handling class imbalance. This highlights its effectiveness in capturing the underlying patterns of extreme price occurrences.

The SHAP-based interpretability analysis provided further insights into the key drivers of extreme electricity prices. The

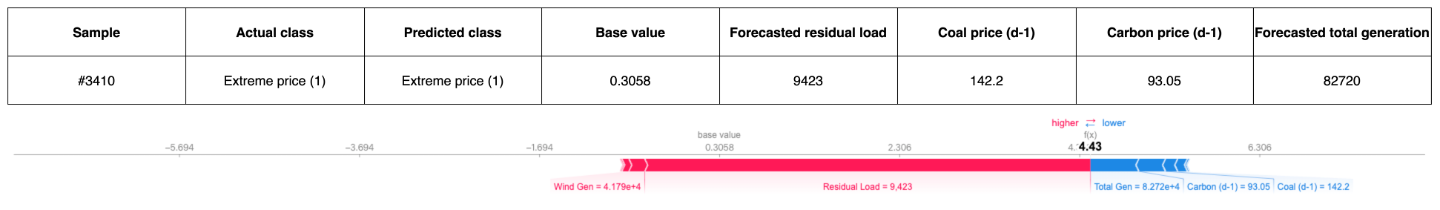
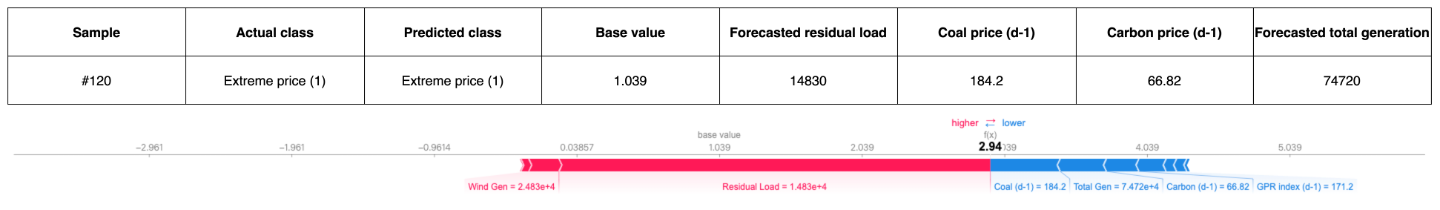
results revealed distinct differences between the determinants of extremely high and extremely low prices. Extremely high prices arise from a complex interaction of supply-demand con- ditions, historical price trends, and external market dynamics, making them more volatile and susceptible to external shocks. Forecasted residual load, grid load, and wind generation play crucial roles, alongside fuel price factors such as gas, carbon, and coal prices, indicating a signiﬁcant inﬂuence of fuel cost ﬂuctuations. In contrast, extremely low prices are primarily driven by forecasted residual load. The lack of strong con- tributions from price-related variables suggests that low-price events are more structurally determined by demand-side imbal- ances and renewable energy availability rather than fuel prices and external market shocks.



* 1. 15-day window
  2. 30-day window
  3. 45-day window

**F I G U R E 10** SHAP force plots for extremely high prices across different time windows.



1. 15-day window
2. 30-day window
3. 45-day window

**F I G U R E 11** SHAP force plots for extremely low prices across different time windows.

Notably, the geopolitical risk index (GPR) was included as a feature to capture broader economic and political disruptions, yet its SHAP values remained consistently low, indicating min- imal inﬂuence on extreme electricity price occurrences. This

suggests that while geopolitical events may impact long-term energy trends, they do not have a direct, immediate effect on short-term price extremes in the German electricity market.

While the proposed model demonstrates strong forecasting capabilities, there are areas for further improvement. First, this study deﬁnes extreme price events using the 90th and 10th quantiles, but future research could explore stricter thresholds (e.g., 95th/5th or 99th/1st percentiles) to assess their impact on forecasting accuracy. Second, while the volatility-based dynamic weighted threshold adapts to market ﬂuctuations, alternative methods such as adaptive quantiles, distribution- based approaches, or extreme value theory (EVT) might reﬁne extreme price identiﬁcation. Third, while the overall classiﬁ- cation performance for forecasting extremely high prices is satisfactory, there is still room for improvement compared to extremely low price forecasts. From the SHAP-based inter- pretability analysis, it is evident that certain external features play a more signiﬁcant role in forecasting extremely high prices. This suggests that incorporating additional external fea- tures, potentially those more directly relevant to extreme price events, could further enhance the model’s ability to accurately forecast extremely high prices. Future work could focus on identifying and integrating such external features to optimize the model’s forecasting power for these events.

By addressing these areas, future studies can provide a more

comprehensive understanding of extreme price dynamics and improve the robustness of forecasting models in increasingly complex electricity markets. These enhancements would not only reﬁne the methodology but also support market partic- ipants and policymakers in better managing risks associated with extreme electricity price occurrences. It is also worth not- ing that the ﬁndings of this study are not limited to the German electricity market. While external conditions and shocks may vary across regions and markets, the methodology proposed in this study is generalizable and can be applied to electricity mar- kets in other regions. This adaptability underscores the broader relevance of the proposed framework for addressing extreme price forecasting challenges in diverse market environments.

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A Column Generation and Label Algorithm for the Electric Vehicle Routing Problem

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1. Introduction

With the growing awareness of environmental protection and sustainable development, electric ve- hicles are gradually emerging as an essential means of transportation in the logistics and distribu- tion sectors. However, compared with traditional internal combustion engine vehicles, electric ve- hicles inherently face limitations in driving range, charging time, and energy management. These challenges necessitate targeted modifications and extensions to the conventional Vehicle Routing

Problem (VRP). To address these issues, the Electric Vehicle Routing Problem with Time Windows (EVRPTW) has been introduced. This problem not only aims to optimize transportation costs under the constraints of customer demands and time windows but also requires careful consideration of key factors such as battery capacity, charging strategies, and energy consumption models.

This study focuses on the practical challenges encountered in electric logistics distribution. First, it provides an in-depth analysis of the energy consumption model and charging process for electric vehicles, exploring the energy losses during operation and the efficiency of charging. Based on this analysis, a mixed-integer programming model is developed that encompasses customers, charging stations, and vehicle operational states (e.g., load, arrival time, and battery energy). To solve this complex optimization problem, a column generation framework combined with a monodirectional

label extension algorithm is proposed. Through iterative refinement and effective pruning of the

search space, the proposed approach efficiently reduces computational complexity while ensuring both feasibility and optimality in route planning.

In summary, this research not only offers a novel theoretical model and solution method for the

route planning of electric vehicles in logistics distribution but also provides practical guidance and technological support for achieving a low-carbon, environmentally friendly, and efficient modern lo- gistics system.

1. Literature review
   1. **Electric Vehicle Routing Problems**

The major problem electric vehicles (EVs) face is battery limitation by [delivery[1].](#_bookmark206) Grunditz and [Thiringer[2]](#_bookmark207) conducted an analysis of more than 40 electric vehicles (EVs) available worldwide,

classifying them into small, medium-to-large, high-performance, and sports categories. All of these EVs have battery capacities ranging from 12 to 90 kWh and driving distances varying between 85 and 528 km. For delivery services, light vans and freight EVs are primarily utilized, though they generally offer a shorter range (160-240 km) compared to internal combustion engine vehicles (ICEVs), which typically have a range of 480-650 km. Thus, for electric vehicle routing problems (EVRP), energy consumption and charge problem should be highlighted.

* + 1. **Energy Consumption**

In the current research, longitudinal dynamics modeling (LDM) is frequently used to accurately estimate energy consumption. Firstly, the underlying dynamics model is introduced by Asamer et [al[3].](#_bookmark208) The force F is defined by equation (1). Here, *m* represents the vehicle’s mass (typically

when empty), *a* stands for acceleration, *v* is the vehicle speed, *g* denotes the gravitational constant,

and *f* accounts for the inertia force of the vehicle’s rotating parts. Additionally, *α* indicates the road slope, *cr* is the rolling friction coefficient, *cd* is the air drag coefficient, *ρ* refers to air density, and *A* is the frontal surface area of the vehicle.

*F* = *mg* sin *α* + *crmg* cos *α* + 0*.*5*cdρAv*2 + *fma* (1.1) And energy consumption*Pb* can be calculated by equation (1.1). Where *µm* represents the trans-

mission coefficient between the electric motor and drivetrain, *µe* is the conversion ratio from chemi- cal to electric energy, and *µg* is the ratio for converting mechanical energy back to chemical energy in the battery. Energy is returned to the battery only when *F <* 0 and the speed exceeds *v*min[[3].](#_bookmark208)

⎧*µe*(*µmFv* + *P*0)*,* if *F* ≥ 0

⎪⎪⎨ *,* if *F <* 0

⎨⎧

*Pb* = 0*,* if *v* ≤ *v*min (1.2)

⎪ *µgFv* + *P*0*,* else

⎩⎩

Goeke and Schneider [[4]](#_bookmark209) enhanced the energy consumption model by incorporating changes in

vehicle load mass during goods transport, excluding acceleration and deceleration phases, thereby refining the solution’s accuracy.

In reality, cars travel at variable speeds, making it challenging to consistently determine acceler- ation and braking. For electric vehicle routing problems, researchers often simplify the longitudi- nal dynamics modeling (LDM) to accommodate these irregularities. [Lera-Romero[5]](#_bookmark210) developed a generic framework for time-dependent Electric Vehicle Routing Problems (EVRP), where battery consumption*P* is influenced by variables grouped into three categories: vehicle mass, speed, and

terrain conditions shows as equation (1.3). Where *mc*,*mq* denotes curb mass and goods mass sep-

arately.

*P* (*v, q*) = (︃ 1 · *c* · *ρ* · *A* · *v*2 + (*mc* + *mq*) · *g* · (sin(*α*) + *cr* · cos(*α*)))︃ · *v* (1.3)

2

*d*

Zhang [[6]](#_bookmark211) applies a similar method to calculate mechanical power and then estimates the indirect carbon dioxide emissions associated with generating the battery energy, based on the quantity of battery energy consumed.

* + 1. **Charging Problem**

The topic of charging electric vehicles can be divided into three discussion areas: charging or swap- ping batteries, various charging measurement rates, and the features of charging stations.

Jie and Yang [[7]](#_bookmark212) adapted the two-echelon Electric Vehicle Routing Problem (2E-EVRP) by replac- ing charging stations with battery switching stations. They employed a hybrid algorithm that com-

bines column generation and adaptive large neighborhood search (CG-ALNS) to optimize com- putations for these battery switching stations. Raeesi [[8]](#_bookmark213) introduced an advanced Electric Vehicle Routing Problem (EVRP) that incorporates time windowing and simultaneous mobile battery swap- ping. This approach transitions the swapping process from stationary stations to mobile vans, al-

lowing both the exchange vans and distribution vehicles to move simultaneously to optimize the

planning of the path, thus reducing time costs. Batteries’ inherent properties impose a typical limit of 80 percent of their capacity for charging [[9].](#_bookmark214) Up to this limit, charging can proceed at a fast linear rate, but any charging beyond this threshold must occur at a slower, non-linear rate to prevent bat- tery damage from overcharging. Montoya et al. [[10]](#_bookmark215) introduced a realistic model of vehicle charg-

ing using a nonlinear function, which they named the Electric Vehicle Path Problem with Nonlinear Charging (E-VRP-NL). This model takes into account various charging technologies and catego- rizes charging stations into three types: slow, medium, and rapid, each associated with specific linear and nonlinear charging rates. The study highlighted that neglecting the nonlinear aspects of charging can result in unfeasible or excessively costly solutions.

However, [Wang[11]](#_bookmark216) expanded the Electric Fleet Size and Mix Vehicle Routing Problem with Time Windows and Recharging Stations (E-FSMFTW) by incorporating partial linear charging strategies. This modification revealed that allowing partial linear charging significantly lowers the logistic costs for large E-FSMFTW instances when compared to the best-known solutions that rely solely on full charging strategies.

* 1. **Vehicle Routing Problem Algorithm**

Since the VRP and its variants are essentially NP-hard problems that cannot obtain an exact so- lution in a short time, many related algorithms have been derived to simplify the computational steps. Anuar [[12]](#_bookmark217) classifies the algorithms of VRP into three categories, namely, exact, heuristic, and meta-heuristic (Figure 1).

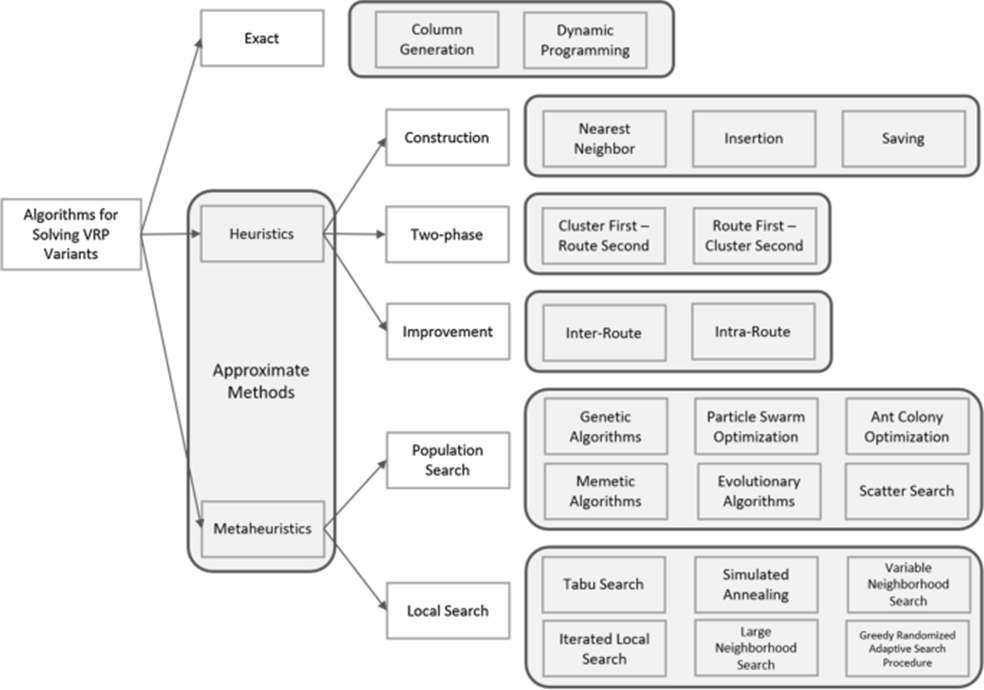
* + 1. **Approximate Methods**

Heuristic algorithms are classified into three main categories, i.e., constructive, two-stage and lo- cal improvement heuristics. Gábor Nagy and Saïd [Salhi[13]](#_bookmark218) developed an integrated heuristic ap-

proach that does not rely on the assumption prevalent in the traditional VRPPD literature that goods can only be picked up after all deliveries have been made. Their proposed approach integrates the pickup and delivery problems by modifying heuristic routines extracted from VRP methods to re-

duce infeasible solutions while constructing problem-specific routines. Many literatures focus on metaheuristic algorithms, which are more advanced procedures that incorporate population search and local search methods. In the domain of home healthcare logistics, Liu [[14]](#_bookmark219) proposed two mixed integer planning models and developed Genetic Algorithm (GA) and Taboo Search (TS) methods

considering the special vehicle scheduling problems of simultaneous delivery and pickup and time windows.GA is based on aligning chromosomes, segmentation process and local search, while TS is based on route assignment attributes, augmented cost function, route re-optimization and route optimization based on the attribute desire level. These heuristic algorithms were tested on an exist-



**Fig. 1.** Classification of VRP algorithms

ing Vehicle Routing Problem with Time Window (VRPTW) benchmarking example and showed ef- fectiveness and superiority in solving home healthcare logistics problems. For the VRP with Simul- taneous Pickup and Delivery problem, Öztaş and Tuş [[15]](#_bookmark220) have designed a hybrid meta-heuristic algorithm that combines meta-heuristic techniques such as iterative local search (ILS), Variable

Neighbourhood Descent (VND), and Threshold Acceptance (TA) in order to search for a near-

optimal solution in a reasonable amount of time. By using a roulette wheel selection mechanism

based on Shannon entropy and an adaptive acceptance criterion, the algorithm efficiently explores and enhances the search space to improve path feasibility and reduce total cost.

* + 1. **Exact Algorithms**

The exact algorithms mainly include Lagrangian relaxation and column generation. Tang [[16]](#_bookmark221) pro- posed an innovative solution that cleverly integrates the Lagrangian relaxation technique with the reinforcement learning framework. With this approach, the investigators were able to transform complex soft constraint problems into more manageable multi-objective optimisation problems. In their work, the Lagrangian relaxation not only effectively handles the trade-off between travelling distance and constraint violation cost, but also improves the efficiency and effectiveness of the al- gorithm in finding near-optimal solutions. [Zang[17]](#_bookmark222) uses column generation as the core technique to break the complex EVRP into smaller, more manageable subproblems. They carefully design custom labeling algorithms and resource extension functions that generate efficient columns, en-

abling the model to effectively balance nonlinear battery depreciation with travel costs. This ap- proach leads to faster convergence toward near-optimal solutions. [Caceres[18]](#_bookmark223) centers on a col-

umn generation strategy to simplify the challenging school bus routing problem for special educa- tion students. By combining a greedy heuristic with a column generation framework, the authors

decompose the problem into tractable subproblems that address mixed loading and heterogeneous fleet configurations. The method iteratively identifies effective routes, ultimately reducing fleet size and overall travel cost while ensuring high service quality.

1. Mathematical formulation

In this section, we first provide a formal description of the Electric Vehicle Routing Problem with Time Windows (EVRPTW), integrating aspects such as vehicle routing, time windows, load, and battery constraints. Based on this comprehensive overview, we then develop a detailed mixed- integer programming formulation that serves as the foundation for our analysis. Furthermore, we introduce a column generation framework designed to efficiently solve the problem.

The basic assumptions of our EVRPTW model are summarized below:

* All customer demands are predetermined and remain constant, with each customer being

served by only one vehicle. Service is limited to delivery, and the visit to both customers and charging stations must be completed within the specified time windows.

* A route is defined as a sequence of nodes (including the depot, customers, and possibly charg- ing stations) that an electric vehicle traverses. Each route begins and ends at the depot, and

the total demand of the customers on a single route must not exceed the vehicle’s load ca- pacity.

* All electric vehicles are homogeneous, sharing the same load capacity and battery capacity.
* The vehicle driving speed and the energy consumption rate are assumed to be constant, and external factors such as traffic conditions, varying loads, and road conditions are not consid- ered.
* Charging stations have unlimited capacity and are assumed to be available at all times. More- over, the adopted charging strategy mandates that vehicles fully recharge at a charging sta-

tion before resuming their route.

* 1. **EVRPTW Model**

We adopt the following notations. Let *K* denote the set of vehicles, *C* the set of customers, and *S*

the set of charging stations. The depot is represented by two nodes: the starting depot, *Do* = {0}, and the ending depot, *Dn*+1 = {*n*+1}. We further define the starting node set as *SC*0 = *Do*∪*S* ∪*C* and the ending node set as *SCn*+1 = *S* ∪*C* ∪*Dn*+1. In our formulation, each electric vehicle departs from a node in *SC*0 and arrives at a node in *SCn*+1, thereby determining its route.

Each arc (*i, j*) in the complete directed graph is associated with a distance *Dij* and a travel time *tij*. For every customer *i* ∈ *C*, a positive demand *qi* is specified together with a hard time window [*ei, li*] and a service time *si*. The depot is assigned a large time-window upper bound *l*0 to relax

time constraints. The parameter *R* denotes the battery capacity (i.e., the energy level when fully charged), while *C* represents the vehicle’s cargo capacity. The energy consumption rate per unit distance is given by *g*, and the charging rate by *h*.

For decision making, we introduce the binary variable *xk* which takes the value 1 if vehicle *k* trav-

*ij*

els directly from node *i* to node *j*, and 0 otherwise. The arrival time of vehicle *k* at node *i* is de-

noted by *tk*. The battery energy level upon arrival is represented by beb*k*, and the battery level af-

*i* *i*

ter service or charging by afb*k*. In particular, afb*k* = beb*k* at customers and depots, while at charg-

*i i* *i*

ing stations afb*k* is reset to *R*. The objective function of the EVRPTW model can be written as:

*i*

min ∑︂ ∑︂ ∑︂ *Dij xk .*

*ij*

*k*∈*K i*∈*SC*0 *j*∈*SCn*+1

*j*̸=*i*

The constraints for building the model are listed below:

∑︂ ∑︂ *k* = 1*,* ∀ *i* ∈ *C,* (2.1)

*x*

*ij*

*k*∈*K j*∈*SCn*+1

*j*̸=*i*

*x*

*ji*

*j*∈*S*∑︂*C*

*n*+1

*j*̸=*i*

*k ij*

*j*∈*SC*0 *j*̸=*i*

*x*

∑︂

−

*k* = 0*,* ∀ *k* ∈ *K,* ∀ *i* ∈ *S* ∪ *C,* (2.2)

∑︂ *qi*(︂ ∑︂ *xk* )︂ ≤ *C,* ∀ *k* ∈ *K,* (2.3)

*ij*

*i*∈*C*

*j*∈*SCn*+1 *j*̸=*i*

*tk* + *si xk* + *tij xk* ≤ *tk* + *l*0(︁1 − *xk* )︁*,* ∀ *k* ∈ *K,* ∀ *i* ∈ (*C* ∪ {0})*,* ∀ *j* ∈ (*SC* ∪ {*n* + 1})*, i* ̸= *j,*

*i ij*

*ij j ij*

(2.4)

*tk* +

*i*

*k*

*i k*

(︂ *R* − beb )︂

*x*

*h ij*

+ *tij xk*

≤ *tk* + *l*0

(︁1 − *xk*

*,* ∀ *k* ∈ *K,* ∀ *i* ∈ *S,* ∀ *j* ∈ (*C* ∪ {*n* + 1})*, i* ̸= *j,*

(2.5)

)︁

*ei* ≤ *tk* ≤ *li,* ∀ *k* ∈ *K,* ∀ *i* ∈ (*SC* ∪ {*n* + 1})*,* (2.6)

*ij*

*j*

*ij*

*i*

afb*k* − *g Dij xk* ≥ beb*k* − *R*(︁1 − *xk* )︁*,* ∀ *k* ∈ *K,* ∀ *i* ∈ *SC*0*,* ∀ *j* ∈ *SCn*+1*, i* ̸= *j,* (2.7)

*i*

*ij*

*j*

*ij*

afb*k* = *R,* ∀ *k* ∈ *K,* ∀ *i* ∈ *S,* (2.8)

*i*

afb*k* = beb*k,* ∀ *i* ∈ *C* ∪ {0*, n* + 1}*,* ∀ *k* ∈ *K,* (2.9)

*i*

*j*∈*S*∑︂*C*

*n*+1

*i*

*k* = 1*,*

*x*

∑︂

0*j*

*i*∈*SC*0

*k*

*i,n*+1

*x*

= 1*,* ∀ *k* ∈ *K,* (2.10)

*xk* ∈ {0*,* 1}*, tk* ≥ 0*,* beb*k,* afb*k* ∈ [0*, R*]*,* ∀ *k* ∈ *K,* ∀ *i, j.* (2.11)

*ij i i* *i*

In this model, constraint [(2.1’)](#_bookmark201) ensures that every customer is visited exactly once by one vehicle.

Constraint [(2.2)](#_bookmark191) guarantees the flow balance at all node. Constraint [(2.3)](#_bookmark192) enforces that the total

demand of all customers visited by a vehicle does not exceed its cargo capacity. Time constraints are divided into two parts: [(2.4)](#_bookmark193) applies when the preceding node is a non-charging node (customer or depot), while [(2.5)](#_bookmark194) applies when the preceding node is a charging station; and the charging time, computed as *R*−beb*k* . Constraint [(2.7)](#_bookmark195) ensures that if a vehicle travels from node *i* to node *j*, the

*i*

*h*

energy available after leaving node *i* (after consumption) is sufficient to reach node *j*. Constraint [(2.8)](#_bookmark196) bounds the battery levels, and [(2.9)](#_bookmark197) updates the battery state.

1. Algorithm framework

As is widely recognized, the Vehicle Routing Problem with Time Windows (VRPTW) is an NP-hard combinatorial optimization problem. In this paper, we extend the classical VRPTW to address the challenges specific to electric vehicles, particularly the recharging requirements that arise during operations. To efficiently solve the models we develop a general column generation framework

and design monodirectiona label algorithms for the pricing subproblems, formulated as elementary shortest path problems with resource constraints (ESPPRCs). Our label algorithm is an extension of the approach in [Desaulniers[19],](#_bookmark224) adapted to the specific constraints and structures of our model.

* 1. **Column Generation**

Let Ω be the set of all feasible routes, i.e., elementary routes that satisfy the requirements some of the customers. For each path *p* ∈ Ω, we define a binary parameter *aip* that equals 1 if customer *i* is visited in path *p* and equals 0 otherwise. We then introduce a decision variable *λp* ∈ 0*,* 1 to indicate whether path *p* is used. Furthermore, we denote by *cp* the operation cost (total distance) of path

*p*. Let *P* ⊆ Ω be the set of already-generated feasible paths, where each path *p* ∈ *P* satisfies all resource constraints. In addition, we associate with each customer *i* a dual variable *πi* and define

the reduced cost of path *p* as ¯*cp*. With these notations, the EVRPTW model can be formulated as a set partitioning program.

min

*λ*

*cp λp,* (3.0)

*p*∈*P*

∑︂

*aip λp* = 1*,* ∀ *i* ∈ *C,* (3.1)

∑︂

*p*∈*P*

*λp* ∈ 0*,* 1*,* ∀ *p* ∈ *P.* (3.2)

Objective function (3.0) aims to minimize the overall operational cost. Constraints (3.1) ensure that each customer is served exactly once by a single vehicle. Lastly, the binary requirements in (3.2) restrict the decision variables to the appropriate integer domain. However, a column generation

approach requires solving a line (3.0)–(3.2) is an integer program. Hence, we relax the binary con- straints in (3.2) to linear ones:

*λp* ≥ 0*,* ∀ *p* ∈ Ω*,* (3.3)

which, combined with (3.0)–(3.1), constitutes the master problem (MP), commonly referred to as the restricted master problem (RMP). Initially, the RMP only includes a limited set of columns and

thus does not represent the complete problem. Solving the RMP yields a provisional best solution and the associated dual variables at each iteration. Let *πi* be the dual variable corresponding to (3.1) for each *i* ∈ *C*. These dual values are used to update the pricing problem, thereby generating additional columns to be incorporated into the RMP. Once the reduced cost

¯*cr* = *cr* − *aip πi*

∑︂

*i*∈*C*

is nonnegative for all potential columns, the RMP is deemed complete, and the final optimal solu- tion is obtained.

The pricing problem aims to locate routes with negative reduced costs and incorporate them into the RMP. This iterative process is repeated until the optimal solution is achieved.To formulate the pricing problem, we continue to use most of the notations mentioned above. Most constraints are also similar because the resource restrictions are the same as in the original problem. The objec- tive of pricing problem is minimize reduced cost:

min

¯*cp* = *cp* − *aip πi.*

*i*∈*C*

∑︂

**Subject to:**

∑︂ ∑︂

*k* ≤ 1*,* ∀ *i* ∈ *C* (2.1’)

*x*

*ij*

*k*∈*K j*∈*SCn*+1

*j*̸=*i*

(2.2)–(2.11)

Only constraint(2.1) is relaxed because the subproblem only needs to generate elementary paths without accessing all clients.

* 1. **Column Generation Procedure**

We implement the column generation process following the framework outlined in Fig.2, and it can be divided into four key steps.

Start

Create Initial Paths

[Algorithm 1]

Solve Relaxed Mas-

ter Problem (RMP)

Obtain Dual

Variables {*πi*}

Solve Subproblem

or [Algorithm 2]

Any Path with

Negative

Reduced Cost?

Yes

Add New Path(s)

to Pathpool

No

Solve Strict Mas- ter Problem (SMP)

End

**Fig. 2.** Column generation procedure

Step 1. Utilizing a saving heuristic (refer to Section 4.2.1 for details), we generate an initial set of solutions to launch the column generation process. For each customer, a basic route is constructed that departs from the origin and returns to the depot. Should the battery level prove insufficient, the vehicle diverts to the nearest charging station.

Step 2. Solve the linear relaxation of the master problem using all currently available columns. Then, update the objective function coefficients of the subproblems based on the newly obtained dual variable values.

Step 3. Employing a secondary savings heuristic (detailed in Section 4.2.2), new columns are gen- erated. Should any subproblem yield a column with a negative cost, the procedure returns to Step

2.

Step 4. The master problem is solved as an integer program by employing standard branch and bound techniques.

* 1. **Generating Initial Solution**

The algorithm (Fig 3) generates a set of initial routes, denoted by *P* , which serve as candidate so- lutions within a broader column generation framework. Specifically, for each customer *i* ∈ *C*, the algorithm computes the energy requirement *E* as the product of a given consumption factor *g* and

the sum of the distances from the depot (node 0) to customer *i* and from customer *i* back to the de- pot (node *n* + 1). If the computed energy *E* is less than or equal to the available battery capacity *R*, a direct route

[ 0 → *i* → (*n* + 1) ]

is deemed feasible and selected. However, if *E* exceeds *R*, the algorithm identifies the nearest charging station *s* ∈ *S* to customer *i* (using an arg min operation on the distance *Di,s*) and con- structs an alternative route

[ 0 → *i* → *s* → (*n* + 1) ]

that incorporates a recharging stop. Each generated route is then added to the set *P* . This initial- ization process ensures that every customer is assigned at least one viable route—either directly or with an intermediate charging station—thus providing a robust starting solution for subsequent optimization steps.

**Input:** *C, S,* 0*, n* + 1*, R, g, Dij* **Output:** *P*

**begin**

/\* Initialization \*/

*P* ← ∅ /\* empty set of routes \*/

/\* Construction \*/ for each *i* ∈ *C* do

(︁ )︁

*E* ← *g* × *D*0*i* + *Di,n*+1

if *E* ≤ *R* then

*r* ← [ 0 → *i* → (*n* + 1) ]

else

*s* ← arg min *s′*∈*S D i,s′* /\* nearest station to *i* \*/

*r* ← [ 0 → *i* → *s* → (*n* + 1) ]

end if

*P* ← *P* ∪ { *r* }

end for

**end**

**Fig. 3.** Algorithm 1 generating initial routes

* 1. **Mono-directional Search**

In this section, we introduce our monodirectional search algorithm that is used to generate feasible routes (or columns) for the column generation framework. The algorithm builds routes by extending labels through the network while updating key resources such as cost, load, time, battery capacity, and customer service status. Below is the pseudocode for the algorithm, followed by an explana-

tion of its structure and key components.

The algorithm (Fig.4) starts by initializing the depot with the label

*L*0 = (0*,* 0*,* 0*, B*max*,* **0**)*,*

which represents zero cumulative cost, zero load delivered, zero elapsed time, full battery capacity

*B*max, and a vector of zeros for customer service status (indicating no customer has been served). In addition, an empty label set Π*i* is created for each node *i* in the network to store the labels that reach that node.

The main loop of the algorithm processes nodes in the set *I* until no further processing is required. For each node *i* in *I*, a temporary set H*ij* is initialized to hold the new labels generated by extend- ing each label *Lp* ∈ Π*i* to every feasible successor node *j* via the Extend procedure. Only exten- sions that satisfy all resource constraints are kept.

Once all labels at node *i* have been extended (shown in below), the temporary set H*ij* is merged with Π*i* and pruned using a dominance function. This function compares cumulative cost, delivered load, arrival time, battery capacity, and customer status to retain only those labels that can poten- tially lead to an optimal route. The node set *I* is then updated by removing nodes that no longer

require processing.

Finally, a last dominance check is applied at the depot (node 0). If any label at the depot corre- sponds to a route with a negative reduced cost, these labels are used to update the column set Ω*R* and reoptimize the restricted master problem (RMP).

* + 1. **Resource Extension Functions**

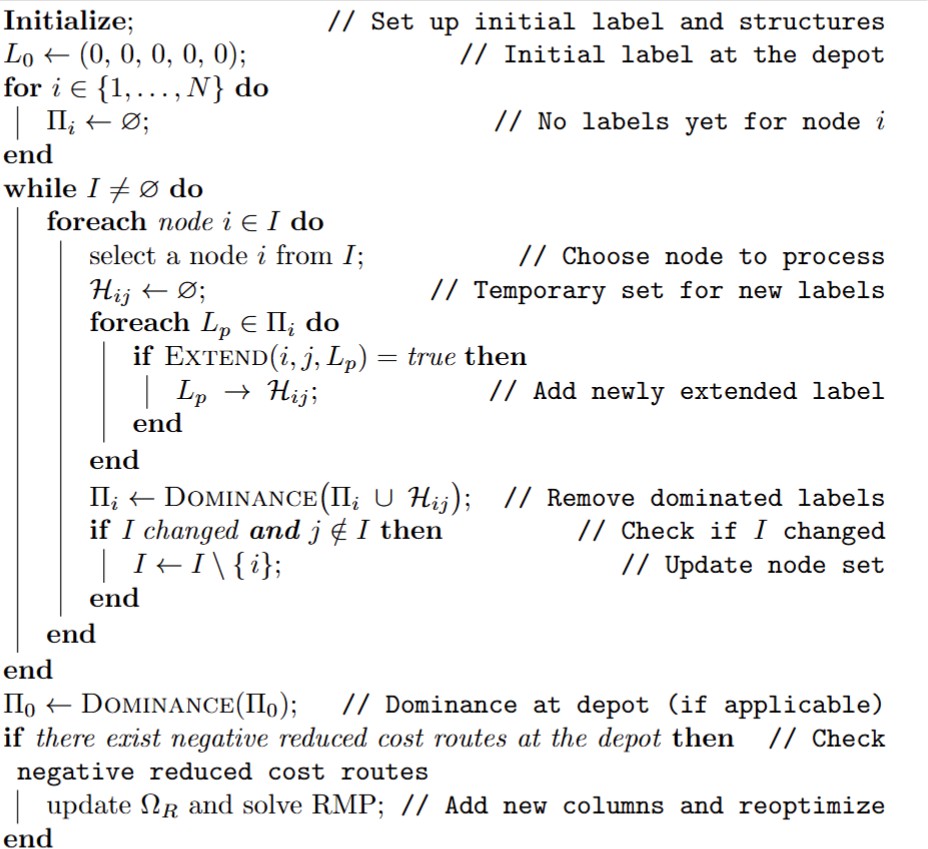
When a label is extended from node *i* to a neighboring node *j*, the algorithm updates the resources associated with the label using a series of functions. First, the load is updated by adding the de-

mand *qj* at node *j* to the current load, which is expressed as

*T* load = *T* load + *qj .*

*j* *i*

This update ensures that the cumulative load reflects the additional delivery at node *j*.



**Fig. 4.** Algorithm 2 monodirectional search

The arrival (or service) time at node *j* is computed based on whether node *i* is a customer or a charging station. If node *i* is a customer, the updated time is calculated as

*T* time = max(︂*ej, T* time + *si* + *tij*)︂*,*

*j*

*i*

where *ej* is the earliest permissible service time at node *j*, *si* is the service duration at node *i*, and

*tij* is the travel time from *i* to *j*. If node *i* is a charging station, the update instead accounts for charg- ing time, and the expression becomes

*T* time = max(︂*ej, T* time + ∆*t*charge + *tij*)︂*,*

*j*

*i*

with ∆*t*charge computed as

∆*t*charge = *B*max − *Bi ,*

*r*

where *Bi* is the battery level at node *i* and *r* is the charging rate. This formulation ensures that the waiting time due to charging is properly incorporated.

Similarly, the battery level is updated based on the type of node *j*. If node *j* is a customer, the bat- tery is reduced by the consumption *bij* required to travel from *i* to *j*, so that

*Bj* = *Bi* − *bij.*

In contrast, if node *j* is a charging station, the battery is assumed to be fully recharged, and hence

*Bj* = *B*max*.*

The cumulative reduced cost is updated by simply adding the cost of traveling from *i* to *j*. This is given by

*T* cost = *T* cost + ¯*cij ,*

*j* *i*

where ¯*cij* represents the reduced cost associated with the arc from *i* to *j*.

Finally, the customer service status is updated for each customer *n* when extending to node *j*. If node *j* corresponds to customer *n*, the status is incremented by one, indicating that the customer has been served. Otherwise, the updated status is determined by taking the maximum of the cur- rent status and a function *U* that checks whether adding customer *n* would violate resource con- straints. This update is expressed as

⎧⎨*T*cust*n* + 1*,* if *j* corresponds to customer *n,*

*i*

*T*cust*n* =

*j*

⎩max{*T , U* (*n, T* load*, T* time*, B* )}*,* otherwise*,*

*i*

cust*n*

*j*

*j*

*j*

where the auxiliary function *U* returns 1 if adding customer *n* would lead to exceeding the capacity *Q*, missing the latest service time *ln*, or not having sufficient battery to serve the customer, and 0 otherwise. This ensures that the feasibility regarding customer service is maintained throughout the label extension process.

* + 1. **Domination Rules**

To control the growth of labels and maintain computational efficiency, the algorithm employs a set of domination rules. These rules compare two labels *L*1 and *L*2 that arrive at the same node. Label *L*1 is said to dominate *L*2 if all of the following conditions hold:

2

1

*T*

≤ *T*

cost

1

*T*

≤ *T*

load

1

*T*

time

cost*,* load*,* time*,*

*B*1 ≥ *B*2*,*

≤ *T*

2

2

*T n,*1 ≤ *T n,*2

∀ *n* ∈ *N,*

cust cust

with at least one of these inequalities being strict. In other words, a label *L*1 dominates another la- bel *L*2 if it incurs no higher cost, delivers no more load, arrives no later, retains no less battery ca- pacity, and has at least as favorable customer status for all customers. By applying this rule, the algorithm discards labels that are clearly suboptimal, thus reducing the overall number of labels that must be considered.

1. Summary

In this work, we have presented a comprehensive framework for addressing the Electric Vehicle Routing Problem with Time Windows (EVRPTW). Our study integrated a detailed mixed-integer

programming formulation that accounts for critical operational constraints—such as battery capac- ity, charging strategies, and customer time windows—with a robust column generation approach

enhanced by a monodirectional label algorithm. The proposed methodology successfully balances the trade-offs between minimizing operational costs and satisfying practical constraints, ensuring both feasibility and near-optimality in route planning for electric vehicles.

Looking ahead, there are several promising directions for future research. One potential avenue is to enhance battery consumption calculations by employing more detailed longitudinal dynamics modeling (LDM). Such an approach would specifically consider factors like acceleration, deceler- ation, and road gradients to provide a more accurate estimation of energy consumption. Another interesting research direction involves addressing the optimization impact of fluctuating charging costs. By integrating dynamic charging rates that reflect time-of-day variations or market-driven pricing, future models could achieve more cost-effective and realistic planning outcomes. Addi- tionally, incorporating dynamic information—such as real-time traffic conditions and charging sta-

tion queue lengths—into the optimization framework could further improve the adaptability and effi- ciency of routing strategies. This integration of dynamic data would allow the model to adjust routes in real time, thereby enhancing the overall performance of the electric vehicle logistics system.

This research not only provides a novel theoretical model and solution method for electric vehicle routing in logistics distribution but also lays the groundwork for future enhancements that address energy consumption accuracy, cost fluctuations, and real-time operational dynamics.

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# A Conceptual Underpinning for Energy Poverty Studies: Categorising Drivers, Indicators, and indices

**Abstract**

*A just and fair transition toward a more sustainable environment requires attention to all members of society, including energy-vulnerable people. Energy poverty is a multi-disciplinary research area that has attracted the attention of both policymakers and scholars for decades. The extant literature uses non- standardized conceptual terminology and constructs, leading to two main problems. First, data-driven studies are difficult to compare and integrate. Second, due to a multitude of conceptual constructs with overlapping semantics, it is hard to distinguish causes from effects and indicators, so policy design and budget allocation may target the wrong factors. This paper proposes a comprehensive conceptual model that makes comparison and integration of energy poverty studies possible based on a three-level structure consisting of drivers, indicators, and indices. Definitions and examples are offered to make these three factors distinguishable, determining drivers as possible targets for policymakers. Moreover, a hypothesis is presented to make an initial point for empirical driver-indicator function determination.*

*Keywords: Energy poverty, taxonomy, conceptual framework, energy informatics, sustainability, data driven models*

**Introduction**

Global warming and the carbon emission crisis are two of the most widely researched problems in the scientific domain. In many countries, policymakers design and implement policies to fight these environmental disasters, but the lingering question if these policies benefit all remains. There are energy- poor people all around the world still dealing the heat or eat dilemma. How zero carbon or low emission policies is going to impact their lives is another major concern. Will renewable energy promotion programs have the unintended consequences of creating even more energy poverty vulnerable people? What supportive schemes are needed to protect them? Researchers in the energy poverty area have proposed several models to identify root causes of energy poverty and given policymakers tools to identify vulnerable groups to design fair policies. More recently, data science research, thanks to machine learning and artificial intelligence (AI), is growing exponentially and gaining millions of annual citations while emphasis on social good challenges is decreasing (Abbasi et al. 2023 JIAS). Information systems (IS) scholars can provide an important contribution to policy design for a sustainable energy transition by developing data-driven tools and systems in the area of energy informatics that help to reduce energy poverty (Watson et al 2022 -JAIS). To underpin the new class of IS systems and tools for energy poverty reduction, two major challenges need to be addressed: First, energy poverty models are not standardized and are extremely difficult to compare across studies. Second, energy poverty researchers do not use a unified terminology for identifying constructs that would facilitate systems design and better communication between researchers and key stakeholders such as policymakers.

The charity National Energy Action (NEA) has estimated that the total number of UK households in fuel poverty increased from around 4.5 million in October 2021 to 6.7 million in October 2022. Their latest estimate is 6.5 million for January 2024. This figure is more than double the official estimate for England alone. NEA define a household as fuel poor if it needs to spend more than 10% of its income on energy to provide a satisfactory heating regime. In 2018, 34 million Europeans expressed that they were unable to maintain a comfortable temperature in their homes (Charlier & Legendre, 2021). Energy poverty is also a major contributing factor to public health problems (Bone et al., 2014). It is estimated that energy poverty costs to the United Kingdom’s National Health Service (NHS) approximately £1.36 billion per year, without considering social care or informal care costs (Grey et al., 2017). According to the Committee on Fuel

Poverty (Committee on Fuel Poverty, 2021), “the addresses of [energy poor] households are unknown and hence it is difficult to target and assist them. Energy poverty significantly affects individuals’ quality of life, health, and productivity and it is connected to Sustainable Development Goals (SDG) of the United Nations. These goals include SDG 7.1., to ensure universal access to affordable, reliable, and modern energy services, SDG 11.1, to ensure access for all to adequate, safe, and affordable housing and basic services, and SDG 12.C., to rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption in a manner that protects the poor and the affected communities. While the IS community has already engaged with 16 of the 17 SDGs, SDG 12 was identified as under researched by the IS community (Watson et al. 2021-CAIS). It is expected that by including data driven studies in multidimensional fields like energy poverty, the IS community will play a key role in helping to tackle SDG 12. Nevertheless, this multidimensional nature presents a considerable challenge for policymakers who try to allocate resources to alleviate it effectively.

According to Bouzarovski (Bouzarovski, 2018) a clear definition of the term fuel poverty, which is an earlier version of energy poverty, was first described in 1991 (B. Boardman., 1991) in British academia and policy making environment. Energy poverty is a multidimensional phenomenon with no universally accepted definition (Santillán et al 2020). Scholars use different approaches and theories in their studies and extant literature use non-standardized conceptual terminology and constructs. The problem of agreement upon conceptual foundations became more severe, considering that studies and policymakers’ actions often resort to a piecemeal approach to alleviation of poverty related problems (Jha et al., 2016). Also, along with fast environmental degradation and increasing social impacts, data’s volume is increasing. Data’s ever- growing volume and diversity leads to more scientific specialization and knowledge fragmentation (Gholami et al 2016-JIAS)

Most studies focus on a small set of constructs, avoiding the broader conceptualization of the entire field. For example, there are studies focusing on a few aspects of energy poverty (Pérez-Fargallo, et al. 2018, Bienvenido-Huertas, et al. 2019, Robles-Bonilla and Cedano 2021) or developing models for decision makers in the societal ecosystem (e.g., different departments of public sector, private sector, or NGOs) (Porras-Salazar 2020, Perez-Fargallo et al 2017). Further examples include studies focusing on income and age (Porto Valente et al., 2022), single parenthood (Sunikka-Blank & Galvin, 2021), gender (Robinson, 2019), housing (Pino-Mejías et al., 2018), and cooling needs (Mastrucci et al., 2019). Another group of studies propose generalised models including several factors in their study, but in most cases, they do not provide a comprehensive conceptual foundation and stop at a proposing two-level model including index in form of weighted summation of all factors (Ismail & Khembo, 2015; Kelly et al., 2020; Robles-Bonilla & Cedano, 2021; Santillán et al., 2020). These two-level models cause two problems. First, they do not consider the concept of intersectionality (Crenshaw, 2013). For example, people have different identity like gender, age, and disability that have impact on energy poverty level of those people (Simcock et al., 2021). Considering each identity in isolation ignores interconnectedness of these identities. Second, they put different types of concepts in the same level. The root problem is the lack of comprehensive and widely used constructs for modelling studies and agreed upon terminology. This problem led to partial and fragmented solutions developed from studies focused on a few aspects that cannot be easily integrated into a comprehensive model.

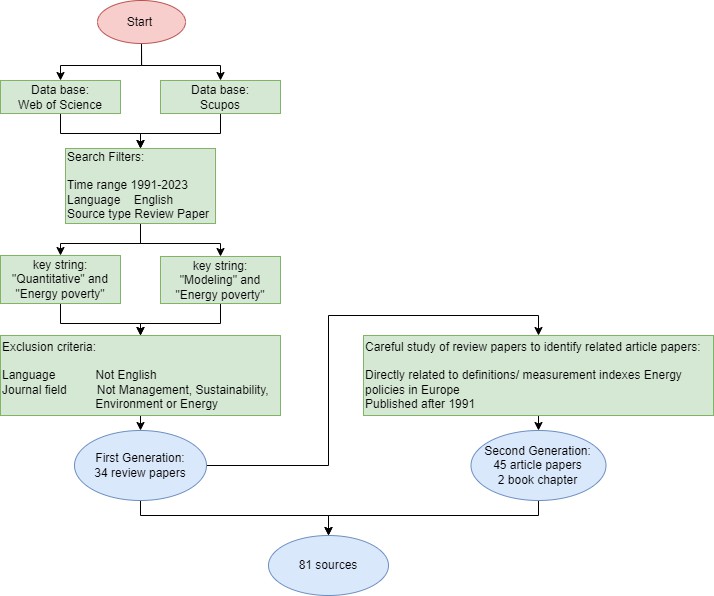
Governments propose several schemes and subsidies to alleviate the energy poverty. At the same time, they are proposing energy related policies like zero carbon or low emission policies to fight sustainability disasters like global warming. These highly related policies have direct and indirect effects on energy poverty level and inequalities in this area. These challenges highlight a need for policy labs. According to (King and Kraemer 2019-JIAS) it is important for Information Systems (IS) scholars who are working on policies to think about promulgation, implementation, and effects. Policy labs promote implementation of policies by providing insights of effects for policymakers. Promulgation demands united front from scholars at least in terminology they use to communicate with each other and policymakers. Also, as a multi- dimensional concept it is expected that several IS integration is needed for developing a comprehensive model.

This research aims to provide a general conceptual underpinning and defined terminology for data driven study of energy poverty enabling integration and comparison between results of studies in this area. This research is framed as a framework article with an objective of integrating and conceptualising, defining boundaries, offering a prospective showing concepts and relationships, and a general framework for developing models, but as it is not a literature review, we do not aim to be comprehensive (Schwarz et al., 2007). Also, as a taxonomy paper provides definitions and labels with an initial point for data driven studies.

**Research Method**

Literature review is a critical first step for this research. Systematic Literature Review (SLR) is chosen for this purpose to answer the main questions including what explicit or implicit conceptual models do researchers use in this field? What terms do they use to describe different concepts and factors in their papers? How these concepts and factors are different or similar among these studies? These questions should be answered before going to the next step. As mentioned, fuel poverty came into attention of the British academics and policymakers’ centre of attention in 1991, so 1991 set as timeline limit of the literature review. For the literature review, Web of Science and Scopus database were used with similar settings in case of time range, key word strings, language, and type of papers. The time range for search was adjusted to the 1991.01.01 to 2023.12.17. The keyword strings were "Energy Poverty" and “Quantitative”, and “Energy Poverty” and “Modelling”. The language and type of paper were limited to English and review papers respectively. Terms “Quantitative” and “Modelling” were included as the focus is on studies that are data driven and offer models rather than explore possible factors or provide qualitative results.

The search results for “Energy poverty” and “Quantitative” string showed 9 review papers from the Web of Science database and 7 review papers from the Scopus database with 5 mutual results. All 11 papers were downloaded and scanned for preliminary exclusion. Language, journal name, title, abstract and keywords were read. The exclusion criteria were not being in English, being in fields other than Management, Sustainability, Environment and Energy. Another criterion, absence of Energy Poverty/ Fuel Poverty in the Title or keywords, was tried and rejected since it excluded valuable resources. 2 review papers were excluded from the Web of Science results since one of them was in Spanish and only its abstract was in English. The other one was in the Fire technology field. None of results from the Scopus database was excluded. Final 9 review paper were read carefully, and the papers directly related to definitions, measurement indexes and energy policies in Europe and published after 1991 were added to the second level lists. The second level list includes 32 article papers and 2 book chapters. Similar process for the “Energy poverty” and “Modelling” string led to 25 review papers. Attentive reading of these review papers has identified 13 article papers and is continuing. As discussed in previous section, it is a framework paper not a literature review, so we do not intend to be comprehensive. These 81 sources were studied in detail to form the general framework that can encompass all studies models and propose shared terminology. Figure 1 shows the SLR process used for this research.



**Figure 1: The flowchart of the SLR for this research**

Bailey (Bailey 1984) approach is used for evaluation of models in the literature and proposing the framework. He suggested a three-level measurement model for sociological concepts and discussed that two-level models are not adequate for these concepts and cause problems for users. The two-level models include conceptual and empirical levels. He divided the concepts into two groups, concepts by intuition and concepts by postulation that have very different roles in measurement theory based on Northrop book (Northrop 1947). Concepts by intuition can be sensed directly, but postulation concepts are designed by postulation of deductive theories of their area. Bailey discussed that these two groups of concepts are radically different, so the models that put both on the same level are not proper. Then he introduced a third level (middle level) named indicator which connects the empirical level to the conceptual level and separate concepts by intuition and concepts by postulation. He provided a few examples. One of these examples is offered here for illustration. The concept of crime is the perception of acts which violate laws and are thus subject to prosecution is the concept level. A single act of this behaviour (e.g., robbery) that can be observed is the empirical level, and indicators can be defined based on crime statistics or a scale of carnality.

**Findings**

***Conceptual model***

In the literature of the energy poverty studies, both two-levels and three-levels models are proposed. The three-level model can be seen in some studies like (Bouzarovski & Petrova, 2015). While it is implicit and offered as 3 of 5 principal elements of energy poverty, there these three levels named driving forces, expressions, and consequences. Other studies do not have the second level, but they do some calculations that can be attributed to the second level factors. For example, Pino-Mejias et al. (Pino-Mejías et al., 2018) calculated the energy consumption. A high level of energy demand can be an indicator of energy poverty. Examples of models that lack the second level are the models developed based on the multidimensional energy poverty index (MEPI) (Robles-Bonilla and Cedano 2021, Santillán et al. 2020, Pablo et al 2019). In these studies, both first level factors and second level factors are included in a weighted summation to form an index. These models are developed based on (Nussbaumer et al 2013) model, so we analyse their model for illustration. Here is their proposed formula.

MEPI = (q/n) \* ∑𝑛 𝑐𝑖 (𝑘)/𝑞

𝑖=1

Where q is the number of energy poor people, n is total number of people, k is cut-off threshold of energy poverty and ci(k) is defined by the formula.

𝑑

Ci= ∑

𝑗=1

𝑔𝑖𝑗

Where gij are elements of deprivation matrix that is calculated based on summation of weights of dimensions (variables) that person i is considered deprived. In summary, it is based on weighted summation of deprivation factors. Variables in this model are very different. For example, access to electricity and fridge ownership are in the same level and are summed. However, these two factors are very different. Fridge ownership is intuition concept, but access to electricity can be provided by electrical grid or distributed generator (DG), also reliability of electricity is important. Hence, electricity access (or lack of access based on definitions) should be placed on second level. In practice, merging two levels makes policy design and policy evaluation hard. The first level factors can be targeted by policy designers, but evaluation is based on second level factors. For instance, the goal is providing clean energy (electricity) access for people that can achieved by providing a reliable electrical grid or proper DG and energy storage system.

Based on Bailey (Bailey 1984) a three-level framework for energy poverty modelling is proposed. The first level includes factor that can contribute to increase the chances of people falling into energy poverty and can be easily measured. The second level is dedicated to the results of presentation of a group of first level factors causing troubles for energy poor people. The third level include factors that show the level of energy poverty for a group of people or area. The third level factor is formed based on a function with second level factors as inputs, and second level factors are formed on functions with first level factors as inputs.

***Terminology***

Researchers can communicate more easily when they use the same terms for the same concepts. Three terms are proposed here to be used for the three levels of energy poverty factors. The proposed term for the first level factors is “driver”. In the literature different names are used to address these factors like drivers (Thomson 2013), driving force (Bouzarovski and Petrova 2015, Bouzarovski et al 2021), indicator (Kelly et al 2020, Siksnelyte-Butkiene et al 2021), intervention (Day et al 2016), variable (Ismail and Khembo 2015, Pérez-Fargallo et al., 2017), and factor (Pérez-Fargallo et al., 2017). Driver is selected based on the first two examples as the third one can make confusion and the rest are too general. The “drivers” are the factors that are the reasons and causes of the energy poverty, but presentation or severity of these factors does not necessarily lead to energy poverty. A few examples of these factors are age, gender, income, access to gas grid, and type of dwelling. Previous studies have shown that old, females, low incomes (Pérez-Fargallo et

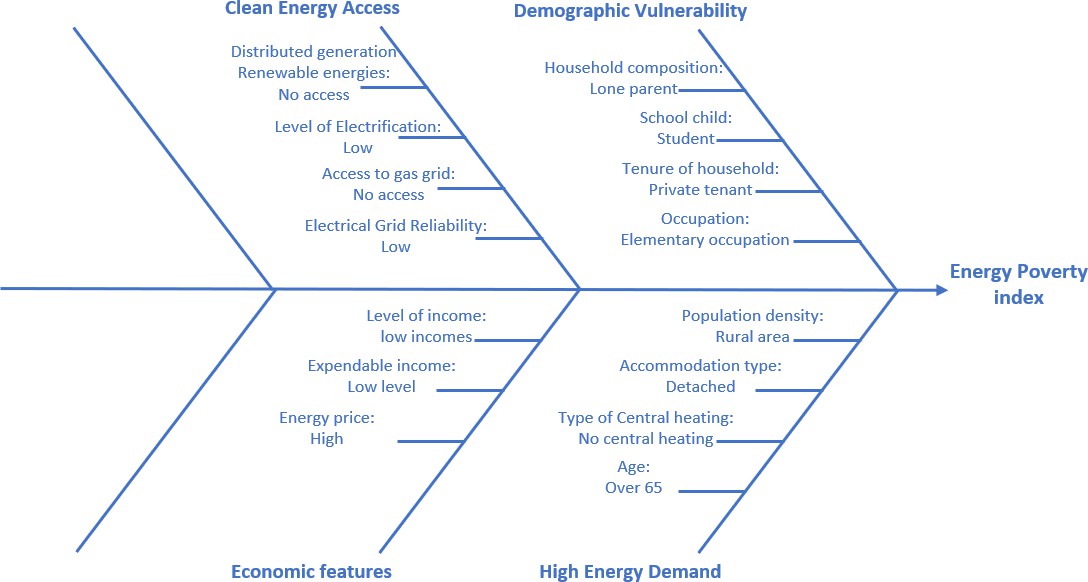
al., 2020), people with no access to gas grid (Hills, 2011)(Papada & Kaliampakos, 2016) and detached houses residents are more vulnerable to energy poverty, but none of them dictates energy poverty. For instance, old people who have a well-isolated home and a good income are not energy poor (simplified and not considering other factors).

Proposed name for the second level factors is “indicator” as proposed in Bailey (Bailey 1984) three-level model. Also, this term is repeatedly used in the literature for addressing all three levels of model, so it is better to keep it in terminology but use it just for one level. Indicators are the signs of energy poverty that cannot be seen/measured directly. A high score in energy poverty indicator is caused by presence of a few related energy poverty drivers. If a family has high score in any indicator, they have a high chance of experiencing energy poverty. Example of energy poverty are economic struggle, demographic vulnerability, high energy demand, and no access to clean energy. For instance, no access to clean energy is caused by no connection to a reliable electric grid and lack of a distributed generator (DG) source like a solar panel.

Fortunately, there is a relative agreement for third level factors. Almost all studies call them “Index”. Index is a criterion of the energy poverty and can be used for comparing energy poverty level of households or areas. Indices are a single number in quantitative or numerical studies of energy poverty. This unique number is calculated based on indicators values. The relationship between the index and the indicators is not necessarily linear.

***The hierarchy illustration in energy poverty***

As discussed in the terminology subsection, there is causality relationship between drivers and indicators. Also, indices are calculated based on indicators, so there is a causality relationship. Fishbone diagram is used for visualisation of these relationship with energy poverty index as the head of the fish, indicators as rib branches and drivers as the sub-branches. Figure 2 shows the energy poverty general fishbone diagram with two examples on drivers and indicators.



**Figure 2: A conceptual framework for energy poverty studies with three main levels: drivers, indicators, and indices**

This diagram is used as it make it easier to map all three factors of energy poverty. Also, visualisation makes communication and tracing root causes (drivers), evaluation point (indicators) and their connections simpler.

Three examples are mapped to this figure as a guide and completion of this figure as framework calls for contribution of scholars in this field. For instance, high or rising energy price is one of the most highlighted drivers which is discussed under different names. High or rising energy price are always a first level factor in studies, but with different names including driving force (Bouzarovski and Petrova 2015, Bouzarovski et al 2021), input data (Pino-Mejías et al 2018), intervention (Day et al 2016), variable/factor (Pe´ rez-Fargallo 2017), and indicator (Kelly et al. 2020). Another example is level of electrification that sometimes is considered a first level factor and sometime a second level factor with different names like driving force (Bouzarovski and Petrova 2015), indicator (Robles-Bonilla, and Cedano 2021, Santillán 2020), intervention (Day et al 2016), and variable (Ismail and Khembo 2015).

Energy poverty models that are developed based on this framework should contain functions or tables that connects drivers to the related indicator and indicator to the energy poverty index. This framework can be used for comparison and integration in three ways. First, researchers may map their data to this framework and propose a change in the main fishbones (indicators) or sub-fishbones (drivers) relationships. Second, new factors (indicators and drivers) can be found as contributors to energy poverty. Scholars may propose adding new fishbones or sub-fishbones to increase the level of accuracy. Third, researchers may find functions that shows connection between drivers and indicators, and indicators and index more accurately. A new model for energy poverty is resulted from these changes that can be used as a start point for the next group of researchers. The new model accuracy is determined based on the improvement of precision of estimating the energy poverty index level. It is advised that whenever a group of researchers improve the model, they redraw the fishbone diagram for faster and clearer communication.

Energy poverty index can be one of the well-established indices like monitory based, minimum need based, perception based, or multidimensional energy poverty indices. The analyses show a huge difference between the results of different approaches and indexes. For instance, in a study in the UK only 2% report IAAW energy poverty in a given year, while each year more than 5% of households are energy poor according to the 10% index, and more than 12.9% according to the LIHC index. Only 1.1% involved a household reporting all three indexes simultaneously in a particular year (Deller et al., 2021). If the indices are not well connected to the root causes, drivers and indicators, it will be hard to find the source of these differences, targeting the right population, design appropriate policy, and allocate the proper budget.

***Hypothesis***

Based on the literature, four main indicators can be considered for the energy poverty. First, demographic vulnerability which is a combination of characteristics of people, drivers, who are more affected like disables, olds, single parent families, families with multiple children or dependants. Second, energy demand which depends on the house and equipment related drivers like location/climate, type of dwelling, central heating systems and appliances efficiency. Third, lack of clean energy access which is caused by no access to DG renewable energy, low levels of electrification, low reliability of electrical grid and lack of access to gas network. Fourth, economic features which includes drivers like level of income, expendable income, and energy price. Based on data and further analysis these indicators may need to be divided. For example, energy demand indicator may be divided to housing indicator and appliances indicator, but this four indicators model seems a proper initial point.

***Previous studies***

Due to lack of agreed framework and terminology, each group of researchers have developed their own terms and structures. Some structures lack one set of factors, mostly indicators, but sometime drivers. Also, some of them used drivers and indicator mixed. Here we provide a table with samples of other terms used for the same factor. Table 1 is not comprehensive as this is not a review paper, but it gives the reader a clue.

|  |  |
| --- | --- |
| Proposed standardised energy poverty factor term | Other unstandardised energy poverty factor terms in the literature |
| Driver | Driving forces, input data, intervention, variable, factor, indicator |
| Indicator | Expressions, No General Term (using specific terms directly like socio- economic effects), category, No General Term (some mid-level calculations) |
| Index | Expenditure approach, consequences |

**Table 1. Standardised and unstandardised terms for energy poverty factors.**

**Contributions and Outlook**

In this paper, lack of a conceptual model and agreed terminology problems are discussed. To address these problems a three-level model including drivers, indicators and indices with clear definition and a few examples are proposed. Using this conceptual model energy poverty area researchers can compare their models and results with previous studies and make theirs comparable and integrable with future studies. Also, involved factors that led to any differences in the results are easily traceable. Another contribution is proposing a hypothesis for indicators.

The main limitation of this framework is that it can be used only for studies that are developed based on the same energy poverty index. Still, the casualty structure of this framework leads to development of one standardised model based on each index. Having just one standardised model per index make comparing effectiveness of different indices easier.

This research will proceed in two ways. First, more data collection on factors that are used in the energy poverty literature and their categorisation. Second, the functions that connects drivers to the related indicators and the function that connects indicator to the index will be found to complete the casualty chain. With a complete causality chain, the final effects of a change in a driver on the energy poverty level is possible. This ability makes the proposed energy poverty model a proper policy lab tool for policy effects studies. Also, policy design and energy poverty alleviation budget will be on target and efficiently allocated.

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Investment decisions analysis with prospect theory: evidence from earnings conference calls

**Abstract**

As an important medium for providing information to investors, earnings conference calls play an important role in the stock market. Although many scholars have been dedicated to exploring the textual characteristics of conference call, the process and analysis of textual information is insufficient. The textual characteristics are often directly used to analyze the effect on the stock market, but the real feelings of investors towards them are ignored. Especially for the stock market, it is difficult for investors to act completely rationally, as their reactions to information are influenced by individual psychological characteristics. Therefore, I will introduce prospect theory to analyze the textual characteristics of earnings calls, digging out the information and exploring the real feelings of investors to the greatest degree. Therefore, this research will achieve accurate evaluation of calls by using prospect theory and predict stock returns combined with company financial performance based on interpretable artificial intelligence, and provide support for investor to make decisions on investment.

**Keywords**: earnings conference calls, textual characteristics, stock market, prospect theory, interpretable artificial intelligence

1. **Literature review**

Earnings conference calls have been established as an informative disclosure medium that provides incremental value-relevant information reflected in stock prices (Frankel, 1997; Bushee, 2003; Brown, 2004). Bowen (2002) pointed out that conference calls can increase the total amount of information available on companies. Companies hold earnings conference calls prior to the release of their annual or quarterly reports to show investors past-earnings performance and explain any differences with analyst forecasts. Brochet (2018) also further emphasized the role of conference calls in information transfer. The stock market is a highly information-intensive market. Because stock prices are very sensitive to information, earnings conference calls enable earnings information to be relayed to the market in advance, preventing sharp fluctuations in stock prices. In the United States (US), in particular, where financial markets are becoming increasingly sophisticated, earnings calls have a significant impact on the stock market. The stock market is full of a wide variety of information. In addition to numerical information, there is a large amount of unstructured textual information in company disclosures.

Clear and accurate understandings of textual information are significant for investors in corporate disclosures. The extraction of textual characteristics is therefore becoming increasingly important. By examining a sample of 10-Ks from 1994 to 2008, Loughran (2011) developed an alternative list of negative words, and five lists of positive, uncertainty, litigious, strong modal, and weak modal words that more accurately reflect the sentiment in financial texts. However, Loughran did not do in- depth research regarding the relationship between the tone of financial texts and stock returns. Huang (2014) took 363,952 analyst reports from the US between 1996 and 2008 as a sample, applied a plain Bayesian machine learning approach to analyse the textual information in analyst research reports and found that the textual information contained more information about a company's expected earnings than numerical information such as earnings forecasts and target prices. Textual information was receiving more and more attention and many features of textual information were

being discovered, so the effects of textual characteristics in company disclosure on the stock market cannot be ignored. Garcia (2023) applied machine learning to further study the reactions of stock prices to textual information, providing new dictionaries for positive and negative words in the financial context.

An earnings conference call consists of two parts, the first potion is a presentation by managers, which explains the company's performance for this quarter. The second portion is the Q&A session between analysts and managers, which can be divided into two part to reflect analysts’ and managers' textual information separately. Matsumoto (2011) found that the Q&A phase was relatively more informative than the presentation phase. Blau (2015) demonstrated that managers do show a more positive tone during earnings calls, especially during the presentation portion when they can prepare in advance. Although it does not have a disproportionate impact on stock prices after market adjustment, it is still worthwhile to devote sufficient attention to this situation. Besides, in Q&A portion the words of analysts and managers also attracts different degrees of attention. Especially investors will pay extra attention to the attitude of analysts. Davis (2015) found that manager-specific optimism had a significant impact on the tone used in conference calls. But in the preliminary analysis of tone and daily returns, Davis do not separate analysts from managers. Moreover, Lee (2016) further pointed out that if managers followed predetermined scripts when answering questions during earnings calls to avoid disclosing bad news, analysts would later downgrade their earnings forecasts and bid-ask spreads would increase. Besides, Huang (2017) proves the role of analysts in information discovery and interpretation in conference calls, especially when managers hide information. Andrew (2021) conducted an in-depth analysis of the textual characteristics of buy- side analysts and found that the tone of the buy-side, especially for hedge fund analysts, was positively correlated with subsequent stock returns by using 81,652 conference call transcripts from 3,446 companies from 2007 to 2016. Therefore, this study will divide the conference calls into three parts to discuss separately.

In a conference call, the tone that contains both positive and negative information is the most important text characteristic. Price (2012) examined the incremental amount of information and the corresponding market reaction to the quarterly earnings call, and demonstrated that the tone of earnings calls was a significant predictor of stock prices and trading volume and that there was a significant positive relationship between positive tones and stock returns. By using Real Estate Investment Trusts (REIT) as an example, Doran (2012) examined the relationship between the tone of conference call and the contemporaneous stock price reaction, and verified that tone had significant explanatory power for abnormal returns. Besides, Jason (2018) provided a comprehensive analysis of the tone in earnings conference calls based on previous research, and discuss the relationship between tone and the intraday stock prices. Fu (2019) further examined the relationship between the tone of earnings calls and future stock price crashes, revealing to some extent the long-term informational role of conference call tone. These studies extended the empirical disclosure literature by examining unique aspects of quarterly earnings conference calls and the subsequent market reaction, and provide much inspiration for future research.

In addition to tone, researchers have also discovered many new textual characteristics. Jancenelle (2019) contends that warm-glow rhetoric can mitigate investors' negative reactions to earnings surprises, and positively moderates the relationship between earnings surprises and financial performance. Suslava (2021) studied the impact of euphemisms on investor reactions, and found that these euphemisms used by managers have a negative relationship with future abnormal returns. Call (2023) proposed humor as a very interesting textual characteristic and examined its role in conference calls. Although these textual characteristics have been proven to have effects on stock returns, there are still doubts about whether the information they contain is sufficient to support research in predicting stock prices. Only textual characteristics which contain the most textual information can accurately capture specific fluctuations in stock prices, rather than just analyzing the effects.

As the most deeply and directly perceived textual characteristic for investors, the tone which reflects the positive and negative attitudes of conference calls has always attracted the attention of scholars. By using computer aided content analysis, Price (2012) proved that conference call linguistic tone is a significant predictor of abnormal returns and trading volume. From the perspective of tone, Bochkay (2020) verified that conference calls extreme words can increases trading volume and has an impact on stock prices, especially for companies with weaker information environments. Fu (2021) pointed out the tone of earnings conference calls can predict future stock price crash risk, and revealed the long-term informational role of conference calls tone. The predictive ability of conference calls tone for stock returns has been extensively proven, however, previous literature only directly used tone to estimate stock prices, which makes it difficult to make full use of all the textual information. Therefore, I will use prospect theory to discuss investors' more authentic feelings towards earnings calls tone from the perspective of their individual psychological characteristics, and help investor to make decisions of investment.

Decision science has been a very important research topic in the field of business and management. Tversky (1979) put forward the prospect theory, which explained the individual decision making behavior from the perspective of psychology. By introducing the psychological characteristics of decision makers into the decision making process, prospect theory has received the attention of many scholars as soon as it appeared. Prior to this, expected utility theory dominated in decision science (Neumann,1944). Prospect theory refines expected utility theory from a psychological perspective, and it is more relevant to realistic decision making behavior by incorporating individual value perception factors into the model. After that, a lot of research on prospect theory has appeared, and it has grown considerably. At the beginning, it was revised from a statistical perspective. Tversky (1992) proposed the cumulative prospect theory to avoid the contradiction with the predominance of first- order stochastic in original prospect theory. Nilsson (2011) proposed a hierarchical bayesian approach to estimate the parameters of the cumulative prospect theory, and

Glöckner (2012) focused on the adjustment of parameters. Cumulative prospect theory was then widely used, up to now it is still a very important analytical method in decision-making problems.

Prospect theory is based on psychology and fully considers the individual's value perception factors. In practice, it is not possible for decision makers to have access to all decision relevant information as described by the expected utility theory, and therefore, decision making behavior cannot be viewed as fully rational. Especially in the stock market information is very complex, and investors find it difficult to grasp and utilize all the information. It is also difficult to achieve complete rationality in the processing of earnings calls information. Steele (2010) demonstrated what the minimum requirements are for determining rational choice. Campitelli (2010) developed the concept of limited rationality and emphasized the importance of the decision makers' expertise in decision making process. And Juechems (2021) further revealed the reasons for the "irrational" behavior of decision makers. The psychological characteristics of decision makers have a very important influence on the interpretation and prediction for decision making behavior. Therefore, the introduction of prospect theory can significantly improve the accuracy of research in analyzing stock prices that reflect investor behavior. Kirshner (2019) modeled optimism and overconfidence through probability weighting functions. Ciccarone (2020) discussed the relationship between market sentiment and fluctuations in economic activity through prospect theory.

The value function and weight function are very important components of prospect theory, which reflect the individuals’ psychological characteristics in the form of mathematical expressions. In this study, they will be used to analyze the positive and negative attitudes of participants in conference calls. From a statistical point of view, the form of the value function has been tested many times, The power, logarithmic, negative exponential and quadratic forms of the value function had all been discussed. Among them, the form of power function has been widely used in practical problems

(De Giorgi, Hens and Rieger, 2010; Kirby, 2011; Gazioglu and Caliskan, 2011) In addition to the statistical perspective, the value function had also been improved from the view of emotion. Individuals' cognitive process can be divided into rational and emotional components. (Bracha and Brown, 2012; Mukherjee, 2011; Garcés and Finkel, 2019) Specially, this phenomenon is reflected mathematically in the dual systems model which divide value into affective and deliberative systems to calculate. (Mukherjee, 2010; Sahlin, Wallin and Persson, 2010) The dual systems model provides a new view for the development of decision theory by combining behavioral economics and neuroeconomics. (Grayot, 2020)

The weight function is highly subjective because it is based on the decision makers' real feelings about objective probabilities. (Krawczyk, 2015) Therefore, they perform differently in different field. (Bracha, 2020) The development of weight functions mainly focuses on two aspects: parameter-free approach and parameter approach.

Parameter-free approaches are aim to describe the statistical characteristics of weight functions through social experiments. Kilka and Webe (2001) proposed a two-stage approach and first use parameter-free approach to explored curve shapes of weight functions. After that, more parameter-free approaches were discussed and applied. (van de Kuilen and Wakker, 2011; Chai and Ngai, 2020) By learning more and more properties of weight functions, based on parameter approach, many specific functional forms were proposed which can be applied to specific scenarios to solve practical problems. The first parameter approach was proposed by Karmarkar (1978), although this model violated many properties of weight functions from the current perspective, it defined the most widely used function form. After that, Tversky (1992) and Prelec (1998) proposed the two most important parameter approaches. On this basis, Wu and Gonzalez discussed the parameters which affect Curvature in the model. And Gonzalez and Wu (1999) further extended them to two-parameter models and analyzed the significance of each parameter. Gradually, more new techniques such as machine learning, and artificial intelligence were used in the analysis for decision science. Cavagnaro (2013) use adaptive design optimization to test several models of

weight function. Cabrera-Paniagua (2015) proposed an autonomous emotion decision making system to support the decision making process in the stock markets. And Mello (2021) also described a methodology for predicting the outcome of individuals' decision making process based on psychological and emotional perspective by using artificial intelligence techniques. In this study, I will use machine learning to discuss all parameter settings for prospect theory in earnings conference calls, in order to evaluate calls more accurately to support the decision making of investor.

1. **Introduction**

As an important medium for providing information to investors, earnings conference calls play an important role in the stock market. Although many scholars have been dedicated to exploring the textual characteristics of conference call, the processing and analysis of textual information is insufficient. The textual characteristics are often directly used to analyze the impact on the stock market, but the real feelings of investors towards them are ignored. Especially for the stock market, it is difficult for investors to act completely rationally, as their reactions to information are influenced by individual psychological characteristics. Therefore, I will introduce prospect theory and analyze the textual characteristics of earnings calls through value functions and weight functions, digging out the information to the greatest degree, and exploring the real feelings of investors. Therefore, this research will achieve accurate evaluation of calls using prospect theory and predict stock returns combined with company financial performance, and provide support for investor to make decisions on investment.

The textual characteristics are often directly used to analyze the impact on the stock market, but the individual preference of investors towards them are ignored. Especially for the stock market, it is difficult for investors to act completely rationally, as their reactions to information are influenced by individual psychological characteristics, and they do not have access to all information and lack adequate analytical tools. Such as, prospect theory suggests that investors tend to avoid losses

when faced with uncertainty. Therefore, for the diversity of tone in calls, and the uncertainty of future stock price, prospect theory can help predict how investors might react in different scenarios. This approach not only helps investors understand true stance of managers and analysts but also provides valuable guidance for predicting market reactions and investor behavior, thereby supporting better investment decision-making.

In Prospect Theory, the value function and weight function are two core concepts used to explain why people deviate from rational decision-making when facing uncertainty and risk, which capturing the psychological biases and irrational behavior often observed in real-world decisions. The value function in prospect theory describes how individuals evaluate the subjective value of outcomes, particularly in the context of gains and losses. And the value function captures the asymmetry in how people experience gains and losses. Importantly, this evaluation is based on relative changes from a reference point rather than absolute values. Thus, the value function can help investors better distinguish positive and negative emotions, and understand how managers and analysts transfer information in conference calls. In this paper, the reference point is simply assumed to be a neutral emotion, so it is straightforward to use the value function for the emotional intensity of positive and negative words.

The weight function in prospect theory describes how people subjectively perceive and handle probabilities, rather than judging them according to objective probabilities. Traditional decision theory assumes that individuals evaluate probabilities in a linear, rational way. However, prospect theory suggests that people will systematically distort probabilities non-linearly, meaning they tend to misjudge low and high probabilities. The weight function captures how people distort probabilities in decision-making under uncertainty, while the value function explains how they perceive gains and losses asymmetrically. Together, these two functions provide a powerful framework for understanding real-world, non-rational decision-making. In this study, they will be used to analyze the positive and negative attitudes of

participants in conference calls, digging out the information to the greatest degree, and providing insights from multiple angles. Therefore, this research will achieve accurate evaluation of calls using prospect theory and predict stock returns combined with company financial performance, and provide support for investor to make decisions on investment.

As the most deeply and directly perceived textual characteristics of conference calls for investors, the tone of participants contains the most textual information. In this study, based on the financial dictionaries constructed by Garcia (2023) and Loughran (2011), I will use four positive words dictionaries and four negative words dictionaries to capture all the attitudes of managers and analysts during conference calls. In addition, considering that investors pay different attentions to presentation portion and Q&A portion, and they focus on analysts’ words, I will divide the calls into two parts to discuss separately, and finally assign different weights to analyze. This paper is verifying whether prospect theory can be introduced to analyze the sentimental words of earnings conference calls, predict stock returns and provide decision support for investors. In this research, I will fully utilize the assumptions and models of prospect theory, and explain the research results from the perspective of irrational investment behavior.

1. **Research methodologies**
   1. **Data**

I can obtain a full sample of U.S. public company quarterly earnings call transcripts from Thomson Reutern from 2003 to 2023 (post Regulation FD era). Given the specificity of finance-related companies and to reflect the general nature of the study, I will remove the sample of finance-related companies using industry codes. I use python to extract corresponding textual characteristics to get files related variables reflecting conference calls information, speakers related variables reflecting participants information and transcripts related variables by different turns from earnings call transcripts. Then I merge these variables with COMPUSTAT for firm

fundamentals and CRSP for capital market outcomes.

According to files related variables and speakers related variables, I can divide all the earnings conference calls into two parts. The first part is the presentation portion, where the managers will introduce the firm's performance for this quarter and explain the reasons for the difference between the actual stock price and the analyst's forecast. The second part is question and answer portion, which reflect analysts’ questions about the presentation portion and managers’ answer. These two parts receive difference degrees of attention from investors and have varying degrees of impact on stock returns. Therefore, I will discuss them separately by assigning them different weights.

For every part, I can extract the transcripts related variables. By using textual analysis I use the Garcia (2023) and Loughran (2011) financial text dictionary to count eight types words which are the number of LM&ML positive words, LM&ML negative words, LM positive words, LM negative words, ML positive words, ML negative words, ML positive binary words, and ML negative binary words. Then I can get the total number of all sentimental words, and calculate the percentage of each type of words. It is noted that in calculations of the percentages, the denominator is equal to the total number of sentimental words rather than the total number of all words. Because I only focus on words which contain information, and exclusion of invalid information can make the analysis results more accurate. So, variables about conference calls textual characteristics for two parts can be obtained which are defined in Appendix B.

Besides, some information for firm fundamentals and capital market can be obtained from COMPUSTAT and CRSP. Given that company fundamentals data are generally published one year late, all company variables use the previous year's data in order to prevent the introduction of future information. And cumulative n-day abnormal returns start from the current earnings conference call date, where abnormal returns

are calculated as the raw return minus the buy-and-hold return on the S&P 500 value- weighted market index (Huang, 2014). As a result, for firm 𝑖 in quarter 𝑡, variables about firm fundamentals can be obtained,

𝐿𝐸𝑉𝐸𝑅𝐴𝐺𝐸𝑖,𝑡 =

(𝐷𝐿𝑇𝑇𝑖,𝑡 + 𝐷𝐿𝐶𝑖,𝑡)

𝐴𝑇𝑖,𝑡

𝑅𝑂𝐴𝑖,𝑡 =

𝑂𝐼𝐵𝐷𝑃𝑖,𝑡

𝐴𝑇𝑖,𝑡

𝐸𝑃𝑆𝑃𝐼𝑖,𝑡

𝐸𝑃𝑖,𝑡 = 𝑃𝑅𝐶𝐶\_𝐶

𝑖,𝑡

𝑆𝑃𝐸𝑖,𝑡 =

𝑆𝑃𝐼𝑖,𝑡

𝐴𝑇𝑖,𝑡

𝐵𝐸𝑖,𝑡

𝐵𝑀𝑖,𝑡 = 𝑃𝑅𝐶𝐶\_𝐶 × 𝐶𝑆𝐻𝑂

𝑖,𝑡

𝑖,𝑡

𝑁𝐼𝑖,𝑡

𝑁𝐼𝐴𝑇𝑖,𝑡 =

𝐴𝑇

𝑖,𝑡

𝑆𝐼𝑍𝐸𝑖,𝑡 = log(𝐴𝑇𝑖,𝑡)

For firm 𝑖 in quarter 𝑡, cumulative n-day abnormal returns can be obtained,

𝐵𝐻𝑅𝐸𝑇\_0\_1𝑖,𝑡 = 𝑎𝑏𝑛𝑜𝑟𝑚𝑎𝑙 𝑟𝑒𝑡𝑢𝑟𝑛\_0\_1𝑖,𝑡

𝑎𝑏𝑛𝑜𝑟𝑚𝑎𝑙 𝑟𝑒𝑡𝑢𝑟𝑛\_0\_𝑛𝑖,𝑡 = 𝑟𝑒𝑡𝑢𝑟𝑛\_0\_𝑛𝑖,𝑡 − 𝑣𝑤𝑟𝑒𝑡𝑒𝑑\_0\_𝑛𝑖,𝑡

𝐵𝐻𝑅𝐸𝑇\_0\_𝑛𝑖,𝑡 = (1 + 𝐵𝐻𝑅𝐸𝑇\_0\_(𝑛 − 1)𝑖,𝑡) × (1 + 𝑎𝑏𝑛𝑜𝑟𝑚𝑎𝑙 𝑟𝑒𝑡𝑢𝑟𝑛\_0\_𝑛𝑖,𝑡) − 1

Above variables are defined in Appendix C and Appendix D.

* 1. **Methodology**

To enable a clearer view to evaluate the earnings conference calls, I will divide it into two parts which are mentioned in last section, and apply prospect theory to analyze separately. After calculating the prospect value of each part, the total prospect value of the conference calls can be obtained based on different weights. And summary statistics for all textual characteristics are presented. In this way, differences between two groups can be observed visually. To prevent the effects of extremes and outlier, I do winsorization for each year for both the textual characteristic data and the firm data. The entire data is divided into 100 parts according to value, and if the data is less than p1 for the year, it is replaced with 𝑝1, and if the data is greater than p99, it is replaced with 𝑝99. It is important to note that the reason for choosing to do a winsorization for

each year is to prevent the introduction of future information.

𝑊𝑝𝑃𝑉𝑝,𝑖,𝑡 + 𝑊𝑞𝑎𝑃𝑉𝑞𝑎,𝑖,𝑡 = 𝑃𝑉𝑖,𝑡 (1) For firm 𝑖 in quarter 𝑡,. 𝑊𝑝, 𝑊𝑞𝑎 represent the weights of the presentation words, the Q&A words. 𝑃𝑉𝑝,𝑖,𝑡 , 𝑃𝑉𝑞𝑎,𝑖,𝑡 represent the prospect value each part, and 𝑃𝑉𝑖,𝑡 represent the total prospect value. Where, 𝑊𝑝 + 𝑊𝑞𝑎 = 1, and 𝑊𝑝 < 𝑊𝑞𝑎.

Next, I will discuss the application of value functions. In this section, I will pay attention to the analysis of intensities for eight types positive and negative words. According to the research of the stock price reaction to the earnings calls for different words (2023), I set the intensity of LM&ML positive words is 5.4 and LM&ML negative words is -5.4, the intensity of LM positive words is 2.1 and LM negative words is -2.1, the intensity of ML positive words is 4.6 and ML negative words is -4.6, the intensity of ML positive binary words is 4.5 and ML negative binary words is -4.5, which are represented 𝑖𝑛𝑡𝑒𝑛𝑠\_𝑝𝑜𝑠\_𝐿&𝑀𝑖,𝑗, 𝑖𝑛𝑡𝑒𝑛𝑠\_𝑛𝑒𝑔\_𝐿&𝑀𝑖,𝑗 , 𝑖𝑛𝑡𝑒𝑛𝑠\_𝑝𝑜𝑠\_𝐿𝑖,𝑗 ,

𝑖𝑛𝑡𝑒𝑛𝑠\_𝑛𝑒𝑔\_𝐿𝑖,𝑗 , 𝑖𝑛𝑡𝑒𝑛𝑠\_𝑝𝑜𝑠\_𝑀𝑖,𝑗 , 𝑖𝑛𝑡𝑒𝑛𝑠\_𝑛𝑒𝑔\_𝑀𝑖,𝑗 , 𝑖𝑛𝑡𝑒𝑛𝑠\_𝑝𝑜𝑠\_𝑀𝐵𝑖,𝑗 , and

𝑖𝑛𝑡𝑒𝑛𝑠\_𝑛𝑒𝑔\_𝑀𝐵𝑖,𝑗.

𝑣(𝑖𝑛𝑡𝑒𝑛𝑠𝑖,𝑗) = 𝑖𝑛𝑡𝑒𝑛𝑠𝑖,𝑗𝛼,𝑖𝑛𝑡𝑒𝑛𝑠𝑖,𝑗 > 0 (2)

𝑣(𝑖𝑛𝑡𝑒𝑛𝑠𝑖,𝑗) = −λ(−𝑖𝑛𝑡𝑒𝑛𝑠𝑖,𝑗)𝛽, 𝑖𝑛𝑡𝑒𝑛𝑠𝑖,𝑗 < 0 (3)

For firm 𝑖 in quarter 𝑡, the value of every type of words can be calculated in each part by using value function. 𝑖𝑛𝑡𝑒𝑛𝑠𝑖,𝑗 represents the intensity of words. Where, 0< 𝛼 < 1, 0 < 𝛽 < 1, 𝜆 > 0.

Then, weight functions are applied to analyze the percentages of every type of words in each part. A prospect 𝑓 is then represented as a sequence of pairs (𝑖𝑛𝑡𝑒𝑛𝑠𝑛,𝑖,𝑡, 𝑝𝑛,𝑖,𝑡), where, the percentage of this type words is 𝑝𝑛,𝑖,𝑡. For firm 𝑖 in quarter 𝑡 and for each part of conference calls, decision weights are defined by:

𝑤+(𝑝

) = 𝑝𝑛,𝑖,𝑡𝛾

(4)

𝑛,𝑖,𝑡

(𝑝

𝑛,𝑖,𝑡

𝛾+(1−𝑝

𝛾 1⁄𝛾

𝑛,𝑖,𝑡

𝑤−(𝑝

) = 𝑝𝑛,𝑖,𝑡𝛿

(5)

𝑛,𝑖,𝑡

) )

(𝑝

𝑛,𝑖,𝑡

𝛿+(1−𝑝

1

𝑛,𝑖,𝑡) )

𝛿 ⁄𝛿

Where 𝑤+(0) = 𝑤−(0) = 0, 𝑤+(1) = 𝑤−(1) = 1, 0 < 𝛾 < 1, 0 < 𝛿 <1.

According to the results of value function and weight function, for firm 𝑖 in quarter 𝑡

and for the first part which represent presentation portion of calls.

∑𝑖𝑛𝑡𝑒𝑛𝑠 >0 𝑣(𝑖𝑛𝑡𝑒𝑛𝑠𝑛,𝑖,𝑗)𝑤+(𝑝𝑛,𝑖,𝑡) + ∑𝑖𝑛𝑡𝑒𝑛𝑠 <0 𝑣(𝑖𝑛𝑡𝑒𝑛𝑠𝑛,𝑖,𝑗)𝑤−(𝑝𝑛,𝑖,𝑡) =

𝑛,𝑖,𝑗 𝑛,𝑖,𝑗

𝑃𝑉𝑝,𝑖,𝑡 (6)

The prospect values of the second part of calls 𝑃𝑉𝑞𝑎,𝑖,𝑡 are defined similarly. Then the total prospect value 𝑃𝑉𝑖,𝑡 can be obtained according to equation (1).

After evaluating earnings conference calls by using prospect theory, the total prospect value can be combined with firm financial performance to predict stock returns.

For firm 𝑖 in quarter 𝑡,

𝐵𝐻𝑅𝐸𝑇\_0\_𝑛𝑖,𝑡 = 𝛽0 + 𝛽1𝑃𝑉𝑖,𝑡 + 𝜷2𝑭𝒊𝒓𝒎 𝑪𝒉𝒂𝒓𝒔𝒊,𝒕 (7) Where, 𝐵𝐻𝑅𝐸𝑇\_0\_𝑛𝑖,𝑡 is the final predicted target. Considering that changes in a company's stock price may be due to some external causes, I use abnormal stock returns to analyze more clearly how stock prices are affected by earnings calls, and the cumulative abnormal returns can reflect the long-term impact of earnings calls.

𝑭𝒊𝒓𝒎 𝑪𝒉𝒂𝒓𝒔𝒊,𝒕 includes 𝐿𝐸𝑉𝐸𝑅𝐴𝐺𝐸, 𝑅𝑂𝐴, 𝐸𝑃, 𝑆𝑃𝐸, 𝑁𝐼𝐴𝑇, 𝐵𝑀 which can reflect the firm characteristics that change over time.

Based on equations (1) to (7), machine learning is applied to estimate all the parameters. Specifically, the data from 2003 to 2018 is used as training set to train the model. The data from 2019 to 2020 is used as validation set to tun the model's hyperparameters, monitor model performance and prevent overfitting during training. The data from 2021 to 2023 is used as test set to evaluate the final performance of the model and ensure the model's generalization ability. These three data sets can effectively prevent data leakage and ensure that the model generalizes well on future data. By appropriately designing the model architecture and loss function, and using suitable optimization algorithms, machine learning methods can be effectively utilized

to estimate and optimize parameters within parametric functions.

1. **Results**

I will use data from a total of 68 Apple earnings calls from 2003-2019 to verify the validity and feasibility of the methodology of this thesis, which is from Thomson Reutern. All variables are presented in Appendix A and defined in Appendix B, Appendix C and Appendix D.

For Apple's data, the data from 2003 to 2017 is used as training set to train the model, and the data from 2018 to 2019 is used as test set to evaluate the final performance of the model and ensure the model's generalization ability. Specifically, I use cumulative abnormal returns on the first day after the calls 𝐵𝐻𝑅𝐸𝑇\_0\_1 as the predicted target. Based on equations (1) to (7), all parameters can be obtained using the training set.

Table 1. Parameters for predicting 𝐵𝐻𝑅𝐸𝑇\_0\_1 in 2003-2017

|  |  |  |
| --- | --- | --- |
|  | Parameter | Value |
| presentation portion | 𝛾 | 0.26 |
| 𝛿 | 0.27 |
| 𝛼 | 0.99 |
| 𝛽 | 0.97 |
| 𝜆 | 1.35 |
| 𝑊𝑝 | 0.48 |
| Q&A portion | 𝛾 | 0.17 |
| 𝛿 | 0.40 |
| 𝛼 | 1.81 ∗ 10−17 |
| 𝛽 | 0.99 |
| 𝜆 | 0.28 |
| 𝑊𝑞𝑎 | 0.52 |
| Coefficient | 𝛽0 | 1.73 |
| 𝛽𝑃𝑉 | 2.10 |
| 𝛽𝐿𝐸𝑉𝐸𝑅𝐴𝐺𝐸 | -0.10, |

|  |  |  |
| --- | --- | --- |
|  | 𝛽𝑅𝑂𝐴 | -0.62 |
| 𝛽𝐸𝑃 | -0.62 |
| 𝛽𝑆𝑃𝐸 | 9.47 |
| 𝛽𝐵𝑀 | -0.003 |
| 𝛽𝑁𝐼𝐴𝑇 | -0.45 |

Similarly, I can also use cumulative abnormal returns one week and one month after the calls as the predicted targets. All parameters can be obtained.

Table 2. Parameters for predicting 𝐵𝐻𝑅𝐸𝑇\_0\_7 in 2003-2017

|  |  |  |
| --- | --- | --- |
|  | Parameter | Value |
| presentation portion | 𝛾 | 0.29 |
| 𝛿 | 0.28 |
| 𝛼 | 0.98 |
| 𝛽 | 0.95 |
| 𝜆 | 1.56 |
| 𝑊𝑝 | 0.48 |
| Q&A portion | 𝛾 | 0.21 |
| 𝛿 | 0.28 |
| 𝛼 | 0.07 |
| 𝛽 | 0.80 |
| 𝜆 | 0.73 |
| 𝑊𝑞𝑎 | 0.52 |
| Coefficient | 𝛽0 | 1.86 |
| 𝛽𝑃𝑉 | 2.04 |
| 𝛽𝐿𝐸𝑉𝐸𝑅𝐴𝐺𝐸 | -0.12 |
| 𝛽𝑅𝑂𝐴 | 0.93 |
| 𝛽𝐸𝑃 | 0.93 |
| 𝛽𝑆𝑃𝐸 | 6.55 |
| 𝛽𝐵𝑀 | -0.03 |
| 𝛽𝑁𝐼𝐴𝑇 | -0.55 |

Table 3. Parameters for predicting 𝐵𝐻𝑅𝐸𝑇\_0\_30 in 2003-2017

|  |  |  |
| --- | --- | --- |
|  | Parameter | Value |
| presentation portion | 𝛾 | 0.28 |
| 𝛿 | 0.30 |
| 𝛼 | 1.00 |
| 𝛽 | 1.00 |
| 𝜆 | 1.34 |
| 𝑊𝑝 | 0.49 |
| Q&A portion | 𝛾 | 0.16 |
| 𝛿 | 0.23 |
| 𝛼 | 1.39 ∗ 10−16 |
| 𝛽 | 0.99 |
| 𝜆 | 0.49 |
| 𝑊𝑞𝑎 | 0.51 |
| Coefficient | 𝛽0 | 2.56 |
| 𝛽𝑃𝑉 | 2.88 |
| 𝛽𝐿𝐸𝑉𝐸𝑅𝐴𝐺𝐸 | -0.52 |
| 𝛽𝑅𝑂𝐴 | 2.42 |
| 𝛽𝐸𝑃 | 2.42 |
| 𝛽𝑆𝑃𝐸 | 2.00 |
| 𝛽𝐵𝑀 | -0.12 |
| 𝛽𝑁𝐼𝐴𝑇 | -1.42 |

Next, these three models containing the obtained parameters are used to predict the returns for different time windows in 2018-2019, and the predicted results are compared with the actual values of stock returns.

Table 4. Comparison of prediction of 𝐵𝐻𝑅𝐸𝑇\_0\_1 in 2018-2019

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Month | Actual value | Predicted value | Error |
| 2018 | 1 | -0.02 | -0.16 | -0.14 |
| 2018 | 4 | 0.07 | 0.27 | 0.20 |
| 2018 | 7 | 0.06 | -0.16 | -0.20 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 2018 | 10 | -0.06 | -0.15 | -0.09 |
| 2019 | 1 | 0.04 | -0.20 | -0.24 |
| 2019 | 4 | 0.04 | -0.20 | -0.24 |
| 2019 | 7 | 0.03 | -0.19 | -0.22 |
| 2019 | 10 | 0.02 | -0.19 | -0.21 |

Table 5. Comparison of prediction of 𝐵𝐻𝑅𝐸𝑇\_0\_7 in 2018-2019

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Month | Actual value | Predicted value | Error |
| 2018 | 1 | 0.04 | 0.23 | 0.19 |
| 2018 | 4 | 0.12 | 0.60 | 0.48 |
| 2018 | 7 | 0.08 | 0.23 | 0.15 |
| 2018 | 10 | -0.11 | 0.24 | 0.35 |
| 2019 | 1 | 0.07 | 0.27 | 0.20 |
| 2019 | 4 | 0.003 | 0.26 | 0.26 |
| 2019 | 7 | -0.003 | 0.29 | 0.30 |
| 2019 | 10 | 0.05 | 0.29 | 0.24 |

Table 6. Comparison of prediction of 𝐵𝐻𝑅𝐸𝑇\_0\_30 in 2018-2019

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Month | Actual value | Predicted value | Error |
| 2018 | 1 | 0.09 | 0.49 | 0.40 |
| 2018 | 4 | 0.10 | 1.14 | 1.04 |
| 2018 | 7 | 0.13 | 0.48 | 0.35 |
| 2018 | 10 | -0.20 | 0.50 | 0.70 |
| 2019 | 1 | 0.10 | 0.58 | 0.48 |
| 2019 | 4 | -0.03 | 0.57 | 0.60 |
| 2019 | 7 | 0.08 | 0.61 | 0.53 |
| 2019 | 10 | 0.07 | 0.60 | 0.53 |

In order to get a clearer view for the predictivity of the prospect theory model, I will present these comparison results in figures, and compare them with the prediction results of the linear model and the prospect theory model which only considers the value function, which are the analysis methods in the previous literature.

Figure 1. Comparison of 𝐵𝐻𝑅𝐸𝑇\_0\_1 prediction based on prospect theory

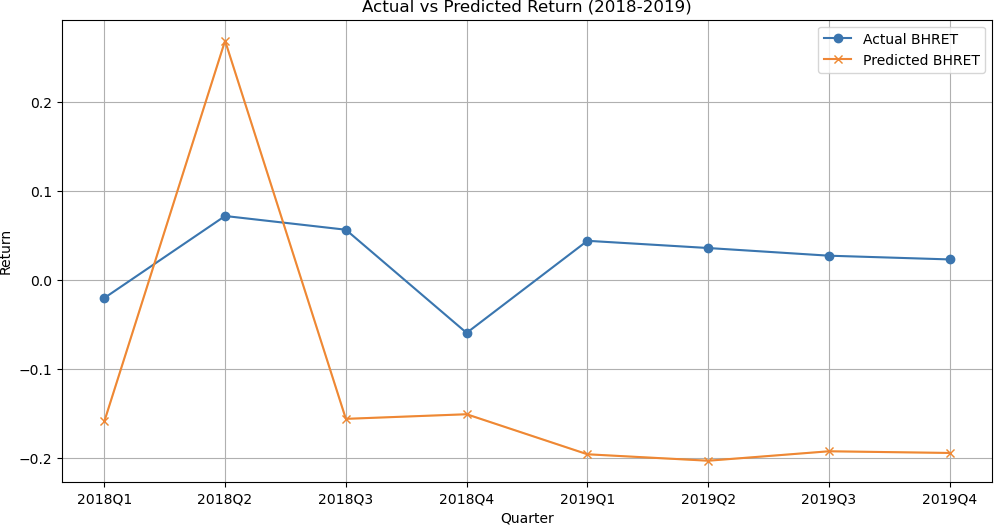
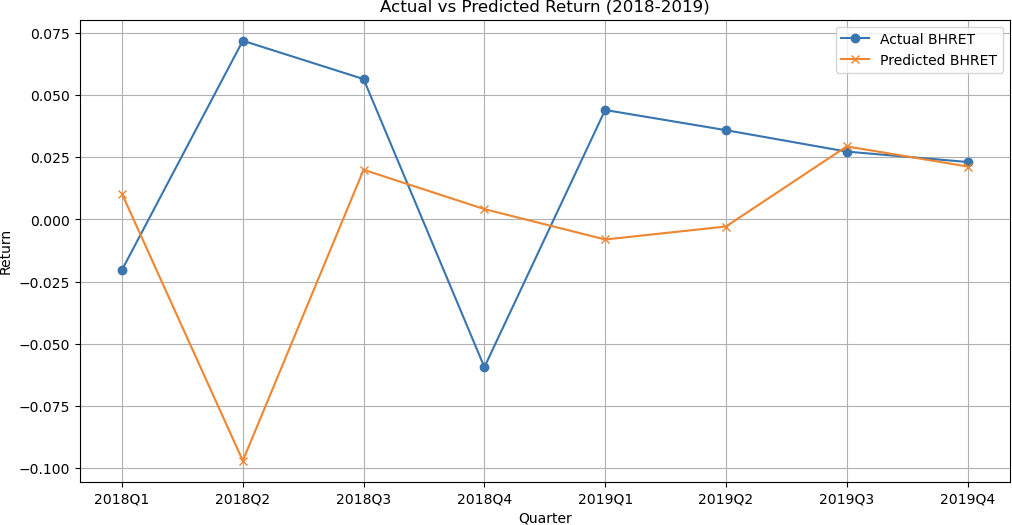
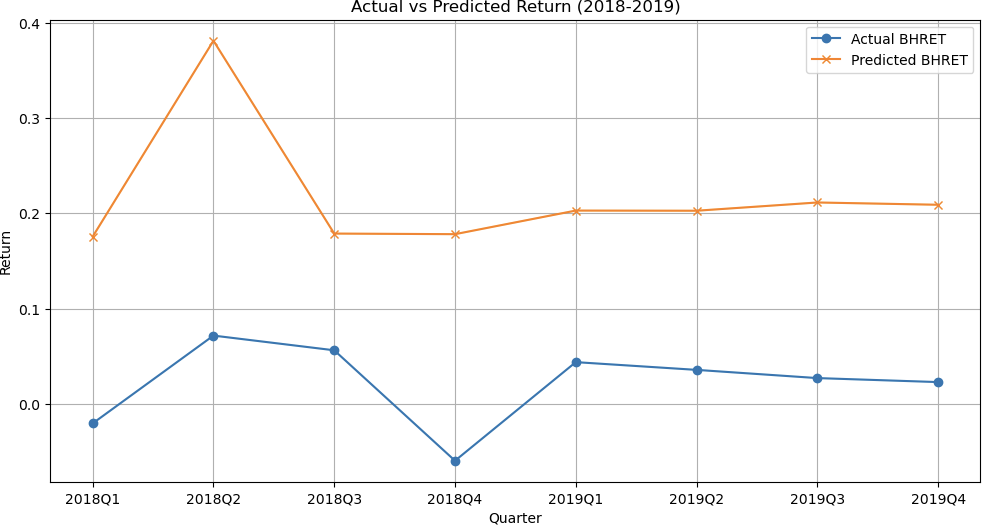


Figure 2. Comparison of 𝐵𝐻𝑅𝐸𝑇\_0\_1 prediction based on linear model



Figure 3. Comparison of 𝐵𝐻𝑅𝐸𝑇\_0\_1 prediction based on incomplete prospect theory

According to figure 1-3, We can find that prospect theory can better predict the trend of stock returns. But obviously its error is greater than the prediction result of the linear model. Considering that this may be because the linear model needs more parameters, the prospect theory may perform better when the sample data is large enough. Besides, the incomplete prospect theory exhibits a greater error.

Figure 4. Comparison of 𝐵𝐻𝑅𝐸𝑇\_0\_7 prediction based on prospect theory

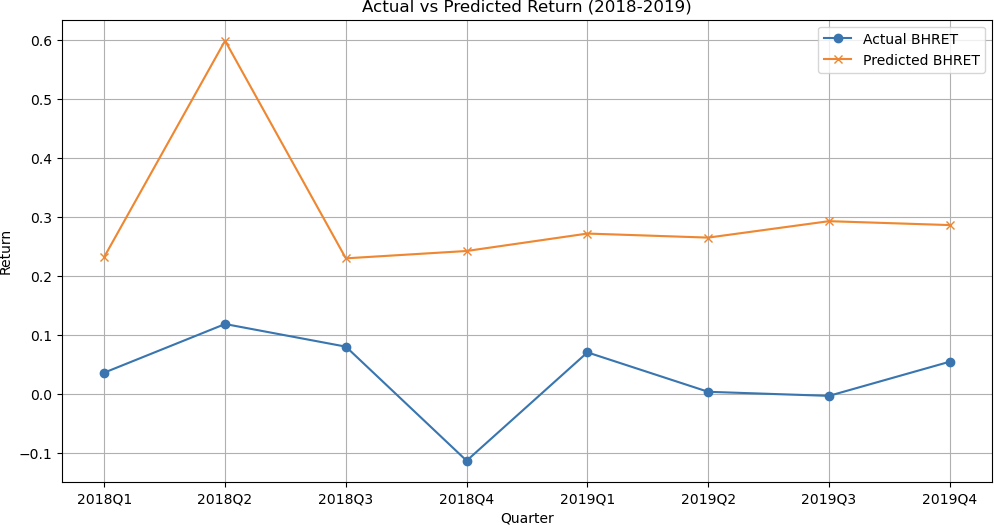


Figure 5. Comparison of 𝐵𝐻𝑅𝐸𝑇\_0\_7 prediction based on linear model

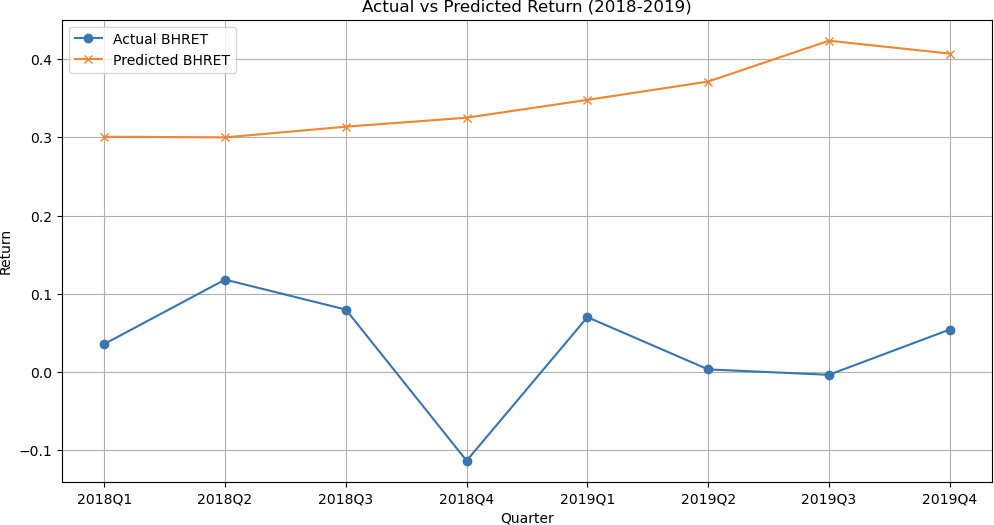
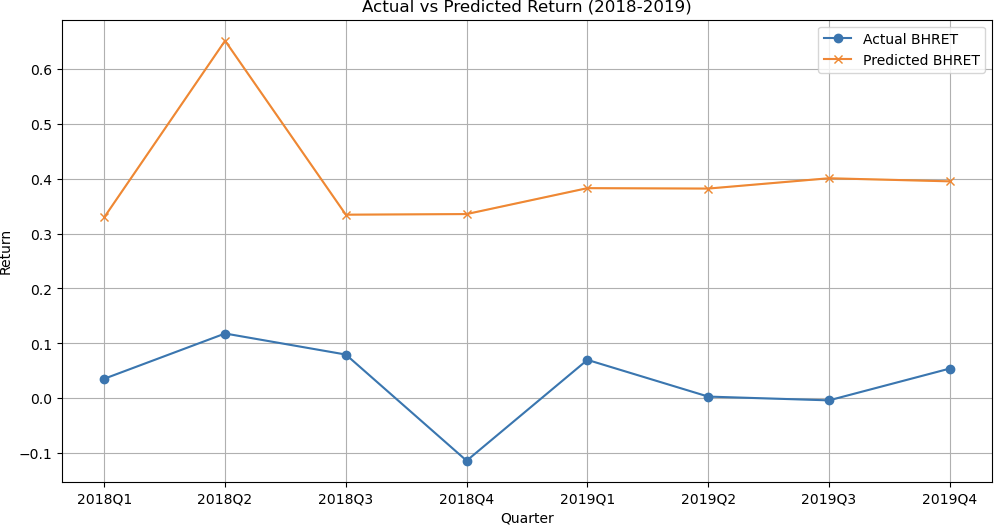


Figure 6. Comparison of 𝐵𝐻𝑅𝐸𝑇\_0\_7 prediction based on incomplete prospect theory



According to figure 4-6, We can find that the prediction error of the linear model increases significantly, which indicates that the linear model can only predict short- term stock returns by relying on more parameters, and its predictivity is not enough to adapt to long-term situation. In contrast, the prospect theory shows a smaller increase in error and can still effectively track the trend of stock returns, which is probably because it takes into account the real decision-making behaviour of investors. And the incomplete prospect theory still exhibits a greater error.

Figure 7. Comparison of 𝐵𝐻𝑅𝐸𝑇\_0\_30 prediction based on prospect theory

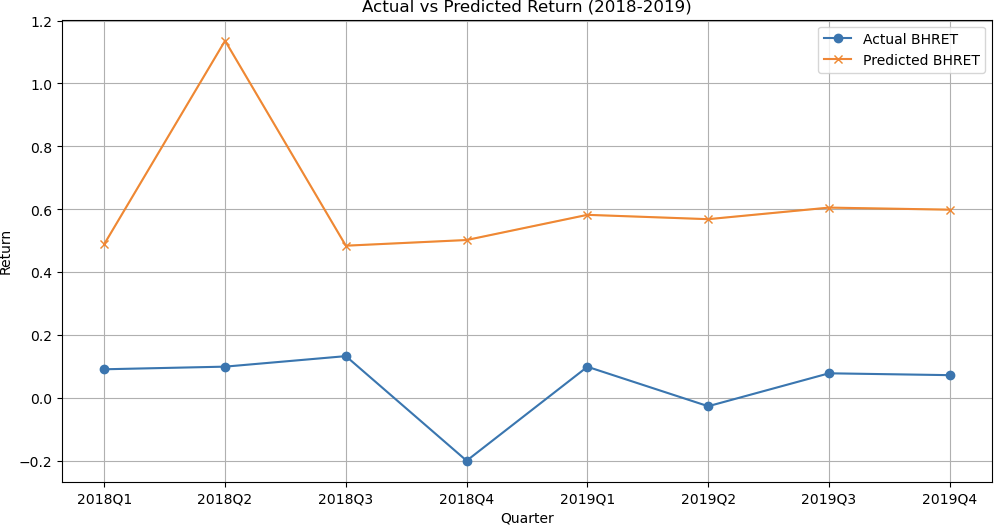
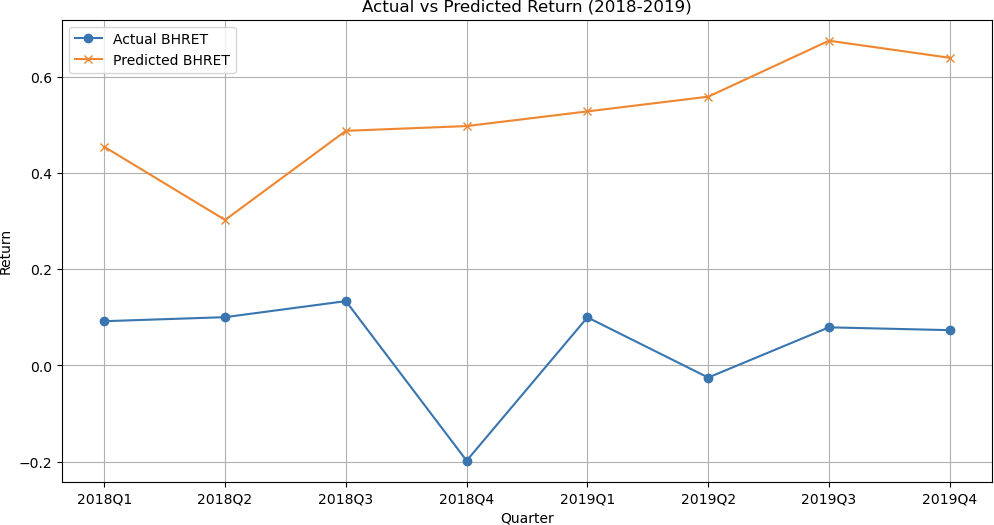
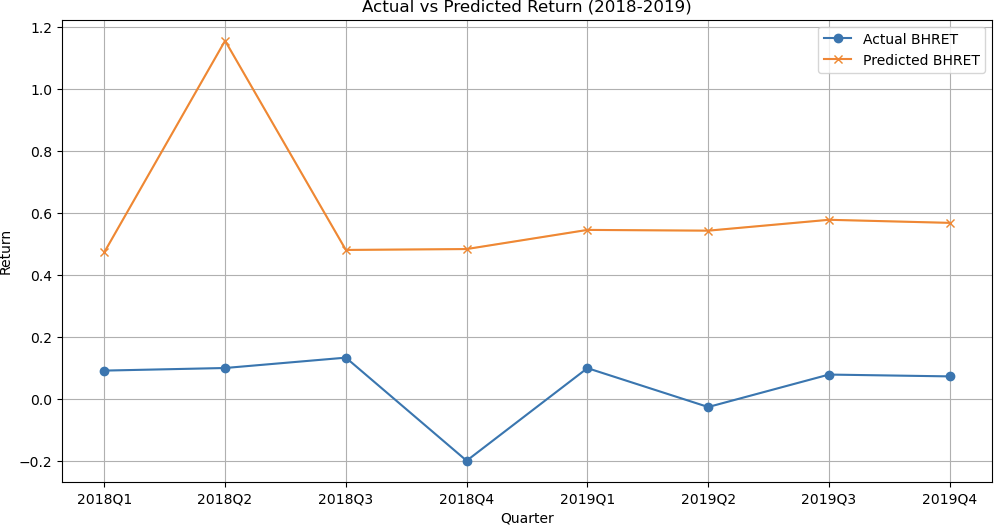


Figure 8. Comparison of 𝐵𝐻𝑅𝐸𝑇\_0\_30 prediction based on linear model



Figure 9. Comparison of 𝐵𝐻𝑅𝐸𝑇\_0\_30 prediction based on incomplete prospect theory

According to figure 7-9, We can find that all three models have lost predictability for the cumulative abnormal return one month after conference calls, because their errors are too large. It can be verified in the future if the predictability of this time window can be improved when the sample data is large enough.

1. **Research conclusion**

In recent years, the rapid development of artificial intelligence technology has brought

new research perspectives to the analysis of textual characteristics in earnings conference calls. In previous studies, the predictive model of conference calls sentimental words for stock returns did not fully digging out all textual information. In this study, I used the complete prospect theory to analyze the textual characteristics of conference calls and verify whether the prospect theory is applicable in this situation. Considering that I only use limited machine learning to estimate parameters in this research, although prospect theory can provide enough explanations for the analysis process of conference calls and the prediction results of stock returns, fixed model assumptions inevitably result in some loss of prediction accuracy. Therefore, balancing interpretability and accuracy of predictions by constructing appropriate models is an important research direction in the future.

Overall, there are three research objectives, Firstly, based on the relationship between earnings conference calls and stock returns, the prediction models for stock returns are estimated. Secondly, the predictive ability of the model is tested, and the investment decisions of investors are supported. Thirdly, the interpretability of the model is validated, and the real feelings of investors towards textual characteristics are verified.

**Appendix A. Apple 2003-2019 data**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 𝒀𝒆𝒂𝒓 | 𝑴𝒐𝒏𝒕𝒉 | 𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑳&𝑴𝒑 | 𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑳𝒑 | 𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑴𝒑 | 𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑴𝑩𝒑 |
| 2003 | 1 | 0.125262 | 0.13436 | 0.16725 | 0.122463 |
| 2003 | 4 | 0.13056 | 0.134604 | 0.160601 | 0.12825 |
| 2003 | 7 | 0.130208 | 0.133102 | 0.155671 | 0.126736 |
| 2003 | 10 | 0.12884 | 0.129336 | 0.155104 | 0.128345 |
| 2004 | 1 | 0.122793 | 0.123596 | 0.166132 | 0.122793 |
| 2004 | 4 | 0.125641 | 0.134188 | 0.162393 | 0.127066 |
| 2004 | 7 | 0.123883 | 0.134604 | 0.163192 | 0.122692 |
| 2004 | 10 | 0.006179 | 0.059732 | 0.292482 | 0.014418 |
| 2005 | 1 | 0.120879 | 0.121664 | 0.142072 | 0.121664 |
| 2005 | 4 | 0.120635 | 0.120635 | 0.154286 | 0.121905 |
| 2005 | 7 | 0.122669 | 0.122669 | 0.146341 | 0.123386 |
| 2005 | 10 | 0.120678 | 0.120678 | 0.154599 | 0.120678 |
| 2006 | 1 | 0.127647 | 0.128252 | 0.162129 | 0.127042 |
| 2006 | 4 | 0.125141 | 0.127396 | 0.16009 | 0.125141 |
| 2006 | 7 | 0.124101 | 0.1253 | 0.154077 | 0.123501 |
| 2006 | 10 | 0.120114 | 0.122246 | 0.169154 | 0.120824 |
| 2007 | 1 | 0.122602 | 0.123436 | 0.155963 | 0.123436 |
| 2007 | 4 | 0.122357 | 0.12492 | 0.163357 | 0.122998 |
| 2007 | 7 | 0.123312 | 0.125661 | 0.159718 | 0.123312 |
| 2007 | 10 | 0.124461 | 0.125693 | 0.155268 | 0.125693 |
| 2008 | 1 | 0.123399 | 0.124747 | 0.153742 | 0.123399 |
| 2008 | 4 | 0.122423 | 0.124297 | 0.1599 | 0.12055 |
| 2008 | 7 | 0.120873 | 0.121462 | 0.154481 | 0.123231 |
| 2008 | 10 | 0.124661 | 0.128576 | 0.167721 | 0.12436 |
| 2009 | 1 | 0.119513 | 0.120571 | 0.164463 | 0.125859 |
| 2009 | 4 | 0.120115 | 0.121839 | 0.165517 | 0.121264 |
| 2009 | 7 | 0.126126 | 0.127716 | 0.159512 | 0.125066 |
| 2009 | 10 | 0.123457 | 0.123951 | 0.161481 | 0.122963 |
| 2010 | 1 | 0.121327 | 0.123223 | 0.169194 | 0.123223 |
| 2010 | 4 | 0.121744 | 0.12235 | 0.158086 | 0.122956 |
| 2010 | 7 | 0.122472 | 0.123596 | 0.155618 | 0.121348 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 2010 | 10 | 0.125 | 0.128925 | 0.151872 | 0.125604 |
| 2011 | 1 | 0.124084 | 0.125061 | 0.146067 | 0.124084 |
| 2011 | 4 | 0.125343 | 0.126715 | 0.150961 | 0.125343 |
| 2011 | 7 | 0.126772 | 0.127606 | 0.14804 | 0.126355 |
| 2011 | 10 | 0.124887 | 0.125792 | 0.150679 | 0.123077 |
| 2012 | 1 | 0.123195 | 0.124549 | 0.151625 | 0.125 |
| 2012 | 4 | 0.124785 | 0.126503 | 0.148827 | 0.124785 |
| 2012 | 7 | 0.099631 | 0.103321 | 0.163592 | 0.098401 |
| 2012 | 10 | 0.103556 | 0.108787 | 0.165272 | 0.106695 |
| 2013 | 1 | 0.108728 | 0.114645 | 0.161243 | 0.107988 |
| 2013 | 4 | 0.107981 | 0.112089 | 0.164319 | 0.106221 |
| 2013 | 7 | 0.10792 | 0.10879 | 0.154917 | 0.106179 |
| 2013 | 10 | 0.106901 | 0.112991 | 0.15088 | 0.107578 |
| 2014 | 1 | 0.103236 | 0.105547 | 0.152542 | 0.101695 |
| 2014 | 4 | 0.104373 | 0.108455 | 0.165015 | 0.103207 |
| 2014 | 7 | 0.092497 | 0.099692 | 0.158273 | 0.092497 |
| 2014 | 10 | 0.086548 | 0.095014 | 0.155221 | 0.085607 |
| 2015 | 1 | 0.097711 | 0.102113 | 0.149648 | 0.098592 |
| 2015 | 4 | 0.102992 | 0.106472 | 0.152401 | 0.104384 |
| 2015 | 7 | 0.092639 | 0.095947 | 0.156328 | 0.092639 |
| 2015 | 10 | 0.103292 | 0.107811 | 0.158812 | 0.103938 |
| 2016 | 1 | 0.114356 | 0.119802 | 0.158416 | 0.111881 |
| 2016 | 4 | 0.118891 | 0.12218 | 0.164944 | 0.113722 |
| 2016 | 7 | 0.084211 | 0.088889 | 0.167251 | 0.087719 |
| 2016 | 10 | 0.10632 | 0.10855 | 0.159108 | 0.10855 |
| 2017 | 1 | 0.10452 | 0.111582 | 0.136299 | 0.105932 |
| 2017 | 5 | 0.100929 | 0.102786 | 0.141796 | 0.101548 |
| 2017 | 8 | 0.106865 | 0.110104 | 0.150259 | 0.106865 |
| 2017 | 11 | 0.100764 | 0.102849 | 0.140375 | 0.102154 |
| 2018 | 2 | 0.105093 | 0.107028 | 0.144423 | 0.105738 |
| 2018 | 5 | 0.005 | 0.0125 | 0.165 | 0.005 |
| 2018 | 7 | 0.100945 | 0.103896 | 0.159386 | 0.101535 |
| 2018 | 11 | 0.102864 | 0.105202 | 0.150205 | 0.104617 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 2019 | 1 | 0.104772 | 0.111903 | 0.168952 | 0.103675 |
| 2019 | 4 | 0.10975 | 0.111281 | 0.155181 | 0.107198 |
| 2019 | 7 | 0.10483 | 0.106476 | 0.150384 | 0.104281 |
| 2019 | 10 | 0.105882 | 0.110486 | 0.150384 | 0.102302 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑳&𝑴𝒑 | 𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑳𝒑 | 𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑴𝒑 | 𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑴𝑩𝒑 | 𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑳&𝑴𝒒𝒂 | 𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑳𝒒𝒂 |
| 0.008397 | 0.140658 | 0.177747 | 0.123863 | 0.127372 | 0.133831 |
| 0.005777 | 0.145003 | 0.164645 | 0.13056 | 0.133979 | 0.140734 |
| 0.008681 | 0.137731 | 0.177662 | 0.130208 | 0.132345 | 0.139035 |
| 0.007433 | 0.144202 | 0.17443 | 0.132309 | 0.130841 | 0.137902 |
| 0.004815 | 0.134831 | 0.192616 | 0.132424 | 0.122672 | 0.131695 |
| 0.005556 | 0.136752 | 0.179772 | 0.128632 | 0.123883 | 0.134604 |
| 0.008338 | 0.136391 | 0.181656 | 0.129244 | 0.130332 | 0.136933 |
| 0.040165 | 0.115345 | 0.441813 | 0.029866 | 0.120879 | 0.121664 |
| 0.014129 | 0.145997 | 0.199372 | 0.134223 | 0.124376 | 0.13186 |
| 0.009524 | 0.137778 | 0.200635 | 0.134603 | 0.127063 | 0.135783 |
| 0.007174 | 0.144189 | 0.198709 | 0.134864 | 0.130287 | 0.13946 |
| 0.009785 | 0.138943 | 0.205479 | 0.129159 | 0.129725 | 0.135404 |
| 0.003025 | 0.138536 | 0.177858 | 0.135511 | 0.129153 | 0.134565 |
| 0.005637 | 0.138106 | 0.18602 | 0.132469 | 0.127738 | 0.134783 |
| 0.007794 | 0.143285 | 0.188849 | 0.133094 | 0.127205 | 0.138448 |
| 0.007818 | 0.143568 | 0.186923 | 0.129353 | 0.128938 | 0.134338 |
| 0.009174 | 0.140951 | 0.186822 | 0.137615 | 0.126952 | 0.132314 |
| 0.008969 | 0.142857 | 0.183216 | 0.131326 | 0.131061 | 0.135415 |
| 0.007634 | 0.139753 | 0.187904 | 0.132707 | 0.12977 | 0.133641 |
| 0.006161 | 0.140481 | 0.189772 | 0.132471 | 0.131421 | 0.136283 |
| 0.006743 | 0.138908 | 0.197572 | 0.13149 | 0.131546 | 0.135277 |
| 0.009369 | 0.141786 | 0.193004 | 0.12867 | 0.131494 | 0.135331 |
| 0.009434 | 0.14092 | 0.198703 | 0.130896 | 0.127192 | 0.130962 |
| 0.006323 | 0.138814 | 0.179765 | 0.12978 | 0.128799 | 0.135344 |
| 0.009519 | 0.141195 | 0.192491 | 0.126388 | 0.129578 | 0.136096 |
| 0.008621 | 0.14023 | 0.198276 | 0.124138 | 0.129327 | 0.133246 |
| 0.005299 | 0.139905 | 0.188129 | 0.128246 | 0.132558 | 0.135772 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0.005926 | 0.145679 | 0.186667 | 0.129877 | 0.130365 | 0.135213 |
| 0.006635 | 0.137915 | 0.191943 | 0.12654 | 0.129915 | 0.136304 |
| 0.00848 | 0.141732 | 0.194428 | 0.130224 | 0.129429 | 0.134186 |
| 0.011236 | 0.144944 | 0.190449 | 0.130337 | 0.127801 | 0.134104 |
| 0.004831 | 0.145531 | 0.188406 | 0.129831 | 0.122333 | 0.130868 |
| 0.009282 | 0.139228 | 0.199316 | 0.132877 | 0.129464 | 0.134524 |
| 0.006862 | 0.142726 | 0.188472 | 0.133577 | 0.128636 | 0.134492 |
| 0.005421 | 0.138866 | 0.19141 | 0.13553 | 0.129362 | 0.132047 |
| 0.00724 | 0.141629 | 0.19638 | 0.130317 | 0.124249 | 0.131497 |
| 0.007671 | 0.143502 | 0.191787 | 0.132671 | 0.130973 | 0.13399 |
| 0.005724 | 0.14024 | 0.194047 | 0.135089 | 0.130945 | 0.134426 |
| 0.02091 | 0.140221 | 0.254613 | 0.119311 | 0.110236 | 0.118898 |
| 0.012552 | 0.138075 | 0.243724 | 0.121339 | 0.10979 | 0.121681 |
| 0.008136 | 0.149408 | 0.234467 | 0.115385 | 0.118756 | 0.129752 |
| 0.014671 | 0.149648 | 0.228286 | 0.116784 | 0.113871 | 0.122774 |
| 0.013925 | 0.154047 | 0.232376 | 0.121845 | 0.120658 | 0.126874 |
| 0.012855 | 0.155616 | 0.2341 | 0.11908 | 0.11277 | 0.118664 |
| 0.016949 | 0.154854 | 0.249615 | 0.115562 | 0.11846 | 0.127803 |
| 0.011662 | 0.145773 | 0.242566 | 0.11895 | 0.111888 | 0.118881 |
| 0.018499 | 0.165468 | 0.263104 | 0.109969 | 0.110685 | 0.121561 |
| 0.021637 | 0.142992 | 0.296331 | 0.116651 | 0.113276 | 0.122209 |
| 0.007923 | 0.154049 | 0.278169 | 0.111796 | 0.1125 | 0.11681 |
| 0.01183 | 0.148921 | 0.255393 | 0.117606 | 0.118644 | 0.127119 |
| 0.01737 | 0.165426 | 0.274607 | 0.105045 | 0.108356 | 0.119137 |
| 0.012266 | 0.147837 | 0.249839 | 0.116204 | 0.115745 | 0.126383 |
| 0.008911 | 0.144554 | 0.218812 | 0.123267 | 0.136683 | 0.140377 |
| 0.007049 | 0.137688 | 0.214756 | 0.120771 | 0.131216 | 0.135753 |
| 0.017544 | 0.174269 | 0.278363 | 0.101754 | 0.117244 | 0.127086 |
| 0.008178 | 0.156134 | 0.230483 | 0.122677 | 0.121379 | 0.127752 |
| 0.013418 | 0.161723 | 0.243644 | 0.122881 | 0.127473 | 0.133187 |
| 0.016718 | 0.15356 | 0.258824 | 0.123839 | 0.126944 | 0.131277 |
| 0.011658 | 0.158031 | 0.23057 | 0.125648 | 0.128878 | 0.133413 |
| 0.011119 | 0.152189 | 0.263377 | 0.127172 | 0.114361 | 0.120471 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0.009671 | 0.146357 | 0.251451 | 0.130239 | 0.131924 | 0.135941 |
| 0.0325 | 0.1725 | 0.53 | 0.0775 | 0.009217 | 0.048387 |
| 0.009445 | 0.145809 | 0.257969 | 0.121015 | 0.128538 | 0.132952 |
| 0.011689 | 0.14962 | 0.253653 | 0.122151 | 0.129177 | 0.134232 |
| 0.010422 | 0.142622 | 0.244652 | 0.113001 | 0.129995 | 0.134921 |
| 0.009188 | 0.149056 | 0.24145 | 0.116896 | 0.131677 | 0.135417 |
| 0.015368 | 0.149287 | 0.248079 | 0.121295 | 0.13184 | 0.135142 |
| 0.013299 | 0.150895 | 0.251662 | 0.11509 | 0.132442 | 0.134167 |

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| 𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑴𝒒𝒂 | 𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑴𝑩𝒒𝒂 | 𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑳&𝑴𝒒𝒂 | 𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑳𝒒𝒂 | 𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑴𝒒𝒂 | 𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑴𝑩𝒒𝒂 |
| 0.169964 | 0.128381 | 0.004643 | 0.137465 | 0.16956 | 0.128785 |
| 0.159198 | 0.134654 | 0.000901 | 0.139158 | 0.157622 | 0.133754 |
| 0.158742 | 0.134334 | 0.001989 | 0.136865 | 0.161996 | 0.134695 |
| 0.162409 | 0.131464 | 0.002908 | 0.137902 | 0.164278 | 0.132295 |
| 0.170666 | 0.127088 | 0.006143 | 0.136495 | 0.179881 | 0.12536 |
| 0.163192 | 0.122692 | 0.008338 | 0.136391 | 0.181656 | 0.129244 |
| 0.165538 | 0.131178 | 0.004909 | 0.136764 | 0.164184 | 0.130162 |
| 0.142072 | 0.121664 | 0.014129 | 0.145997 | 0.199372 | 0.134223 |
| 0.173557 | 0.126158 | 0.004277 | 0.134177 | 0.179081 | 0.126515 |
| 0.163968 | 0.12971 | 0.004983 | 0.136562 | 0.171598 | 0.130333 |
| 0.161373 | 0.129947 | 0.003907 | 0.137252 | 0.166808 | 0.130967 |
| 0.169122 | 0.131145 | 0.002662 | 0.135049 | 0.165217 | 0.131677 |
| 0.166667 | 0.129713 | 0.003733 | 0.139604 | 0.167787 | 0.128779 |
| 0.165569 | 0.131261 | 0.004135 | 0.138459 | 0.169398 | 0.128657 |
| 0.168651 | 0.127646 | 0.003748 | 0.137566 | 0.169753 | 0.126984 |
| 0.162016 | 0.129838 | 0.004725 | 0.140189 | 0.170792 | 0.129163 |
| 0.163854 | 0.128844 | 0.00615 | 0.137202 | 0.175367 | 0.129317 |
| 0.160787 | 0.130311 | 0.004354 | 0.139318 | 0.168443 | 0.130311 |
| 0.163318 | 0.130876 | 0.002028 | 0.13788 | 0.171613 | 0.130876 |
| 0.158645 | 0.132718 | 0.001945 | 0.140496 | 0.165937 | 0.132556 |
| 0.154208 | 0.132652 | 0.002764 | 0.141219 | 0.169407 | 0.132928 |
| 0.167355 | 0.131494 | 0.003837 | 0.136954 | 0.163666 | 0.12987 |
| 0.164727 | 0.130143 | 0.004262 | 0.139158 | 0.17407 | 0.129487 |

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| 0.1669 | 0.128331 | 0.00374 | 0.139551 | 0.169004 | 0.128331 |
| 0.163563 | 0.13175 | 0.003724 | 0.14013 | 0.164804 | 0.130354 |
| 0.163945 | 0.131123 | 0.004082 | 0.138635 | 0.169007 | 0.130634 |
| 0.15659 | 0.132405 | 0.002755 | 0.140211 | 0.167611 | 0.132099 |
| 0.156402 | 0.131262 | 0.004848 | 0.142395 | 0.168073 | 0.131442 |
| 0.157438 | 0.129751 | 0.002457 | 0.137451 | 0.174476 | 0.132208 |
| 0.156496 | 0.130906 | 0.003281 | 0.140912 | 0.173228 | 0.131562 |
| 0.169118 | 0.128151 | 0.004377 | 0.13813 | 0.170343 | 0.127976 |
| 0.171835 | 0.124893 | 0.006828 | 0.139403 | 0.18037 | 0.123471 |
| 0.156548 | 0.130357 | 0.003423 | 0.141667 | 0.173661 | 0.130357 |
| 0.164526 | 0.130336 | 0.002833 | 0.139025 | 0.170193 | 0.129958 |
| 0.153691 | 0.13104 | 0.005201 | 0.141275 | 0.177181 | 0.130201 |
| 0.167115 | 0.125906 | 0.005177 | 0.140195 | 0.179333 | 0.126527 |
| 0.157327 | 0.131608 | 0.003969 | 0.140022 | 0.171138 | 0.130973 |
| 0.160238 | 0.1308 | 0.003335 | 0.142111 | 0.167488 | 0.130655 |
| 0.197244 | 0.112205 | 0.005118 | 0.140157 | 0.205512 | 0.11063 |
| 0.200951 | 0.115339 | 0.007531 | 0.137535 | 0.196591 | 0.110583 |
| 0.180961 | 0.120641 | 0.005655 | 0.138549 | 0.186616 | 0.11907 |
| 0.182287 | 0.113402 | 0.008903 | 0.143861 | 0.203843 | 0.111059 |
| 0.169653 | 0.119196 | 0.004753 | 0.13638 | 0.197441 | 0.125046 |
| 0.180747 | 0.117485 | 0.008644 | 0.141847 | 0.199214 | 0.120629 |
| 0.178625 | 0.118087 | 0.005979 | 0.14574 | 0.188715 | 0.116592 |
| 0.168831 | 0.112388 | 0.011988 | 0.143856 | 0.214286 | 0.117882 |
| 0.196417 | 0.108125 | 0.006398 | 0.136276 | 0.214331 | 0.106206 |
| 0.190418 | 0.113683 | 0.00812 | 0.139261 | 0.197726 | 0.115307 |
| 0.182759 | 0.114224 | 0.00819 | 0.137931 | 0.213793 | 0.113793 |
| 0.172425 | 0.121578 | 0.005867 | 0.137549 | 0.195567 | 0.121252 |
| 0.185445 | 0.109434 | 0.007547 | 0.137466 | 0.221024 | 0.11159 |
| 0.184255 | 0.119149 | 0.006809 | 0.134468 | 0.194894 | 0.118298 |
| 0.152075 | 0.135944 | 0.001478 | 0.140869 | 0.157 | 0.135574 |
| 0.161278 | 0.131972 | 0.001324 | 0.139913 | 0.166572 | 0.131972 |
| 0.178434 | 0.12024 | 0.001712 | 0.137356 | 0.198545 | 0.119384 |
| 0.167729 | 0.124276 | 0.006083 | 0.13876 | 0.190035 | 0.123986 |

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| 0.154725 | 0.127473 | 0.007253 | 0.141538 | 0.178901 | 0.129451 |
| 0.165435 | 0.127708 | 0.004333 | 0.13816 | 0.17716 | 0.128983 |
| 0.157518 | 0.130549 | 0.002148 | 0.140095 | 0.17685 | 0.130549 |
| 0.166303 | 0.117852 | 0.00873 | 0.142732 | 0.211261 | 0.118289 |
| 0.161522 | 0.131501 | 0.003594 | 0.138055 | 0.165116 | 0.132347 |
| 0.281106 | 0.025346 | 0.023041 | 0.119816 | 0.479263 | 0.013825 |
| 0.155025 | 0.130356 | 0.004414 | 0.139704 | 0.176318 | 0.132693 |
| 0.158663 | 0.130862 | 0.002808 | 0.140972 | 0.173547 | 0.129739 |
| 0.164751 | 0.129995 | 0.001916 | 0.136563 | 0.17214 | 0.129721 |
| 0.158654 | 0.132479 | 0.004006 | 0.140759 | 0.166132 | 0.130876 |
| 0.152123 | 0.132311 | 0.003302 | 0.139858 | 0.171462 | 0.133962 |
| 0.155306 | 0.132873 | 0.003236 | 0.140638 | 0.167817 | 0.13352 |

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| 𝑩𝑯𝑹𝑬𝑻\_𝟎\_𝟏 | 𝑩𝑯𝑹𝑬𝑻\_𝟎\_𝟑 | 𝑩𝑯𝑹𝑬𝑻\_𝟎\_𝟕 | 𝑩𝑯𝑹𝑬𝑻\_𝟎\_𝟏𝟓 | 𝑩𝑯𝑹𝑬𝑻\_𝟎\_𝟑𝟎 |
| 0.016077 | 0.003601 | 0.054279 | 0.087579 | 0.127275 |
| -0.02519 | -0.01553 | 0.006205 | 0.29065 | 0.221086 |
| 0.086907 | 0.07452 | 0.101126 | 0.034976 | 0.090688 |
| -0.05354 | -0.0478 | -0.05921 | -0.06729 | -0.16849 |
| -0.06062 | -0.07451 | -0.07399 | -0.07309 | -0.02996 |
| 0.091752 | 0.048738 | 0.020542 | 0.000576 | 0.077741 |
| 0.13335 | 0.106212 | 0.080192 | 0.109492 | 0.144912 |
| 0.191502 | 0.253619 | 0.259438 | 0.411031 | 0.572629 |
| 0.0836 | 0.079998 | 0.109965 | 0.191562 | 0.336629 |
| -0.10507 | -0.13284 | -0.1396 | -0.11503 | -0.06559 |
| 0.065415 | 0.088854 | 0.140837 | 0.107196 | 0.203601 |
| -0.01133 | 0.075837 | 0.128076 | 0.128372 | 0.242482 |
| -0.07041 | -0.07421 | -0.15637 | -0.18344 | -0.18983 |
| 0.017704 | -0.00782 | 0.060895 | 0.050138 | -0.0444 |
| 0.132493 | 0.139637 | 0.19879 | 0.173152 | 0.196342 |
| 0.059807 | 0.087594 | 0.070081 | 0.08934 | 0.191691 |
| -0.07753 | -0.10017 | -0.1178 | -0.13005 | -0.0957 |
| 0.05084 | 0.071753 | 0.064594 | 0.128735 | 0.315471 |
| 0.103727 | 0.074891 | 0.029893 | -0.04023 | 0.024289 |

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| 0.078423 | 0.063368 | 0.07739 | -0.05838 | 0.089001 |
| -0.149 | -0.20404 | -0.19822 | -0.24988 | -0.2484 |
| 0.048251 | 0.06112 | 0.103328 | 0.130892 | 0.142723 |
| -0.03399 | -0.02944 | -0.04902 | 0.024954 | -0.00265 |
| 0.074195 | 0.104187 | 0.167412 | 0.055138 | 0.110636 |
| 0.102316 | 0.103917 | 0.12067 | 0.18848 | 0.32035 |
| 0.026502 | 0.012721 | 0.005379 | -0.06029 | 0.041683 |
| 0.021862 | 0.013554 | 0.024674 | 0.016242 | 0.029326 |
| 0.054471 | 0.086332 | 0.077788 | 0.073404 | 0.034595 |
| 0.042486 | 0.016505 | 0.00433 | 0.022013 | 0.070344 |
| 0.039324 | 0.074163 | 0.074926 | 0.076371 | 0.159038 |
| 0.035529 | 0.024334 | 0.018059 | 0.006969 | 0.000144 |
| -0.00553 | -0.01687 | -0.0248 | -0.02847 | -0.02167 |
| -0.01788 | -0.05056 | -0.01759 | -0.00386 | -0.00734 |
| 0.0175 | 0.010208 | -0.01033 | 0.003366 | 0.025947 |
| 0.018398 | 0.02112 | 0.054139 | 0.119318 | 0.121672 |
| -0.05657 | -0.09178 | -0.10503 | -0.09608 | -0.13049 |
| 0.036091 | 0.041933 | 0.050327 | 0.157482 | 0.206122 |
| 0.049946 | 0.026758 | 0.002179 | -0.00325 | 0.042273 |
| -0.0395 | -0.05553 | -0.00181 | 0.010209 | 0.064263 |
| -0.02271 | -0.04797 | -0.08575 | -0.06482 | -0.13429 |
| -0.10842 | -0.11339 | -0.11328 | -0.08648 | -0.16819 |
| 0.004704 | 0.031214 | 0.090348 | 0.058063 | 0.088973 |
| 0.039376 | 0.036214 | 0.063306 | 0.154006 | 0.199401 |
| -0.02246 | -0.00204 | -0.00534 | -0.01935 | 0.062801 |
| -0.07374 | -0.08748 | -0.04228 | -0.02564 | -0.05721 |
| 0.070133 | 0.129082 | 0.11548 | 0.122425 | 0.189691 |
| 0.027513 | 0.037507 | 0.039474 | 0.045394 | 0.039678 |
| 0.020161 | 0.040192 | 0.048985 | 0.042203 | 0.08724 |
| 0.043849 | 0.064882 | 0.0574 | 0.115145 | 0.085426 |
| 0.004345 | -0.02278 | -0.02086 | 0.000511 | 0.00055 |
| -0.04561 | -0.03631 | -0.06552 | -0.11908 | -0.09247 |
| 0.025644 | 0.034037 | 0.039704 | 0.002328 | 0.024778 |

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| -0.06499 | -0.05369 | -0.0451 | -0.03421 | -0.04428 |
| -0.07487 | -0.10159 | -0.09115 | -0.08863 | -0.07458 |
| 0.057159 | 0.065541 | 0.092973 | 0.118648 | 0.098946 |
| -0.01039 | -0.01997 | -0.03119 | -0.09964 | -0.09562 |
| 0.05738 | 0.051203 | 0.078211 | 0.092036 | 0.113745 |
| 0.005624 | 0.013599 | 0.053791 | 0.049619 | -0.02479 |
| 0.055059 | 0.05024 | 0.065851 | 0.089696 | 0.064349 |
| 0.030389 | 0.043922 | 0.045038 | 0.039336 | 0.010883 |
| -0.02021 | 0.018857 | 0.035669 | 0.081571 | 0.092145 |
| 0.071839 | 0.105193 | 0.118032 | 0.102176 | 0.100526 |
| 0.056425 | 0.081074 | 0.079678 | 0.110594 | 0.133938 |
| -0.05935 | -0.08558 | -0.11364 | -0.18915 | -0.19833 |
| 0.044004 | 0.041697 | 0.070001 | 0.048446 | 0.100106 |
| 0.035892 | 0.032471 | 0.003163 | -0.06086 | -0.02523 |
| 0.027286 | 0.000947 | -0.00372 | 0.049108 | 0.079371 |
| 0.023095 | 0.044629 | 0.054176 | 0.061162 | 0.073484 |

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| 𝑳𝑬𝑽𝑬𝑹𝑨𝑮𝑬 | 𝑹𝑶𝑨 | 𝑬𝑷 | 𝑺𝑷𝑬 | 𝑩𝑴 | 𝑵𝑰𝑨𝑻 |
| 0.050175 | 0.02604 | 0.012561 | -0.0046 | 0.84061 | 0.010321 |
| 0.050175 | 0.02604 | 0.012561 | -0.0046 | 0.84061 | 0.010321 |
| 0.050175 | 0.02604 | 0.012561 | -0.0046 | 0.84061 | 0.010321 |
| 0.050175 | 0.02604 | 0.012561 | -0.0046 | 0.84061 | 0.010321 |
| 0.044607 | 0.020073 | 0.008891 | -0.00382 | 0.538857 | 0.010125 |
| 0.044607 | 0.020073 | 0.008891 | -0.00382 | 0.538857 | 0.010125 |
| 0.044607 | 0.020073 | 0.008891 | -0.00382 | 0.538857 | 0.010125 |
| 0.044607 | 0.020073 | 0.008891 | -0.00382 | 0.538857 | 0.010125 |
| 0 | 0.061925 | 0.011491 | -0.00286 | 0.201357 | 0.034286 |
| 0 | 0.061925 | 0.011491 | -0.00286 | 0.201357 | 0.034286 |
| 0 | 0.061925 | 0.011491 | -0.00286 | 0.201357 | 0.034286 |
| 0 | 0.061925 | 0.011491 | -0.00286 | 0.201357 | 0.034286 |
| 0 | 0.15719 | 0.022952 | 0 | 0.129503 | 0.115574 |
| 0 | 0.15719 | 0.022952 | 0 | 0.129503 | 0.115574 |
| 0 | 0.15719 | 0.022952 | 0 | 0.129503 | 0.115574 |

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| 0 | 0.15719 | 0.022952 | 0 | 0.129503 | 0.115574 |
| 0 | 0.154769 | 0.027817 | 0 | 0.142846 | 0.115606 |
| 0 | 0.154769 | 0.027817 | 0 | 0.142846 | 0.115606 |
| 0 | 0.154769 | 0.027817 | 0 | 0.142846 | 0.115606 |
| 0 | 0.154769 | 0.027817 | 0 | 0.142846 | 0.115606 |
| 0 | 0.185663 | 0.020396 | 0 | 0.087684 | 0.137926 |
| 0 | 0.185663 | 0.020396 | 0 | 0.087684 | 0.137926 |
| 0 | 0.185663 | 0.020396 | 0 | 0.087684 | 0.137926 |
| 0 | 0.185663 | 0.020396 | 0 | 0.087684 | 0.137926 |
| 0 | 0.16959 | 0.064206 | 0 | 0.286275 | 0.122157 |
| 0 | 0.16959 | 0.064206 | 0 | 0.286275 | 0.122157 |
| 0 | 0.16959 | 0.064206 | 0 | 0.286275 | 0.122157 |
| 0 | 0.16959 | 0.064206 | 0 | 0.286275 | 0.122157 |
| 0 | 0.261552 | 0.043752 | 0 | 0.178549 | 0.173365 |
| 0 | 0.261552 | 0.043752 | 0 | 0.178549 | 0.173365 |
| 0 | 0.261552 | 0.043752 | 0 | 0.178549 | 0.173365 |
| 0 | 0.261552 | 0.043752 | 0 | 0.178549 | 0.173365 |
| 0 | 0.256933 | 0.047774 | 0 | 0.176308 | 0.186385 |
| 0 | 0.256933 | 0.047774 | 0 | 0.176308 | 0.186385 |
| 0 | 0.256933 | 0.047774 | 0 | 0.176308 | 0.186385 |
| 0 | 0.256933 | 0.047774 | 0 | 0.176308 | 0.186385 |
| 0 | 0.306021 | 0.069259 | 0 | 0.225249 | 0.222753 |
| 0 | 0.306021 | 0.069259 | 0 | 0.225249 | 0.222753 |
| 0 | 0.306021 | 0.069259 | 0 | 0.225249 | 0.222753 |
| 0 | 0.306021 | 0.069259 | 0 | 0.225249 | 0.222753 |
| 0 | 0.331959 | 0.083883 | 0 | 0.264209 | 0.237033 |
| 0 | 0.331959 | 0.083883 | 0 | 0.264209 | 0.237033 |
| 0 | 0.331959 | 0.083883 | 0 | 0.264209 | 0.237033 |
| 0 | 0.331959 | 0.083883 | 0 | 0.264209 | 0.237033 |
| 0.081932 | 0.269353 | 0.071352 | 0 | 0.277591 | 0.178923 |
| 0.081932 | 0.269353 | 0.071352 | 0 | 0.277591 | 0.178923 |
| 0.081932 | 0.269353 | 0.071352 | 0 | 0.277591 | 0.178923 |
| 0.081932 | 0.269353 | 0.071352 | 0 | 0.277591 | 0.178923 |

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| 0.152239 | 0.260737 | 0.058797 | 0 | 0.203559 | 0.17042 |
| 0.152239 | 0.260737 | 0.058797 | 0 | 0.203559 | 0.17042 |
| 0.152239 | 0.260737 | 0.058797 | 0 | 0.203559 | 0.17042 |
| 0.152239 | 0.260737 | 0.058797 | 0 | 0.203559 | 0.17042 |
| 0.221916 | 0.281363 | 0.088163 | 0 | 0.244231 | 0.183814 |
| 0.221916 | 0.281363 | 0.088163 | 0 | 0.244231 | 0.183814 |
| 0.221916 | 0.281363 | 0.088163 | 0 | 0.244231 | 0.183814 |
| 0.221916 | 0.281363 | 0.088163 | 0 | 0.244231 | 0.183814 |
| 0.27055 | 0.215353 | 0.072095 | 0.001704 | 0.249611 | 0.142024 |
| 0.27055 | 0.215353 | 0.072095 | 0.001704 | 0.249611 | 0.142024 |
| 0.27055 | 0.215353 | 0.072095 | 0.001704 | 0.249611 | 0.142024 |
| 0.27055 | 0.215353 | 0.072095 | 0.001704 | 0.249611 | 0.142024 |
| 0.308218 | 0.18849 | 0.054778 | 0 | 0.190835 | 0.128826 |
| 0.308218 | 0.18849 | 0.054778 | 0 | 0.190835 | 0.128826 |
| 0.308218 | 0.18849 | 0.054778 | 0 | 0.190835 | 0.128826 |
| 0.308218 | 0.18849 | 0.054778 | 0 | 0.190835 | 0.128826 |
| 0.31303 | 0.223023 | 0.076138 | 0.000645 | 0.143421 | 0.162775 |
| 0.31303 | 0.223023 | 0.076138 | 0.000645 | 0.143421 | 0.162775 |
| 0.31303 | 0.223023 | 0.076138 | 0.000645 | 0.143421 | 0.162775 |
| 0.31303 | 0.223023 | 0.076138 | 0.000645 | 0.143421 | 0.162775 |

**Appendix B. Variables description about conference calls characteristics**

𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑳&𝑴𝒑,𝒊,𝒕 represents the percentage of the LM&ML positive words to total number of sentimental words in presentation portion for firm 𝑖 in quarter 𝑡.

𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑳&𝑴𝒑,𝒊,𝒕 represents the percentage of the LM&ML negative words to total

number of sentimental words in presentation portion for firm 𝑖 in quarter 𝑡.

𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑳𝒑,𝒊,𝒕 represents the percentage of the LM positive words to total number of sentimental words in presentation portion for firm 𝑖 in quarter 𝑡.

𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑳𝒑,𝒊,𝒕 represents the percentage of the LM negative words to total number of

sentimental words in presentation portion for firm 𝑖 in quarter 𝑡.

𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑴𝒑,𝒊,𝒕 represents the percentage of the ML positive words to total number of words in presentation portion for firm 𝑖 in quarter 𝑡.

𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑴𝒑,𝒊,𝒕 represents the percentage of the ML negative words to total number

of sentimental words in presentation portion for firm 𝑖 in quarter 𝑡.

𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑴𝑩𝒑,𝒊,𝒕 represents the percentage of the ML positive binary words to total number of sentimental words in presentation portion for firm 𝑖 in quarter 𝑡.

𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑴𝑩𝒑,𝒊,𝒕 represents the percentage of the ML negative binary words to total

number of sentimental words in presentation portion for firm 𝑖 in quarter 𝑡.

𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑳&𝑴𝒒𝒂,𝒊,𝒕 represents the percentage of the LM&ML positive words to total number of sentimental words in Q&A portion for firm 𝑖 in quarter 𝑡.

𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑳&𝑴𝒒𝒂,𝒊,𝒕 represents the percentage of the LM&ML negative words to total

number of sentimental words in Q&A portion for firm 𝑖 in quarter 𝑡.

𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑳𝒒𝒂,𝒊,𝒕 represents the percentage of the LM positive words to total number of sentimental words in Q&A portion for firm 𝑖 in quarter 𝑡.

𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑳𝒒𝒂,𝒊,𝒕 represents the percentage of the LM negative words to total number

of sentimental words in Q&A portion for firm 𝑖 in quarter 𝑡.

𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑴𝒒𝒂,𝒊,𝒕 represents the percentage of the ML positive words to total number of sentimental words in Q&A portion for firm 𝑖 in quarter 𝑡.

𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑴𝒒𝒂,𝒊,𝒕 represents the percentage of the ML negative words to total number

of sentimental words in Q&A portion for firm 𝑖 in quarter 𝑡.

𝒑𝒐𝒔\_𝒑𝒄𝒕\_𝑴𝑩𝒒𝒂,𝒊,𝒕 represents the percentage of the ML positive binary words to total number of sentimental words in Q&A portion for firm 𝑖 in quarter 𝑡.

𝒏𝒆𝒈\_𝒑𝒄𝒕\_𝑴𝑩𝒒𝒂,𝒊,𝒕 represents the percentage of the ML negative binary words to total

number of sentimental words in Q&A portion for firm 𝑖 in quarter 𝑡.

**Appendix C. Variables description about firm fundamentals**

𝑨𝑻𝒊,𝒕 represents total assets for firm 𝑖 in quarter 𝑡.

𝑩𝑬𝒊,𝒕 represents book value for firm 𝑖 in quarter 𝑡.

𝑪𝑺𝑯𝑶𝒊,𝒕 represents common share outstand for firm 𝑖 in quarter 𝑡.

𝑫𝑳𝑪𝒊,𝒕 represents total debt in current liabilities for firm 𝑖 in quarter 𝑡.

𝑫𝑳𝑻𝑻𝒊,𝒕 represents total long-term debt for firm 𝑖 in quarter 𝑡.

𝑬𝑷𝑺𝑷𝑰𝒊,𝒕 represents earnings per share (basic) divided by including extraordinary items for firm 𝑖 in quarter 𝑡.

𝑵𝑰𝒊,𝒕 represents net income for firm 𝑖 in quarter 𝑡.

𝑶𝑰𝑩𝑫𝑷𝒊,𝒕 represents operating income before depreciation for firm 𝑖 in quarter 𝑡.

𝑷𝑹𝑪𝑪\_𝑪𝒊,𝒕 represents stock price for firm 𝑖 in quarter 𝑡.

𝑺𝑷𝑰𝒊,𝒕 represents Special Items for firm 𝑖 in quarter 𝑡.

**Appendix D. Variables description about cumulative abnormal returns**

𝒂𝒃𝒏𝒐𝒓𝒎𝒂𝒍 𝒓𝒆𝒕𝒖𝒓𝒏\_𝟎\_𝒏𝒊,𝒕 represents abnormal return on day n after the current earnings call date for firm 𝑖 in quarter 𝑡.

𝑩𝑯𝑹𝑬𝑻\_𝟎\_𝒏𝒊,𝒕 represents cumulative n-day abnormal return starting from the current

earnings conference call date for firm 𝑖 in quarter 𝑡.

𝒓𝒆𝒕𝒖𝒓𝒏\_𝟎\_𝒏𝒊,𝒕 represents stock return on day n after the current earnings call date for firm 𝑖 in quarter 𝑡.

𝒗𝒘𝒓𝒆𝒕𝒆𝒅\_𝟎\_𝒏𝒊,𝒕 represents value weight return with dividend on day n after the

current earnings call date which is market index for firm 𝑖 in quarter 𝑡.

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**Theoretical Perspectives on AI-Human Collaboration: A Multi-level Review of Employee Impacts and Future Directions**

#### Abstract

With the increasing adoption of artificial intelligence (AI) in service industries such as hospitality, there is growing concern about its impacts on employees. Previous studies predominantly examined AI's effects on customers or organisational outcomes, often neglecting the critical role employees play in successful AI integration. This systematic review aimed to identify and evaluate the theories and models utilised in empirical research exploring AI-human collaboration's impact on employees. We analysed 33 empirical articles, identifying nine theories grouped into five categories across four analytical levels: intrapersonal (cognitive paradigm), interpersonal (social exchange and social comparison paradigms), group/team (social identity paradigm), and organisational (institutional/cultural paradigm). Notably, this review found an absence of research explicitly employing theories from the dispositional paradigm (e.g., Big Five personality traits) despite the use of related variables such as proactive personality and self-efficacy as moderators. Furthermore, the review highlighted limited theoretical integration across multiple analytical levels and a relative lack of attention to social and cultural contexts influencing AI acceptance. Consequently, key theoretical gaps were identified, and directions for future research are proposed to facilitate a comprehensive understanding of employee reactions to AI-human collaboration.

#### Introduction

Due to the swift advancements in technology, artificial intelligence (AI) has become increasingly integrated into various sectors, especially in service industries like hospitality and tourism intending to improve operational efficiency and enhance the overall customer experience (Prentice, et al., 2020). Although the application of AI brings many benefits such as automation (Fernandez & Aman, 2018; Tojib, et al., 2023), more effective processes (Noble, et al., 2021), enhancement of human intelligence through advanced analytics (Gabriel, et al., 2016; Syed & Mohd Abdul, 2023), and providing support in HR decision-making processes (Maaitah, 2023; Schepers & Van der Borgh, 2020), many organisations have not realized the expected benefits (Chowdhury, et al., 2022). Organisations frequently struggle to assimilate AI with their current employees, procedures, and business strategies (Chowdhury, et al., 2022), for which organisations lack comprehension and professional knowledge regarding the best practices to develop collaborative ability in the workplace (Makarius, et al., 2020).

Similarly, human workers also have a limited understanding of the influence of AI on their work, which results from low trust in AI, limited AI-related skills, and lack of knowledge (Chowdhury, et al., 2022). This can further cause employees to face uncertainty and negative perceptions which can affect their performance and lead to adverse psychological outcomes related to their work (Brougham & Haar, 2018; Stamate, et al., 2021). Particularly, the spreading adoption of AI in organisations has aroused concerns among employees about the potential displacement of positions, particularly in the service industries (Li, et al., 2019). Most research on the application of AI in the hotel industry focuses on its impact on customers or organisations (Ghahramani, 2017; Moravčík, et al., 2017; Mukherjee, et al., 2022; Russell, 2010) rather than employees. However, Prentice et al. (2020) argue that employees are more likely than customers to encounter AIs during work, while Braganza et al. (2021) propose that employees’ frequent interaction with AI can impact them negatively in terms of job insecurity and job burnout. Therefore, investigating the impact of AI on employees has significant value.

In 1956, McCarthy (2007) initially defined AI as “the science and engineering of creating intelligent machines”. Over many decades, AI has developed into intelligent machines and algorithms that have the capabilities to reason and adapt in accordance with particular regulations and environments (McCarthy, 2007; Ng, et al., 2021). This review needs a definition that can delineate the domain of AI and facilitate the measurement of AI construct. Thus, in the context of this review, AI is characterised as the capability of a system to accurately

interpret external data, learn from this data, and then apply the acquired knowledge to accomplish specific objectives and tasks through adaptable adjustment (Kaplan & Haenlein, 2019).

Among existing research, the theoretical understanding of AI’s impact on employees is inconsistent, especially in its development and transformation. There is no review to specifically investigate the theory-based frameworks used in empirical research on the relationship between AIs and employees. One review reveals the influence of multilevel factors (individual, group, and organisational) on the interaction between humans and AI by structuring around five themes (Bankins, et al., 2023), and it briefly provides some examples of used theories without detailed explanations. Another review evaluates the applications of theories in AI-HRM studies while it does not interpret the content of theories and measure variables in detail (Pan & Froese, 2023). In addition, the review of Mariani et al. (2022) has extensively discussed the theoretical frameworks utilized in AI research, but it focuses on the fields of marketing, consumer research, and psychology. However, seldom reviewed articles discuss and analyse the theoretical frameworks used in relevant empirical research (AI-human interaction). Additionally, increasing studies on AI and humans are emerging while there is an absence of an updated review of the used theories and models.

To fill these gaps, we reviewed theories and models adopted in the existing empirical studies of AI-human collaboration. We intended to answer two research questions: 1) What are the theories and models used in the existing empirical studies to explain the influences of AI- human collaboration on employees? 2) What factors inferred by these theories and models are identified to be significantly associated with AI-employee collaboration? Answers to these questions can help us build a clearer understanding of how the influence was explained, identify theoretical gaps, and explore opportunities for future investigations.

#### Methodology

The systematic literature review method is adopted to achieve a robust, repeatable and clear process (Denyer & Tranfield, 2009; Papaioannou, et al., 2019). The state-of-the-art guidelines (Snyder, 2019) underpin the review scope, selection criteria formulation, data generation, incorporation of results, framework development and establishment of future research on the relationship between artificial intelligence (AI) and employees. The method is detailed below.

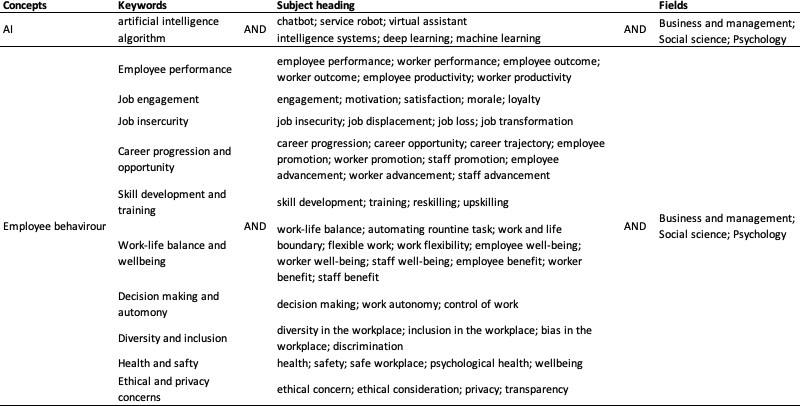
* 1. Search strategy

The PRISMA protocol was used in this review for the article identification (Moher, et al., 2015; Page, et al., 2021; Snyder, 2019) due to its focus on preparing and presenting data for systematic reviews. It encompasses four steps: identification, screening, eligibility, and inclusion (Hosany, et al., 2022; Moher, et al., 2015).

***Step 1: Identification***

Four aspects were considered in this step, namely database, keywords, period and source type. Firstly, the search was operated in two main databases (Web of Science, and Scopus), which ensured extensive coverage of related literature. Secondly, the search terms or keywords including concepts relating to artificial intelligence and employee performance appearing in Titles, Abstracts or Keywords were employed in both databases (see Table 1 for detailed searching keywords). Thirdly, in accordance with previous systematic reviews (Srivastava, et al., 2020; Vlacic, et al., 2021), only peer-reviewed journals were selected for accuracy in concepts and methodology (book sections, conference proceedings, etc. were not included). Only articles in English and limited to the subjects of business and management, social science, and psychology were selected. Finally, no time constraints were established so that the evolution of the research topic could be illustrated. The initial search generated 1732 papers with coverage from 1972 to 2024 (53 years).

Table 1: Searching Keywords of Systematic Literature Review



***Step 2 & 3: Screening and eligibility***

The screening was conducted by deleting repeated articles from the two databases. A total of 139 papers were removed and 1593 papers remained. Eligibility was processed via scanning keywords and abstracts. Papers were assessed according to two main criteria: that they focused on employee management, like human resources management and organisational behaviour, and that research of the article should be operated in the field of business and management rather than healthcare or education sectors because it was not in the scope of this review. Besides, articles that only focus on CRM or customers or organisations or firms or companies are removed.

In particular, gig work or platform work is supposed to be viewed as a separate topic from AI for which it shows a diverse labour model that is essentially influenced by technology promotion. Namely, AI can be regarded as the foundation of gig work and platform work on account that AI has the potential to convert gig work by allowing more competent job matching, changing the work demands of gig workers, and further impacting the required skills of these workers (Crayne & Newlin, 2024; Rand & Stegeman, 2023). Therefore, the number of remaining papers was 394.

***Step 4: Inclusion***

During this process, if necessary, the full context of each article was examined to ensure that articles focused on the impact brought by AI while having the same definition of AI. Articles with customers as participants were maintained where research was conducted with employees (Belanche, et al., 2020; Chatterjee, et al., 2021; Chen, et al., 2021), or where the impact of AI on employees was evaluated from the perspective of customers (Jan, et al., 2023; Prentice, et al., 2023; Ruan & Mezei, 2022). To acknowledge current research directions from high-ranking journals, papers from journals with an impact factor over 3 were kept. Reviewing these inclusion criteria identified 95 relevant articles.

Considering this review focuses on the applied theories in specific research areas, articles that do not explicitly specify theories adopted to underpin the influences of AI-human collaboration on employees were removed. Besides, only prominent and frequently used theories are included to ensure relevance and manageability, theories or models identified in only a single study or those with limited empirical support were excluded from further analysis. The final sample included 33 articles (See Figure 1).

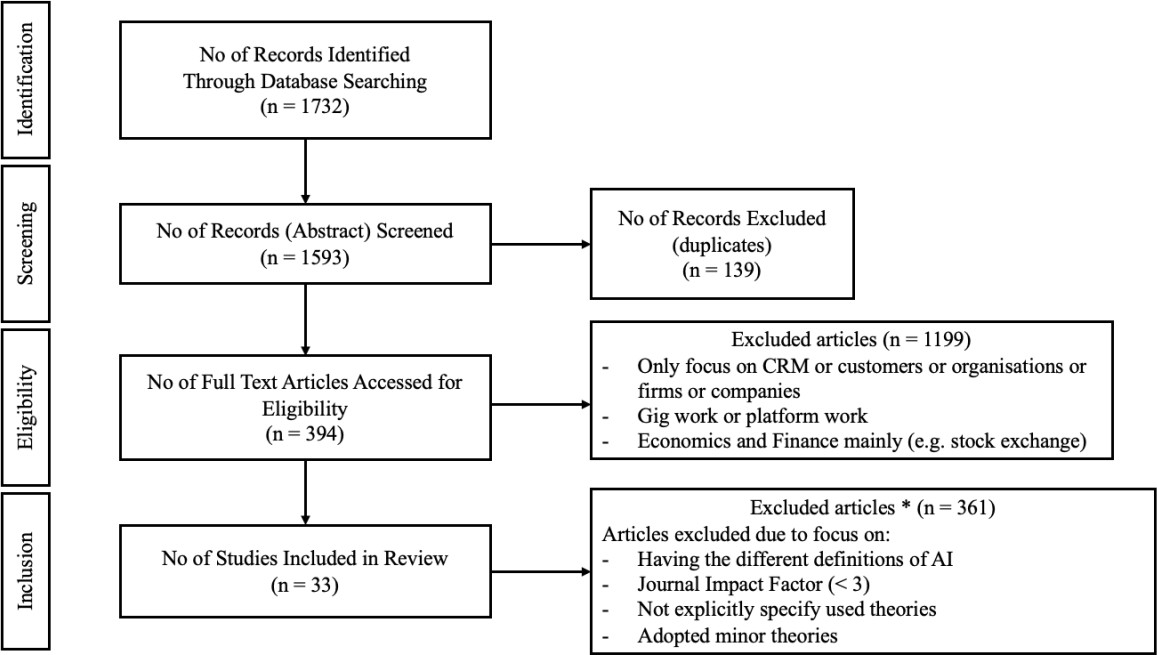


Fig. 1. Flow Diagram of the Selection of Literature Reviewed based on PRISMA.

#### Results: Theories and models that guide AI-employee collaboration research

This review identified 9 theories/models from the 33 articles and grouped them into 5 categories and 4 levels. Table 2 lists these theories/models by category and level, and the variables related to these theories/models examined in the included studies.

In organisational behaviour research, 6 main theoretical paradigms offer unique lenses through which to analyse workplace dynamics. This review categorised these paradigms at different analytical levels. Specifically, these include the cognitive paradigm (intrapersonal level), social exchange and social comparison paradigms (interpersonal level), social identity paradigm (group/team level), and institutional/cultural paradigm (organisational level). Paradigms such as the dispositional (between-person level) and evolutionary (multilevel) paradigms are not included, as relevant theories from these paradigms were not applied in the reviewed articles. Each paradigm and its associated theories will be discussed in detail in subsequent sections.

Table 2: Theories and Models that Guide AI-employee collaboration research

**Levels and paradigms Summary** No.of

studies

**Variables measured Emprical studies**

lntrapersonal level

*Category 1: Cognitive paradigm Cognilive Motivation*

SeH-Determiuation lbeory Indicates that the need for autonomy stin111lates

employees' intrinsic motivation leads to significant work outcomes, including behavior change and effective performance.

Innovative behavior Kong et al. (2024) Techonology-related belief - positive Bergdahl et al. (2023)

attitudes toward AI

*CogniJive apprisal*

\Vork engagement

Psychological health

Turnover intetion

Job burnout

Wu et al. (2025)

Stamate et al. (2021); Tan et al. (2023)

Tahir el al. (2024); Koo el al. (2021)

Kong etal. (2021)

Conservation of resource theory Presents a core principle that individuals arc apt to

maintain the resources they have gained,

particularly when faced with real or perceived

6 Work autonomy - service innovation Li et al. (2024) behaviow-

threats to these resources.

Service hospit.1blenes.s Proactive service behaviors

Qiu el aI. (2022) Li eta I. (2024)

Job Insecurity- workplace harassment Song (2021)

Work withdrawal Teng et al. (2023) Aging-and-tech o·utcomes vulnerability Alcover eta!.(2021)

Job Demands-Resources: Model Explains employee well-being and performance by

distinguishing two primary workplace factors: job demands and job resow-ces.

Cognitive appralsal theory Explain the coping process that takes place when a

person faces a novel or challenging situation.

Transactional 1beory or Stress: Indicates that the way individuals react to a

specific stress.or is shaped by their perception or evaluation of it

Interpersonal level

*Category 1: Social exchange paradigm*

Service performance

Job crafting - Job insecurity Service innov.1tive behavior

Al perceived usefulness - Psychological health

Job engagement Well-being

Employees' positive behavior

4 Employee organizational deviance Job insecurity

Turnover intention

4 Proactive service behaviors. Job crafting

Extra-role s.ervice behavior

Innovative work behavior

He et al. (2023)

Liang **et** al. (2022)

**Stamate etal.** (2021)

Willems et al. (2023)

Wu and Zhang (2024) Zhao et al. (2023)

Cai (2024); Chiu **et** al. (2021); Yam et al. (2022)

Huang & Gursoy (2024) Cheng ct al. (2023) Yang elal. (2024)

Dong et al. (2025)

**Social Exchange Theory**

*Cutegory 3: Soc:iu/ compurison puradigm*

Social Comparison Theory

Grottplteam level

*Category 4: &,c:iu/ identity parudigm*

Posits that relationships among individuals primarily consist of both tangible and intangible exchanges

suggests that people assess their own social and personal values by comparing themselves to others.

Social loafting

AI surveillance - work engagement

Unemployment risk perception and knowledge hiding

Decreased employee performance

Guan eta I. (2025) Zhao et al. (2023) Xu and Xue (2023)

Vorobeva et al. (2022)

**Anlhropomorpbism Theory** Refers to the psychological tendency of individuals

to attribute human-like characteristics to non­

human agents.

2 Job insecurity

�sistance to robot.deployment

Tojib et al. (2023)

Organisational level

*Category 5: bt•JtituJuJnal/Cu/Jural Paradigm*

Organisational Change Theory Refers that organizations continuously adapt and

evolve to respond effectively to internal and external changes in their environments

Social presence - psychological safety Hu et al. (2024)

Leadership - hotel employees Xu et al. (2020)

* 1. Intrapersonal level

The intrapersonal level paradigm focuses on processes occurring within individuals, emphasising their internal psychological mechanisms such as perception, cognition, attitudes, emotions, motivations, and decision-making processes like the cognitive paradigm (Ruiter, et al., 2020).

***Category 1: Cognitive paradigm***

This paradigm views employee behaviours and attitudes as outcomes of how individuals internally process, interpret, and evaluate information from their organisational environment. For example, cognitive appraisal theories explain how employees evaluate and respond emotionally to workplace events (Lazarus & Folkman, 1984).

**Motivation perspective:** Motivation perspective emphasises cognitive processes related to goal-directed behaviour, self-regulation, and intrinsic or extrinsic motivation. Theories under this perspective (e.g., Self-Determination Theory) explore how cognitive factors such as expectations, values, and goals influence employees' effort, persistence, and work outcomes. In these AI-related studies, the psychological need (e.g. need for relatedness and the need for autonomy) is the major predictor of employees’ reactions to collaborating with AIs.

**Self-Determination Theory**

The self-determination theory (SDT) can be understood as “experiencing a sense of choice in initiating and regulating one’s actions” (Deci, et al., 1989) and is based on the regulatory process and following experiences driven by extrinsic and intrinsic motivation (Kong, et al., 2024; Ryan & Deci, 2000). This theory implies that when individuals are driven by intrinsic motivation, they feel self-governing and adequate, which would result in work outcomes such as effective performance and job satisfaction (Gagné & Deci, 2005). SDT has been extensively utilised as a theoretical framework for understanding different aspects of engagement-related behaviours (Koo, et al., 2021; Meyer & Gagne, 2008).

In the context of applying AI-related technologies in the workplace, SDT can explain the influences of employees’ technology-related beliefs on their attitudes toward AI ( (Bergdahl, et al., 2023). To be more specific, when employees believe that their basic psychological demands of employees (autonomy, competence, and relatedness) can be met by collaborating with AI, they would show higher AI positivity and lower AI negativity (Bergdahl, et al., 2023)., which can further positively affect work engagement (Wu, et al., 2025) and innovative behaviours of

employees (Kong, et al., 2024).

However, AI-human collaboration changed the environmental forces, which can impact the internal motivation of employees (Ryan & Deci, 2017). For example, autonomy as one of individuals’ psychological needs can be treated by the fear of being replaced by AI, leading to job insecurity (Koo, et al., 2021). When the internal motivations of employees are decreased by cooperating with AI, employees would show job burnout (Kong, et al., 2021) and turnover intentions (Koo, et al., 2021; Tahir, et al., 2024) as their motivations are not sufficient to drive higher performance (Tan, et al., 2023). In the long term, if the basic psychological needs are not fulfilled, the psychological health of employees would be damaged, like psychological energy consumption (Stamate, et al., 2021).

SDT can effectively act as the theoretical framework for research that aims to explore the factors that can enhance internal motivation (Kong, et al., 2023), work satisfaction (Koo, et al., 2021), and innovative behaviours (Kong, et al., 2023) due to the influence of perceived AI- supported autonomy on employees. While studies have generally explored how psychological needs influence employee reactions to AI, there is a gap in understanding how these dynamics vary across different employee demographics, job roles, or industries. Research could investigate how individual differences (such as age, job tenure, or skill level) affect the relationship between psychological needs and attitudes towards AI.

**Appraisal perspective:** This perspective highlights cognitive processes involved in evaluating and interpreting workplace events or situations. Existing articles applied appraisal-related theories to explore the process by which individuals evaluate and interpret the significance of events and stimuli in their environment (Chiu, et al., 2021; Smith & Lazarus, 1993), such as cognitive appraisal theory and conservation of resources theory. In these studies, the reactions of employees toward AI are not determined by objective circumstances but rather by how individuals perceive and interpret the circumstances.

**Conservation of resource theory**

Conservation of resources (COR) theory presents a core principle that individuals are apt to maintain the resources they have gained, particularly when faced with real or perceived threats to these resources (Halbesleben, et al., 2014; Hobfoll, 1989). The term “resource” in this theory is described as things to help individuals reach their goals (Halbesleben, et al., 2014), rather than valuable things as it is possible to be counterproductive when it cannot embody value in

some situations (Gorgievski, et al., 2011). Besides, the COR theory is frequently used to comprehend the impact of stress or adverse occurrences on work-related activities and results (Hobfoll, 1989; Teng, et al., 2023). Namely, the COR theory interprets the role of resources in changing work attitudes and behaviours.

Li et al. (2024) found out that AI can increase the work autonomy of employees, and considering the COR theory, work autonomy can be viewed as a resource that can diminish the negative behaviour of employees caused by pressure. AI-human collaboration can positively impact employee innovation behaviour (Li, et al., 2024), for which AI can increase work autonomy, resulting in more effective distribution and adjustment to deal with the demands and hindrances of the workplace. In the hotel sector, AI can act as an external resource for hotel employees to decrease the over-tension resulting from providing services and supplement their resources so that employees would increasingly spend their resources on showing proactive service behaviour (Li, et al., 2024) and providing service hospitableness (Qiu, et al., 2022).

However, the dark side of AI for employees should be noticed. According to the COR theory, when employees recognise that AI causes they to be under the threat of potentially or significantly losing their resources, they are likely to experience job insecurity, work burnout, exhaustion and other negative emotions, which could lead to hypercompetitive attitudes or behaviours such as workplace harassment and bullying (Song, 2021). In the same vein, Teng et al. (2023) examine that AI-human collaboration as an impediment stressor could exhaust employees' resources, potentially resulting in work withdrawal which represents various negative outcomes for employees. In particular, ageing workers who have fewer personal and social resources available are more vulnerable to facing challenges in collaborating with AI, they are more likely to experience job insecurity, psychological distress, and risk of clinical depression (Alcover, et al., 2021).

**Job Demands-Resources Model**

The Job Demands-Resources Model (JD-R) was created by Demerouti et al. (2001) to explain the combined impact of job demands and job resources on the performance and engagement of employees (Bakker & Demerouti, 2007; Menguc, et al., 2017). According to the JD-R model, all work attributes are categorized into two main groups: job demands and job resources (Demerouti, et al., 2001). Job demands can be understood as the aspects of work that encompass physical, psychological, or social elements, necessitating continuous physical, cognitive, or emotional exertion from employees (e.g. heavy workloads and uncomfortable

physical environment) (Chi & Wang, 2018; Demerouti, et al., 2004; He, et al., 2023). In simpler terms, job demands are tasks or requirements that need to be completed with effort. Job resources mean resources provided by or attained from various aspects of work such as physical, psychological, social, or organisational elements of work (Demerouti, et al., 2001; Liang, et al., 2022), which can support individuals to (1) minimise the physical and mental strain resulting from job demands (Chi & Wang, 2018; Demerouti, et al., 2001), (2) foster individual advancement and professional progress within organisations (Liang, et al., 2022; Xanthopoulou, et al., 2007), (3) encourage individual advancement and development (Demerouti, et al., 2001).

The JD-R model has been extensively applied to identify factors that affect well-being and performance at both the personal and organisational levels (Kaiser, et al., 2020) for which job resources and demands are viewed as two key psychological processes (strain and motivation) to affect organisational and individual outcomes (Demerouti & Bakker, 2011; Willems, et al., 2023). Besides, Bakker and Demerouti (2017) further discuss that job demands playing a hindrance can cause extra pressure on employees and lead them to a condition of depleted resources; while, when it works as a challenge, it can drive employees to participate in proactive actions to achieve higher performance. Moreover, job resources and job demands together can influence the process of motivation and strain, which subsequently shapes employee performance (Bakker & Demerouti, 2017; He, et al., 2023).

Based on this, this review discovers that drawing on JD-R theory, researchers explore the impact of AI awareness on the service performance of employees in dual pathways (challenge and stressor). He et al. (2023) point out that the relationship between understanding or knowledge of AI and the level of engagement in one's job is complex and multifaceted. Normally, when employees view AI as a challenge, AI-related knowledge can be viewed as an individual resource which can boost job engagement of employees by supporting them to navigate AI-related job demands with conviction (He, et al., 2023). AI awareness has both beneficial and detrimental influences on the positive behaviour (Wu & Zhang, 2024) and innovative behaviours (Liang, et al., 2022) of employees in collaboration with service robots.

While it can lead to converse results when employees view AI as a hindrance. Significantly, job insecurity of employees would be aggravated especially for those who perceive AI as an obstacle and perceive greater stressors/threats from AI on job loss with more understanding about AI (He, et al., 2023). Their research implies that AI awareness can act as a double-edged sword (He, et al., 2023; Liang, et al., 2022) that previous literature has largely overlooked. On the other hand, exploring the dual effects of AI awareness can provide a more nuanced and

comprehensive perspective on the influence of this emerging technology in the workplace.

Stamate et al. (2021) developed a new framework based on three theories that combine individual factors such as general mental ability (GMA) with the psychological outcomes associated with AI in the workplace. And one of the theories used by Stamate et al. (2021) is the JD-R model for which individual factors like GMA can impact the psychological job demands of employees by impacting their perception of AI and further impact their psychological health and well-being. Besides, the importance of understanding individual perceptions towards AI can mitigate potential negative impacts on psychological health and suggests that AI's integration into workplaces and relevant job resources should be managed carefully to support workers' psychological needs and well-being (Stamate, et al., 2021). However, the research of Willems et al. (2023) adopts the JD-R model to point out that some employees expect robots to alleviate certain job demands, but they do not anticipate robots to replenish job resources, so the majority agree that AI has a neutral effect on their job engagement and well-being.

**Cognitive appraisal theory**

The Cognitive appraisal theory was developed by Lazarus and Folkman (1984) to ascertain the coping process of individuals when they encounter a new or challenging situation. And this situation would cause an individual initial appraisal that is managed by two factors including the perception of the situation and individual beliefs such as knowledge, beliefs, values, and objectives (Chiu, et al., 2021; Smith & Lazarus, 1993). Bhattacherjee et al. (2018) point out that this appraisal considers both cognitive and affective components that can provoke various coping processes reflected by attitudes and behaviour. Namely, identifying the impact of an evaluation of an experience that evokes emotions through appraising a stimulus, which can result in negative and positive emotions (Choi & Choi, 2019; Smith & Lazarus, 1993). This theory can explain the reactions of individuals to incentives in different situations (Chiu, et al., 2021; Shi, et al., 2023).

By viewing AI as a pressure, Zhao et al. (2023) adopted the CAT to confirm that employees are likely to choose more radical strategies (i.e. intentionally breaking organisational rules) to deal with AI or other new technologies. Cai (2024) discovered that hospitality workers experience robot-phobia (as a job stressor) regardless of their sector or position, which can cause job insecurity. To cope with this potentially stressful situation, employees engage in cognitive appraisal processes based on their own knowledge and personal use of AI. Employees’

concerns regarding AI (e.g. job loss) can negatively impact their affective attitude toward acceptance of AI, which can further result in insecurity and turnover intentions (Chiu, et al., 2021; Yam, et al., 2023). One notable discovery is that employees are likely to have ambivalent attitudes (both positive and negative) toward AI, due to the complexity of human attitudes and the variations among individuals. For example, although the employees worry about the negative influence of AI on their jobs or society (negative affective attitudes), they would hold positive cognition toward AI as they agree that AI can bring some advantages (Chiu, et al., 2021).

There are some gaps in the reviewed studies. It is noted that individual beliefs and perceptions influence cognitive appraisal, more research could explore how specific differences such as age (Alcover, et al., 2021), personality traits like proactive personality (Wang & Hou, 2025), and desire for autonomy like completed work by self (Paluch, et al., 2022) can affect the appraisal process. This could provide nuanced insights into why individuals react differently to similar technological changes. Besides, due to the influence of additional information, experiences, or organisational changes, the appraisals of employees toward AI are dynamic and change over time, such as the stress appraisal process (Eschleman, et al., 2012; Marsella & Gratch, 2009). Thus, the changes in the appraisal process are suggested to more effectively examine the impact of specific factors on employees’ appraisals (e.g. longitudinal studies).

**Transactional Theory of Stress**

Transactional theory indicates that the way individuals react to a specific stressor is shaped by their perception or evaluation of it (Lazarus & Folkman, 1984). The adoption of AI within organisations, identified as a significant source of information in the work environment, inherently triggers stress among employees due to concerns about job replacement (Koo, et al., 2021). As employees encounter this stressor, their interpretation can lead to viewing it either as a challenge to overcome or a hindrance to their career progress. Transactional theory elaborates that an individual's perception of a stressor is influenced by the interaction between the stressor and their personal characteristics (Lazarus & Folkman, 1984).

Based on this, some researchers posited that an employee's appraisal of AI integration in their organisation as either a challenge or a hindrance is dependent on their unique traits (Cheng, et al., 2023; Huang & Gursoy, 2024). And their study discovered that individuals with an internal locus of control would regard AI adoption as a career opportunity, engaging in innovative work behaviour (Dong, et al., 2025), proactive service behaviour (Huang & Gursoy, 2024) and

positive job crafting (Cheng, et al., 2023), those with an external locus view it as a threat, adopting preventive job modifications (Huang & Gursoy, 2024). Besides, the anthropomorphism of service robots can affect employee extra-role service behaviours through employee perceived warmth of robots (Yang, et al., 2024).

* 1. Interpersonal level

At the interpersonal level, organisational behaviour research focuses on interactions, relationships, and exchanges among individuals within an organisation. It examines how employees interact with colleagues, supervisors, or customers, emphasising the quality, dynamics, and outcomes of these interactions.

***Category 2: Social exchange paradigm***

The social exchange paradigm fits explicitly at this interpersonal level because it views organisational relationships as ongoing, reciprocal exchanges involving resources such as support, trust, effort, and rewards (Blau, 1964). According to this paradigm, individuals are guided by principles of reciprocity and mutual obligation, continually evaluating relationships based on perceived fairness, rewards received, and resources exchanged (Cropanzano & Mitchell, 2005).

**Social exchange theory**

Social exchange theory posits that relationships among individuals primarily consist of both tangible and intangible exchanges (Blau, 1964). According to this theory, individuals adhere to a reciprocity norm (Gouldner, 1960). If reciprocity is absent, the individual may experience discomfort, which can lead to either failure to meet their obligations or the implementation of social penalties against the other party involved in the exchange (Miles, 2012; Yan, et al., 2016). This theory is frequently applied to examine the dynamics between organisations and employees (Guan, et al., 2020), as well as interactions between customers and employees (Priporas, et al., 2017). Additionally, research has indicated its relevance in interactions between customers and robots (Kim, et al., 2022).

Under the social exchange theory, when organisations provide more support to employees, employees feel obligated and expect to reciprocate by exerting more dedication to their work (Nisula, 2015; Rich, et al., 2010). The research of Zhao et al. (2023) points out that employees would view collaboration with AI as a way for organisations to surveil their work behaviour,

which can damage employees’ feeling of being supported by organisations, which further decreases job satisfaction and work engagement. Similarly, the unemployment risk perception under the disruption of artificial intelligence transformation reduces the perceived organisational support of employees, which results in knowledge hiding (Xu & Xue, 2023).

According to the social exchange theory, there exists a social exchange relationship between employees and AI, because both humans and AI contribute resources to the collaborative process in AI-employee collaboration scenarios (Le, et al., 2025). In such scenarios, service performance is structured as a team effort, making it difficult to distinguish individual contributions, and the visibility of these service tasks is low (Price, et al., 2006), which undermines employees' expectations of receiving equivalent value from the collaboration. As a result, the research of Guan et al. (2025) proves that in AI-human collaboration, the lack of precise measurement standards for individual performance can diminish employees' motivation to exert effort, leading to social loafing.

***Category 3: Social comparison paradigm***

The social comparison paradigm also clearly belongs to the interpersonal level of organisational behaviour because it specifically examines how individuals evaluate their attitudes, abilities, and outcomes by comparing themselves to others (Festinger, 1954). Within organisations, these interpersonal comparisons influence self-perceptions, emotions, motivations, and behaviours (Mussweiler, 2019; Wood, 1996).

**Social comparison theory**

Social comparison theory suggests that people assess their own social and personal values by comparing themselves to others (Festinger, 1954). Significantly, social comparison, whether intentional or unintentional, would influence self-perception, emotional responses, motivation, and behaviour (Mussweiler, 2019; Wood, 1996).

Vorobeva et al. (2022) propose that artificial agents, especially those equipped with artificial intelligence (AI) capabilities, can act as comparison standards in the evaluation of ability and performance, which extend the social comparison among people to artificial agents. However, comparisons between employees and AI can lead to perceptions of decreased personal capabilities, which might serve as a basis for job insecurity, thereby triggering fears of being replaced and decreased performance caused by self-doubt toward ability (Vorobeva, et al., 2022).

* 1. Group/team level

The group/team level of organisational behaviour focuses on dynamics within and between groups, examining how group membership influences individual attitudes, behaviours, and performance within organisational contexts.

***Category 4: Social identity paradigm***

The **social identity paradigm** belongs explicitly to this group/team level. It emphasises how individuals define themselves based on their memberships in particular groups, such as work teams, departments, or organisations. Social identity influences organisational outcomes by shaping group cohesion, intergroup relations, collective decision-making, conformity to group norms, and collaboration. Employees derive self-esteem and identity from group memberships, leading them to align their behaviours and attitudes closely with group objectives and values (Ashforth & Mael, 1989).

**Anthropomorphism Theory**

Anthropomorphism involves ascribing human traits to non-human entities (Epley, et al., 2007). Anthropomorphism theory developed by Epley et al. (2007) suggests that the propensity to anthropomorphize is influenced by three key factors: Sociality motivation (the desire for social interaction), Effectance motivation (the need for control and to reduce uncertainty), and Elicited agent Knowledge (the use of human-centric knowledge on non-human agents). When anthropomorphism happens (typically subconsciously upon first encountering a non-human agent), consumers perceive the service as being provided by a 'someone' rather than a 'something,' leading to more human-like treatment of those agents (Letheren, et al., 2021).

In the context of robot-employee collaboration, Tojib et al. (2023) examined the high-level anthropomorphism of robots that challenges the human distinctiveness of employees, which would lead to a more significant threat to job security (e.g. losing their identity by being forced to relinquish some autonomy to robots) and aggravate employees’ resistance to robot deployment. However, the studies of Hu et al. (2024) combine anthropomorphism with social presence theory to prove that collaborating with anthropomorphic AI can improve employees’ feeling of social presence and feel more connected to the technology, potentially enhancing of psychological safety.

The opposite findings of Tojib et al. (2023) and Hu et al. (2024) may be caused by different theoretical lens. Tojib et al. (2023) combine Anthropomorphism theory with the lens of

technological threat or identity threat, emphasising the risks to human distinctiveness and autonomy as robots perform tasks traditionally reserved for humans. This approach highlights the potential threats posed by high-level anthropomorphism, such as compromised job security and identity, which could exacerbate employee resistance to technological integration. Conversely, Hu et al. (2024) incorporate social presence theory, suggesting that anthropomorphic features in robots can enhance their perceived presence, thereby fostering better interpersonal interactions and psychological safety among human colleagues. This perspective posits that human-like traits in AI can transform these systems from mere tools to integral team members, potentially improving workplace dynamics and employee perceptions of AI (Hu et al., 2024). Thus, the theoretical lens critically influences research outcomes, underscoring the nuanced impact of AI in professional settings.

* 1. Organisational level

At the organisational level, organisational behaviour research focuses on how broader institutional environments, cultural norms, values, and external societal expectations shape organisational structures, practices, and behaviours.

***Category 5: Institutional/Cultural Paradigm***

The institutional/cultural paradigm emphasises that organisations operate within a larger social and cultural context and must conform to established norms and expectations to achieve legitimacy, resources, and long-term survival (DiMaggio & Powell, 1983; Scott, 2008). This paradigm highlights that organisational behaviour is profoundly shaped by the interplay of external cultural and institutional demands, influencing organisational strategies, practices, and routines.

**Organisational Change Theory**

Organisational change theory (Armenakis & Bedeian, 1999) posits that organisations continuously adapt and evolve to respond effectively to internal and external changes in their environments (Choi & Ruona, 2011). According to this theory, successful adaptation requires leaders to anticipate challenges, equip employees with the necessary skills, and cultivate a culture is receptive to change (Battilana, et al., 2010).

Based on organisation change theory, Xu et al. (2020) state that organisational structures and processes of hotels should concurrently undergo significant transformations as service robots

are integrated into hotel operations to collaborate with employees. Otherwise, increasing concerns among employees (e.g. fears of redundancy and uncertainty regarding future roles) potentially lead to reduced morale and resistance to change, even if hotel leaders might embrace service robots to lower costs and enhance competitive positioning (Xu, et al., 2020). Therefore, it is important to foster a collaborative organisational culture during the implementation of new technological processes supported by Tapscott (2014). For example, proactive leadership strategies can mitigate negative employee responses and ensure smooth organisational adaptation via developing transparent communication and cultivating a collaborative organisational culture (Xu, et al., 2020).

#### Discussion: Theoretical gaps and future directions

The reviewed theories and models have improved our comprehension of the influence caused by AI-human collaboration on employees; however, there is still room to deepen our understanding of this phenomenon.

* 1. Between-persons context: Dispositional paradigm

This review did not identify any studies examining the influence of AI-human collaboration on employees using theories explicitly belonging to the dispositional or trait paradigm, such as the Big Five personality traits. Although some reviewed articles discussed individual-level variables such as proactive personality (Kong, et al., 2024) or self-efficacy (Zhao, et al., 2023), these were utilised primarily as moderators without applying or explicitly referencing established theoretical frameworks like trait theory or self-efficacy theory. For example, Kong et al. (2024) examined proactive personality as a moderator in the relationship between perceived AI-supported autonomy and employees' innovative performance in hospitality, drawing primarily on self-determination theory. Similarly, Stein et al. (2024) explored the associations between personality traits, specifically the Big Five, and attitudes towards AIs, and discovered individuals with agreeableness are more positive to AI while susceptibility to conspiracy beliefs connects to a more negative attitude. However, there is a lack of research explicitly utilising trait theory to explain employee responses to AI collaboration. Hence, a clear gap remains regarding the explicit application of trait-based theories to better understand how stable dispositional traits influence employee reactions to AI interactions. Future research could address this by systematically employing frameworks such as the Big Five personality

traits or self-efficacy theory to clarify these relationships further.

* 1. Theoretical integration

Artificial intelligence (AI) represents a wicked problem characterized by complex impacts requiring collaborative insights from diverse stakeholders (Rittel & Webber, 1973; Bao et al., 2022). AI is positively noted for enhancing employee engagement (Braganza et al., 2021; Song et al., 2022) and well-being (Stamate et al., 2021; Willems et al., 2023), yet criticized for exacerbating social inequalities, including racial disparities (Tian et al., 2021; Zalnieriute & Cutts, 2022) and gender discrimination in hiring (Nadeem et al., 2021; O’Connor & Liu, 2023). Simplistic categorization of public attitudes towards AI as merely positive or negative fails to capture the complexity of human reactions. Bao et al. (2022) emphasise the necessity of understanding diverse group perceptions to inform effective policy and regulation. Individual differences in perceptions of AI's risks and benefits arise from social contexts and personal values, such as political orientation or religiosity (Castelo & Ward, 2021; Mantello et al., 2023).

The intentions of employees to collaborate with AI can strongly be influenced by the fulfilment of psychological needs, social factors (such as social norms and social identity) and cognitive factors (such as attitudes and expected outcomes). However, none of the reviewed studies has combined cognitive frameworks with theories belonging to higher-level theories (e.g. social identity paradigm, institutional/cultural paradigm). Future research should explore how these theoretical perspectives might be integrated or mutually reinforce one another, facilitating a more comprehensive understanding of the impacts brought by AI-employee collaboration.

* 1. Social and cultural context

Most frequently cited theories and models in this review emphasise individual-level cognitive factors, whereas social and cultural influences on AI-human collaboration have received comparatively less attention. Social norms and values significantly shape individuals' perceptions and behavioural intentions toward AI technologies (Hsu & Lin, 2008; Jeon, et al., 2018). Gursoy et al. (2019) demonstrate that consumers' acceptance of AI devices is positively influenced when these devices receive social approval, indicating that social norms can precede and influence users' attitudes and intentions.

According to social identity theory (Tajfel, et al., 1979), the adoption of AI technologies may enhance one's social identity, particularly when group norms favour their use (Gursoy, et al.,

2019). Cultural contexts similarly influence AI acceptance, as exemplified by Atwal et al. (2021), who found that traditional cultural values discouraged AI adoption in Burgundy's wine industry. Additionally, Filieri et al. (2022) identified significant differences between Western and Chinese consumers regarding AI, highlighting cultural nuances affecting AI acceptance.

Future research should deepen the understanding of these social and cultural dynamics. Researchers are encouraged to integrate theories such as diffusion of innovations or the theory of planned behaviour to expand perspectives on AI acceptance. Moreover, incorporating cultural dimensions frameworks (e.g., Hofstede’s dimensions, Schwartz's values, or the GLOBE study) and concepts like machine enculturation into technology acceptance models could further elucidate how AI technologies can effectively align with diverse cultural values and social norms, enhancing their global acceptability and usability.

#### Conclusion

The growing adoption of artificial intelligence (AI) within service industries underscores the importance of understanding its implications for employees. A comprehensive theoretical perspective on AI-human collaboration is essential for informing effective managerial strategies and targeted interventions. This review addresses this critical need by examining 33 empirical studies using nine different theories, which were classified into five categories across four levels of analysis. Key theoretical gaps identified include the absence of explicit application of dispositional theories, such as the Big Five personality traits, and the limited integration of theories across different analytical levels. To our knowledge, this is the first detailed review exploring theoretical frameworks specifically related to employee experiences with AI-human collaboration. Nevertheless, this study has limitations. Firstly, the scope of theories and constructs reviewed was constrained to those explicitly used in selected studies; future reviews could broaden the range to include additional theoretical frameworks and empirical results. Secondly, theories were assigned to categories primarily based on their primary focus, potentially overlooking their relevance at multiple analytical levels. Future research should further investigate these cross-level connections. Lastly, although this review suggested potential theoretical integrations, empirical validation is needed to support and refine these comprehensive frameworks for understanding AI-human collaboration.

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Actor-Network Theory methodology in studying citizens' participation in the development of localised and sustainable innovation ecosystems.

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**Abstract**

The paper explores the methodological implications of Actor-Network Theory (ANT) as a methodology and approach to understanding the outcomes of the education and collaborative participation of young people with stakeholders in participatory and high-order thinking adaptive approaches for sustainable innovation and solution development to tackle local and global challenges; alongside how these adaptive approaches can be evaluated against sustainable societal development and global impacts that contribute to the UN SDGs.

Actor-network theory offers a resourceful methodology for examining the complex interactions between humans and non-humans in social science research. By decentring humans, following the actors, and tracing relationships, it offers a distinctive perspective for understanding the dynamics of networks and how they are constructed and sustained (Luxi, 2023).

ANT presents challenges, such as the complexity of practical implementation due to its emphasis on following actors and tracing relationships, which requires a high degree of researcher reflexivity and adaptability (Souza and Petrini, 2023). It has also been criticised for its symmetry in treating humans and non-humans, which can result in a lack of critical engagement with power relations and social inequalities. This situation necessitates examining the emergence and stabilisation of power within networks (Crawford, 2020).

Leveraging ANT to offer new theoretical insights into the dynamics of relationships and engagements in co-creation assemblages, where young people engage with stakeholders in their local communities, will enable a comprehensive analysis of the meanings and interpretations attributed by actors to their actions and social dynamics. This approach aims to prioritise theoretical development over hypothesis validation, thus facilitating valuable qualitative insights for this research.

**Actor-Network Theory**

**Brief overview of Actor-network theory (ANT)**

Actor-network theory (ANT) combines two words (actor and network), usually considered opposites, in a unique constructivist approach to understanding complex ecosystems by emphasising the relational dynamics among diverse human and non-human actors. It challenges hierarchical distinctions and advocates for a flat ontology, adopting a symmetrical constructivist approach focusing on how knowledge and practices emerge through networks of associations. ANT highlights the emergence of agency from networks of relations of non- human agency in shaping interactions and recognises that phenomena are continually performed and sustained through these networks beyond human intentionality (Crawford, 2020). This distinctiveness makes it a valuable framework for analysing the complexities of stakeholder activities in multidimensional and multistakeholder environments (Greenhough 2017, (Crawford, 2020; Luxi, 2023) (Callon 2001). ANT focuses on concepts such as punctualisation, heterogeneity, and translation to facilitate the analysis of interactions and relationships among diverse actors, highlighting how knowledge and practices are negotiated and translated across various stakeholders involved in unique ecosystems (Cressman 2009).

Key concepts of ANT include:

* Actors: ANT recognises actors as human and non-human entities. It treats non-

humans (such as technologies and artefacts) as actors on par with humans. ANT posits that all human and non-human entities exist within a network of relations that

influence each other’s actions, thereby allowing for a more inclusive understanding of ecosystems. These actors are integral network members whose interactions form the

basis of social and organisational structures and constructs (Koole, 2023; Yoon, 2024). ANT adopts a symmetrical constructivist approach that posits that all actors, technical or social, should be equally placed and treated in a perspective that allows tracing the dynamics of power and agency without predefining boundaries (Hald and Spring, 2023; Luxi, 2023).

* Translation and network formation: ANT introduces the concept of ‘translation’ as a process by which actors negotiate and stabilise their roles and interests within a

network. Raising issues and mobilising and registering actors are crucial for forming stable networks in ANT’s translation process. This process of relationships is

meaningful for learning and understanding how networks form, maintain themselves and sometimes dissolve. Translation underscores the fluidity of social relationships

and the ongoing negotiation of meaning within networks. (Denise, 2014; Denisova, Polonskaya and Susimenko, 2022). These include ANT’s interpretation of the meanings, sources, functions, and consequences of human and non-human actions alongside institutional practices and how these are implicated in local and broader contexts (Hammersley, Atkinson and Ebscohost, 2019) (Yoon, 2024).

* Black Box: ANT encourages the analysis of events as the outcomes of interactions and unstable networks of associations of actors. The actors become a ‘black box’ that simplifies complex interactions into manageable entities of established stable

relationships that appear as single entities. Therefore, ANT approaches research with a broader perspective on the various organisational forces, material objects, and human, social, and cultural factors underpinning social phenomena' emergence and translation across diverse spheres. (Elder-Vass, 2019; Mclean and Aroles, 2016) (Yoon, 2024)

ANT highlights the importance of network formation and establishing stable relationships among actors within the ‘black boxes.’

* Heterogeneity: ANT emphasises that actors' heterogeneity is performative and that networks are not static; instead, they are continually enacted and reenacted through the interactions of their constituent actors (Hald and Spring, 2023; Jackson, 2015).

**Actor-network theory as a methodology**

Actor-network theory, ANT’s approach to challenging traditional human-centric perspectives in recognising the agency of non-human actors is a methodological shift for research to consider the participation of non-human entities, such as technology, documents, and natural elements, in shaping social processes (Denisova, Polonskaya and Susimenko, 2022; Luxi, 2023). ANT’s methodological shift proposes that researchers ‘follow the actors’ by tracing the associations and interactions between actors without imposing preconceived notions and boundaries (Bussular, Burtet and Antonello, 2019; Ginger and Govender, 2021).

Alongside diverse applications, ANT has also been used in diverse contexts. This includes challenging the standard ethnographic view of texts in analysing historical texts, where texts are treated as actors within a network for researchers to explore how they mediate relations and shape practices (Nimmo, 2011). ANT has also been increasingly used in education studies to examine the socio-material dynamics of educational phenomena. For example, in a study to understand Latin American educational policies and analyse the integration of ICT in schools to highlight the role of non-human actors such as curriculum guides and infrastructure in shaping educational practices; Dussel (2020) stated that “Classrooms with technologies are not

simply or solely “expanded classrooms”; they are inscribed within complex networks that have to be carefully and dutifully assembled”, and therefore “tried to visibilize the agents - human and nonhuman - that silently operate to produce the reform network: the political rhetoric of social inclusion; the computers; the plugs, cables, software, and platforms; the booklets and material of the program; the walls and desks of schools; the teacher trainers, teachers, students, and principals; the funding; the technological assistants; the diverse state agencies; and the evaluation rationales and personnel, among many others. Mainstream studies on school reforms pay little or no attention to these agents”, yet significant factors in the formation of the reform network included distinct rhetorical interests in social and cultural inclusion, technological change, and the impact of institutional actors - such as educators and evaluators

- who contributed their historical context to the dynamic interaction (Dussel, 2020). Similarly, Ginger and Govender (2021) utilised ANT to highlight the mutual dependence between the technical and social in a study about ICT integration in the education system in Mozambique.

Other sector studies that have used ANT, especially in science and technology, include health information technology to study the implementation of electronic health records (Cresswell, 2019), supply chain management to study the dynamic and fragile nature of supply chains (Hald and Spring, 2023), safety science to develop a more nuanced understanding of safety risks and their management in complex sociotechnical systems (Capaverde, Fogaça and Henriqson, 2023), medical education to study the socio-material dynamics of teaching and learning by examining the roles of non-human actors such as curriculum guides, mannequins, and simulation technologies (Capaverde, Fogaça and Henriqson, 2023) and in media studies to explore intersections of media and society to analyse the production, circulation and consumption of media content more holistically (Spöhrer, 2019). However, the implications of ANT in social sciences remain peripheral due to its risk of lack of theoretical unity. This risk is linked to the inherent diversity of Actor-Network Theory (ANT) approaches and the tendency to complicate the establishment of a unified methodological framework, leading to varied interpretations and sometimes divergent theoretical applications (Denisova, Polonskaya and Susimenko, 2022; Jackson, 2015). This diversity, however, contributes to ANT’s potential to contribute to a wide range of interdisciplinary fields, from organisation studies to environmental research, by engaging with ANT’s core principles and methodological implications to develop new insights into complex networks that shape social and material worlds (Hald and Spring, 2023; Scott-Conner, 2023).

Another challenge of ANT is its methodological complexity and criticisms of symmetry. The methodological implications of ANT’s emphasis on following the actors and tracing relations can be complex and challenging to implement in practice. Navigating the iterative nature of ANT-informed research requires a high degree of researcher reflexivity, adaptability and a systematic approach to documenting the “network of actors” continuously and continuously refining the research design in response to emerging insights in order to mitigate unforeseen data collection and analysis (Bussular, Burtet and Antonello, 2019; Souza and Petrini, 2023)challenges. Additionally, ANT’s symmetrical approach in its treatment of humans and non-human actors has been criticised in arguments that it can lead to a lack of critical engagement with power relations and social inequalities, whereby proponents of ANT have emphasised the need to critically examine how power is enacted and stabilised within networks in developing more nuanced analysis of social relations and their implications of justice and equity (Crawford, 2020; Denisova, Polonskaya and Susimenko, 2022).

**Importance of utilising ANT in the context of this research**

Actor-network theory (ANT) treats human and non-human entities as equal actors, providing a robust approach to understanding and interpreting the interconnectedness and dynamics of collaborative learning systems. It reveals a perspective that translates and highlights how relationships are formed and maintained in the activities of diverse stakeholders. Unlike social constructivism, systems thinking and participatory action research, ANT differs significantly in conceptualising agency, process and the nature of knowledge construction.

This research to study the learning, participation and contributions of young people in collaboration with educators and professional stakeholders for sustainable innovation will benefit from an all-encompassing approach of study and methodology that envelopes the focus, interests and challenges of engagement in defining outcomes of engagement activities. Actor- network theory’s view of humans and non-humans as equal actors in this research will emphasise unfixed relationships that encourage fostering community-centeredness and moving away from traditional theories to promote community-centeredness (Yoon, 2024).

Furthermore, to understand the intricacies and distinctions that underpin the assemblages, translations, forces, and interactions within this research— which seeks to unravel the beliefs, ideologies, and power relations inherent in processes rather than presuming a neutral, value- free approach - ANT will facilitate the exploration of how diverse networks of actors emerge, translate, and negotiate various dynamics and power struggles, as well as how distributed action

and agency support the stabilisation of specific outcomes through routine practice. (Latour, 2013; Tatnall, Wickramasinghe and Bali, 2012).

ANT allows a nuanced understanding of contributions and influences by mapping the complex interactions between human and non-human actors within a network. Its focus on relational dynamics helps uncover the often-overlooked contributions of different actors. This research includes establishing visibility of the outcomes of all stakeholders within youth-focused collaborative learning environments focused on sustainable problem-solving and innovation. It will require observing how interests and roles stabilise and adapt over time, as well as the translations, negotiations, and advantages of actions in the collaborations of multiple stakeholders.

Actor-network theory (ANT) will be crucial for capturing the social, material, and various other influential forces of the anticipated yet unpredictably complex interactions among humans and non-humans, as well as material and immaterial elements, in encompassing contexts rather than through a positivist approach focused on definite and generalised findings (Saunders, Lewis and Thornhill, 2019).

**Place-based, local context-specific influences**

Conducting a multi-case study and multi-geographical research, ANT will facilitate observations of local heterogeneous networks and interactions by capturing and contextually analysing groups of participants' assemblages to effectively unveil the underlying circumstances that may play crucial roles in influencing outcomes (Aroles and Mclean, 2021). Utilising ANT will also facilitate the dismantling and examination of established divides (e.g., nature/culture, structure/agency, macro/micro, etc.) and the effects on perceptions from preconceived notions. This will further aid the focus on local people’s actual experiences to correlate or contrast with the externally perceived ideal experiences, specialised interests and influences of power (Elder-Vass, 2008; Law, 1992; Nimmo, 2011). The geographical aspects of this research on place and sustainable globalisation will also be enriched by engagement with assemblage thinking to address shortcomings in the empirical operationalisation of pre- existing relational perspectives and focus on interaction and adaptation practices while maintaining an emphasis on the diversity, indeterminacy, and multiplicity of relations and their intersection in place (Müller and Schurr, 2016; Woods et al., 2021).

Therefore, using ANT in an ethnographic style allows further observations to explore potentially under-theorized epistemological elements of the study (Macleod et al., 2019), such

as the potential of collaborations between young people, experts, and communities to co-create and implement innovative solutions to global problems within local contexts.

**Conclusion**

While ANT provides a robust framework for understanding complex relationships and interactions, it could also present challenges in complicated social dynamics where the emphasis on network formation may overlook individual agency, the unique contributions of specific stakeholders and the power dynamics and inequalities that can exist among different actors, thereby potentially skewing the understanding of stakeholder interactions (Crawford, 2020; Denisova, Polonskaya and Susimenko, 2022).

Nonetheless, ANT remains a valuable approach for exploring this research with multifaceted interactions of diverse collaborators and empirical settings. ANT’s qualitative approach, more suited to theory development rather than hypothesis testing, also enables observations to focus on underlying and emerging effects of the various actors' activities, perspectives, and negotiations. It will also enable the most effective documentation and analysis of the meanings and interpretations that these actors attach to their actions and social interactions (Latour, 2005).

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**Patriarchy and Working Women’s Life Course in China**

1. **Abstract**

Patriarchy and its implications for the social and working lives of women throughout the globe continue to be open empirical questions. Patriarchy has historically manifested in a deep- rooted gendered division of labour (Dousin, Collins and Kler, 2022). Early studies of patriarchy from an employment perspective have focused on its impact on gender diﬀerences, in particular, diﬀerential treatment and outcomes between men and women within organizations and institutional settings (Batton and Wright, 2019; Anderson and Tomaskovic- Devey, 1995). A less studied problem is how patriarchy shapes women’s perceptions and decision-making on their employment and life trajectory; for instance, the role of patriarchy in shaping women’s choices of educational and professional paths or when dealing with tensions between career and personal aspirations at a structural, societal and institutional levels.

This project brings together the individual and the structural dimension to understand how patriarchy interplays within these dimensions to shape women’s lifecourse decisions, employment and personal outcomes and overall experiences in society and the labour market. This proposal brings an interdisciplinary approach that combines theoretical insights from sociology of work and organizations, gender and instersectionality, and human resource management. The qualitative research will adopt interpretivism as a philosophical position and will apply biographical, semi-structured interview. The research will interview 40 women between 25-50 years of age who work in the ﬁnancial industry in China. The ﬁnancial industry is chosen because ﬁnancial industry has high level of gender inequality which negatively inﬂuences the development of women, and the increasing competitiveness of ﬁnancial industry intensiﬁes contradiction between patriarchy and women’s growing self-awareness (Baeckström, 2022; He and Wei, 2023). The setting for the research is China; its relatively recent developments in the economic, policy and demographic domains have gradually sharpened tensions between men and women’s aspirations and employment outcomes (Walker and Millar, 2020). Therefore, the research contributes to ﬁgure out lifecourse and employment trajectory for women in ﬁnancial industry with the interaction of patriarchy to deepen theoretical understanding so that promoting gender equality in China.

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1. **Introduction**

Women are undoubtedly in a weak and vulnerable position in the society, which is historically originated from the notion of patriarchy (Poorhosseinzadeh and Strachan, 2021). The deﬁnition of patriarchy has developed from governmental system to social systems in which women are dominated by men (Weber, 1947; Duncan, 1994). Though still many scholars critique the existence of patriarchy concept when analyzing gender relations, women’s weakness in the society is still undeniable and could be reﬂected in passive and active perspective (Gottfried, 1998; Pollert, 1996; Walby, 1989).

On the one hand, from a passive acceptance perspective, women are usually unfairly treated compared with men in the labour market, which is theorized by gender segregation (Salem and Yount, 2019; Caven, Astor and Urbanavičienė, 2022). Gender segregation is divided into horizontal and vertical gender segregation, which refers to women’s less favourable treatment in the same position compared with men and women’s underrepresentation at higher positions respectively (Salem and Yount, 2019; Caven, Astor and Urbanavičienė, 2022). Nevertheless, it could argue that reasons for the segregation is that women generally have lower educational level so that demonstrating men’s relative high capability (Wang, 2005). However, it is believed that the lower prevalence of women’s education can also be recognized as a passive manifestation of gender inequality because educational opportunities in some cases depend on parents rather than women themselves (Wang, 2005). Speciﬁcally, it is demonstrated that women own less educational resources in a family, meaning that parents tend to prioritize men’s educational investment. Thus, women in the society are forced to passively accept the reality that educational opportunities among men and women are not completely fair. Apart from passively accepting unfair mechanism in the society, on the other hand, women subconsciously and actively sacriﬁce themselves while facing subjective choices especially conﬂict between work and life (Halfacree, 1995; Halfacree, 2004). Sometimes women even seek husbands’ approval for job promotions (Retnaningsih, 2022). This means that the disadvantaged and subsidiary position has internalized into women’s minds, and women have recognized the authority of patriarchal consciousness under social rights. Therefore, regardless of passive acceptance and subjective decision-making, gender inequality inﬂuenced by patriarchal ideology is unquestionable.

Gender inequality also exists in China (Woodhams, Xian and Lupton, 2015; Liu, 2024; Coleman, Haiyan and Yanping, 1998). Not only do women have to passively accept some unfair structural oppression and take overburdened responsibilities, but they also actively sacriﬁce themselves while facing conﬂict between their job tasks and caring role at home (Woodhams, Xian and Lupton, 2015; Liu, 2024; Coleman, Haiyan and Yanping, 1998). The willingness to

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sacriﬁce themselves indicates that the patriarchal thinking that usually refers to women’s weak, subsidiary and vulnerable position has largely legitimized by women. However, surprisingly, it is relieved to ﬁnd that some women tend to break the traditional shackles of women in the pursuit of personal development based on their growing self-awareness (You, Yi and Chen, 2021; Evans, 2021). This means that not every woman indulges in stereotypical route of traditional society that is usually characterised as struggling in working and taking almost all caring role at home. Women’s diﬀerent reactions and behaviour that might be inﬂuenced by diﬀerent identities and personal background while facing the shackles placed on them inspires and makes me curious about how patriarchy shapes women’s subjective choices in their lifecourse under the Chinese context.

1. **Literature review**

When it comes to gender equality, tendency might have been transforming from superﬁcial gender roles to how gender is embedded in social structures. The contextual understanding of topic will start from the patriarchy concept to explore the known dimensions through the lens of historical materialism and expose its academic gaps. Thus, the literature review will apply historical materialism as a theoretical thread to critically discuss the initial development, continuity and evolution of patriarchy (Farrelly, 2011). According to Farrelly (2011), historical materialism could be divided into three categories including Marx’s basic materialism, Marx’s synchronic materialism and Marx’s diachronic materialism.

* 1. **The Initial Development of Patriarchy**

The initial development of patriarchy in the society could be elaborated through Marx’s basic materialism (Farrelly, 2011). It is believed that human beings need labour to sustain their basic survival needs in early society, and gender relations are originally manifested in the primitive process of labour production that sustains the necessity of human beings (Farrelly, 2011). However, men and women have diﬀerent advantages and disadvantages, which creates the possibility to gender division of labour (Farrelly, 2011). Speciﬁcally, the early gender division of labour assumes that women undertake reproduction work and men participate in the war to maintain female reproduction (Farrelly, 2011). The division of labour lays foundation for unfair gender relations and male oppression (Farrelly, 2011). Therefore, Marx’s basic materialism could be applied to elaborate the initial development of gender relations in early society from historical materialism perspective, and the primitive gender relations are commonly deﬁned as patriarchy (Walby, 1989).

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However, discussions pertaining to the notion of patriarchy vary diﬀerently in the academia (Weber, 1947; Waters, 1989; Hartmann, 1976; Duncan, 1994; Walby, 1989). Weber (1947) primarily stated that patriarchy belongs to authoritative governmental system. Water (1989) also added that the governmental system is based on kinship relations, which might exist in early society. In addition, from the perspective of production and reproduction sphere, patriarchy is deﬁned as a mechanism of social reproduction, because it involves women oppressed reproductive work which mainly refers to childbirth job at home (Waters, 1989). However, it is critiqued that distinguishing between production and reproduction indicates high level of ideology that women are in a lower position and play subsidiary role in society (Waters, 1989). Because the distinguishment specializes childbirth, and the childbirth can only be realized by women based on current technological level. Thus, the word “reproduction” is controversial and the use of “reproduction” in deﬁning patriarchy needs to be reconsidered (Waters, 1989). Hartmann (1976) avoided the disputable discourse “reproduction” while deﬁning patriarchy and stated that patriarchy is “a set of social relations which has a material base and in which there are hierarchical relations between men, and solidarity among them, which enable them to control women”. This indicates that the way in which Hartmann (1976) deﬁnes patriarchy inherently believes that the social relations result in structural female oppression by men. It is also obvious that Hartmann (1976) attached signiﬁcance to how social hierarchy posits men and women in the society. Similarly, Walby also stated that patriarchy is “a system of social structures and practices in which men dominate, oppress and exploit women” (Duncan, 1994). Based on the various ways of deﬁning patriarchy mentioned above, it is concluded that not only does the patriarchy deﬁnition need to cover male dominated position in practice, but it also needs to involve the embedded attribution of social structure.

After critically discussing the deﬁnition of patriarchy, it is necessary to consider its classiﬁcations. Patriarchy is usually categorized into public and domestic sphere by Walby (1989), which refers to national-level regulations and informal rules within family members respectively. However, Acker (1989) critiqued the simplistic way of categorizing patriarchy and stated that the separation pays much attention to forms of patriarchy and exists the dualist ideology. Walby (1989) suggested that the optimization of patriarchy forms should cover structures of patriarchy. She summarized six structures of patriarchy, which includes patriarchal mode of production, patriarchal relations in paid labour, the patriarchal state, male violence, sexuality of patriarchal relations and patriarchal culture (Walby, 1989). The extraction of comprehensive patriarchal system structure stimulates great inﬂuence in exploring gender equality ﬁeld. Nevertheless, the utilization of the word “structure” needs to be reconsidered. It is confused that the “structure” means the way in which patriarchy is shaped or the formation of patriarchy concept. The diﬀerentiation results in diﬀerent understanding of patriarchy. The former indicates that there are six ways in which patriarchy is shaped. The latter indicates there are only one way patriarchy could be shaped and the six “structures” are six dimensions of patriarchy. Even though it might be useful to explore the

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classiﬁcations of patriarchy expression especially when it comes to having a deeper understanding of patriarchy, failing to unify the expression forms of patriarchy might not be advantageous to explore the various characteristics of patriarchy manifestation in diﬀerent regions and periods.

After elaborating deﬁnition and classiﬁcation of patriarchy, it is necessary to illustrate the way in which people follow patriarchal rules. Masculinity deﬁnes the way in which women and men should perform according to patriarchal identity and recognition, and diﬀerent forms of masculinity reinforce patriarchy in the society (Martin, 1998). Connell (1987) believed that masculinity refers to relative position of men and women in daily interaction and reﬂects social identity. Hegemony masculinity is the most respectable form in all masculinity types, which is explained by the fact that “ideologically legitimated the global subordination of women to men “(Connell and Messerschmidt, 2005). However, a reminder that the deﬁnition of hegemony masculinity refers to a dominated type of masculinity under current situation of society, thus, speciﬁc manifestation is not ﬁxed and to some extent depends on social contexts (Martin, 1998). Hegemony masculinity could be divided into external hegemony and internal hegemony (Demetriou, 2001). Internal hegemony refers to the privilege among male population group; comparatively, external hegemony refers to male domination in gender relations and male advantageous position in front of women (Demetriou, 2001).

However, masculinity features are distinguished in diﬀerent historical periods (Waters, 1989). Taking the example of domestic allocation sphere, viriarchy is a concept that categorizes masculinity from the perspective of domestic allocation among gender in diﬀerent historical periods (Waters, 1989). Viriarchy is deﬁned as adult male domination and it divides masculine gender system (MGS) into four dimensions including direct patriarchy, direct viriarchy, extended patriarchy and extended viriarchy (Waters, 1989). The two dimensions involve four evolutionary stages which are nomadic pastoralism society, feudalism society, early European capitalism and advanced capitalism (Waters, 1989). The classiﬁcations draw pictures of characteristics regarding relations between gender and domestic allocations in diﬀerent historical stages (Waters, 1989). To sum up, masculinity is the most dominant way of being patriarchy and provides speciﬁc guidance for men and women on displaying patriarchal images in practice; and it has been found that distinctions of masculinity in diﬀerent historical periods have been theorized by viriarchy especially in the domestic allocation ﬁeld.

Nevertheless, not all categorizations of gender relations are based on historical periods (Walby, 2020). Gender relations could also be conceptualized and classiﬁed in a country-based approach (Walby, 2020). Researchers categorized gender relations in diﬀerent countries using gender regime, which can be divided into domestic gender regime and public gender regime

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(Kocabicak, 2022; Walby, 2020). In domestic gender regime countries, women are usually oppressed by men at home and are trapped outside the labour market without uniﬁed national supervision (Walby, 2020). It is believed that women are usually excluded from the labour market and have the responsibility to take the caring role at home (Walby, 2020). Comparatively, in public gender regime countries, the state advocates and promotes gender roles from a macro-national perspective (Walby, 2020). Even though the public gender regime does not separate women from the labour market, nevertheless, it still fails to completely liberalize women in employment relations and exists certain level of restrictions in paid work (Walby, 2020). Moreover, public gender regimes are further divided into normal gender regime, neoliberal gender regime and social democratic gender regime based on diﬀerent restrictions (Kocabicak, 2022). For example, Sweden belongs to social democratic gender regime, and women are able to accept welfare and support from the state (Krigel and Benjamin, 2020). However, it needs to mention that this protection might assume that women are in a lower and subsidiary position in the society, thus, the existence of democratic gender regime ideologically sustains the patriarchal awareness in employment (Krigel and Benjamin, 2020). Therefore, the categorization of gender regime helps to reﬂect diﬀerent types of patriarchal manifestation in a country-based approach.

Even though the deﬁnition and classiﬁcations of patriarchy are popular topics, still many scholars critiqued and discussed the existence of patriarchy due to the inherent ﬂaws of patriarchy (Gottfried, 1998; Pollert, 1996; Walby, 1989). Gottfried (1998) critiqued that patriarchy is over abstract based on historical materialism and believed that it is more appropriate to focus beyond patriarchy. This argument is derived from Pollert (1996), and she stated the necessity to reconsider gender and class in practice rather than continue to emphasize the conceptualization of patriarchy. In addition, Acker (1989) believed that the assumption of patriarchy concept fails to be gender neutral. This means that patriarchy originally believes the status of women is below than that of men, which generates obstacles to women survival in the society. Even though the creation of patriarchy is not supposed to be discriminated against women, patriarchy is still believed hard to capture the dynamics of multiple dimensions, resulting in singularity of analysis dimension (Walby, 1989). Thus, patriarchy’s static expression reduces the availability of practical level analysis especially regarding gender relations (Walby, 1989). Similarly, Walby (1989) and Duncan (1994) argued the tendency of essentialism and ahistorism and critiqued that the theoretical basis of patriarchy is static and fails to reﬂect changes in objective historical events. Nevertheless, the engagement of intersected factors might to some extent reduces the weakness of static expressions of patriarchy (Gottfried, 1998). Gottfried (1998) supports the adoption of feminist historical materialism that is beyond historical materialism and allows the interaction of intersected factors such as class while analysing gender relations from diversiﬁed practices. The diversiﬁed factors allow deeper analysis and exploration of practice diﬀerences. Further, Pollert (1996) also supported the feminist historical materialism lens to analyse patriarchy and

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attached signiﬁcance to actual practices when it comes to capturing the complexity of diversity and dynamics of gender relations in diﬀerent places and periods rather than from theoretical perspective. Overall, the main drawbacks about patriarchy that can be corrected centre around its static nature and the diﬃculty of adapting to diﬀerent places and historical periods. Therefore, the future research might focus on characteristics of patriarchy in diﬀerent regions and historical stages with the engagement of other intersected factors.

After theoretically engaging in the discussions regarding deﬁnitions, classiﬁcation, the way in which people express patriarchal awareness and critiquing of patriarchy, it has been found that the patriarchal relations can be highly penetrated into organization practices (Bailey, 2015; Cohen and Hartmann 2023). Thus, it is necessary to elaborate the extent to which patriarchy is penetrated in organizational practice. The most intuitive manifestation of patriarchy in organizations is that women get less beneﬁts than men caused by privilege diﬀerences, which can be theorized by “patriarchal dividend” (Bailey, 2015). The “patriarchal dividend” is reﬂected in multiple aspects including job recruitment and promotion (Bailey, 2015). The dividend provides men multiple advantages so that making women negatively inﬂuenced in organizations (Bailey, 2015). Cohen and Hartmann (2023) even mentioned that women are more likely to endure mental illness due to double burden in the workplace and at home due to patriarchy. Thus, women get more negative impacts from patriarchy and are in a lower position compared with men’s superior position, though it is undeniable that how patriarchy theoretically shapes women’s employment trajectories is still a research gap in the academia.

Even more unfavourable to women, men’s superior position also inﬂuences the way in which regulations are set in the workplace (Poorhosseinzadeh and Strachan, 2021). The “ideal workers” explicitly deﬁnes the requirements of excellent employees **(**Poorhosseinzadeh and Strachan, 2021**)**. A distinct feature for “ideal worker” is that ideal workers are not restricted to extra caring responsibility at home, however, it has been widely believed that women are in a subsidiary position in gender relations and are usually tied down by childcare role **(**Poorhosseinzadeh and Strachan, 2021**)**. Thus, the “ideal worker” concept is not gender- neutral, and the rule-setting of expectations in organization fails to take women into consideration (Poorhosseinzadeh and Strachan, 2021). For example, the complicated procedure for applying maternity leave could be the manifestation of indirectly implementing control for women. Because organizations fail to routinise maternity leave that is exclusive for women, rather, it still needs approval from superiors. Therefore, men are in an advantaged position which results from patriarchy, and the higher position of men in organizations impacts organizational rule setting.

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However, women are not the only victims under the patriarchal context (Shah, 2023). Men’s dominant position is undisputable in organizations, nevertheless, Shah (2023) stated that patriarchy also has negative impacts on men. Men are required to maintain energetic image so that satisfying expectations from superiors just because they are men (Shah, 2023). Based on ﬂexibility stigma, it reﬂects men’s negative feelings to make a sabbatical leave (Shah, 2023). Speciﬁcally, the image of men who take holidays contradicts with the positive impressions that excellent employees should devote themselves on work (Shah, 2023). However, Shah (2023) stated that economic factor determines the perceptual capability for ﬂexibility stigma, and male employees who have higher economic basis are deemed to be less likely to feel ashamed. But it is still undeniable that male employees who break the patriarchal rules are in the lower position of hierarchal system, which is conceptualized as patriarchal hegemony **(**Poorhosseinzadeh and Strachan, 2021**)**. Therefore, it is not appropriate to state that women are the only victims of patriarchy.

* 1. **The Maintenance of Patriarchy**

After analysing the initial development of patriarchy with historical materialism, it is necessary to evaluate how patriarchy sustains and maintains in the society. Historical materialism can also be applied to illustrate the maintenance of patriarchy (Farrelly, 2011). It is believed that the mutually reinforcing relationship between base economic structure and superstructure sustains the stable development of the society over time (Farrelly, 2011). Theoretically, Marx’s synchronic materialism explicitly deﬁned base (economic structure) and superstructure (Farrelly, 2011). Economic structure is deﬁned as the relationship among productive forces, producers and non-producers (Farrelly, 2011). Superstructure refers to “legal, political, religious and other non-economic institutions” (Farrelly, 2011). Historical materialism believes that economic structure determines the superstructure (Farrelly, 2011). Taking the example of public sphere in China, from the perspective of economic structure, gender relations of production are female subsidiary and male dominated, thus, men are believed to have more advantages than women in the labour market (Woodhams, Xian and Lupton, 2015). According to historical materialism, economic structure determines superstructures (Farrelly, 2011). Thus, from the perspective of superstructure, as mentioned, superstructure refers to the regulations and setting especially regarding culture and legislation (Farrelly, 2011). On the one hand, common sense in Chinese culture tells us women are supposed to take reproduction role at home to support family caring issue while men are supposed to be the breadwinner. On the other hand, Chinese regulation settings are not similar to neoliberalism countries that promotes women to join paid labour market such as UK (Poorhosseinzadeh and Strachan, 2021**)**. But it is still undeniable that the existence of certain women-friendly policies to some extent guarantees the relative balance and stability of the relative position for men and women in society (Cooke, 2011). Therefore, women’s subsidiary role in gender relations

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determines the setting of culture and legislation so that sustaining and maintaining the existence of patriarchy in Chinese society.

However, it is argued that economic structure and superstructure are interrelated, meaning that superstructure to some extent inﬂuences economic structure as well (Farrelly, 2011). Because the practice of institutional settings (superstructure) in society reinforces the gender relations of productions (economic structure) in practice, which also serves the purpose of stabilising patriarchal society (Farrelly, 2011). Therefore, it could be concluded that economic structure and superstructure are intertwined between each other which provides the condition under which patriarchy sustains in Chinese society. Though the complicated relationship between economic structure and superstructure still needs further elaboration because a disputable argument is that the one exists without the other. The argument might indicate that the eﬀect of one on the other is moderating rather than dependent. Therefore, the historical materialism could be applied to evaluate the maintenance of patriarchy in the society, and the conditions under which patriarchy is maintained are established. However, the relationship between economic structure and superstructure is still disputable.

Nevertheless, Pollert (1996) believed that it is not appropriate to analyse from a theoretical level such as mainly focusing on patriarchy concept, it is still of signiﬁcance to consider from individual and daily interaction perspective to uncover the complexity of gender relations when it comes to the maintenance of patriarchy (Pollert, 1996). Similarly, Duncan (1994) believed that it is more appropriate to view gender relations as research emphasis rather than deeper patriarchy concept itself. To be more concrete, West and Zimmerman (1987) found that “gender” can be “doing” in practice which could be reﬂected in gender embeddedness of daily interactions among men and women. Thus, West and Zimmerman (1987) studied “doing gender” and evaluated gender relations from a practical and daily interacted lens. Speciﬁcally, men and women behave and express in a way that is considered to be in line with traditional social value in Chinese society, for instance, men are supposed to be brave and aggressive while women are supposed to be considerate. Therefore, the repetition of the behaviour styles maintains the existence of patriarchy in the society in practice over time (West and Zimmerman, 1987).

After illustrating the reasonability of maintaining patriarchy from historical materialism lens and its alternative analysis from individual daily interaction perspective, it is essential to consider the inﬂuence factors of the maintenance of patriarchy in society. Women’s relative invisibility towards its subsidiary and oppressed position might be a signiﬁcant factor that promotes the maintenance of patriarchy (Acker, 2000). Akanle and Nwaobiala (2020) conducted research regarding the division of labour between men and women. Some women

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aﬃrmed their supportive and subsidiary role in gender relations, which means they failed to realize that it is the rigid and unfair patriarchal pattern that blocks the awakening of self- awareness for women (Akanle and Nwaobiala, 2020). Thus, even though some women are restricted to the outside of labour market, the inequality is still invisible for them so that blocking women to rebel against patriarchy. For women, the low awareness of inequality might reduce the possibility to resist the current situation; for men, they are as vested interests and are certainly less likely to rebel against the status quo. Therefore, certain groups of women are invisible to their subsidiary and oppressed position so that promoting the maintenance of patriarchy.

After illustrating the inﬂuence factors of the maintenance of patriarchy, it has also been found that the maintenance of patriarchy in society has created its legitimacy and can be manifested in organizations (Salem and Yount, 2019; Caven, Astor and Urbanavičienė, 2022). Gender segregation is signiﬁcant manifestation of legitimacy, indicating that gender largely determines organizational decisions (Salem and Yount, 2019; Caven, Astor and Urbanavičienė, 2022). It is found that organizational decision is conducive to men based on the principle that women are in a subsidiary position (Salem and Yount, 2019). Thus, women are usually forced to accept inferior treatments. Even worse, Walker (1998) stated that some women have to endure violence from men especially in Goa, which might be the negative consequence of gender segregation. However, it is not detailed enough to merely deﬁne organizational gender treatment diﬀerences as gender segregation. Because it confuses the position diﬀerences and organizational treatment diﬀerences among gender. Thus, mainstream arguments categorize the gender segregation into two dimensions including horizontal segregation and vertical segregation separately (Batton and Wright, 2019; Anderson and Tomaskovic-Devey, 1995). Further, the signiﬁcance of gender segregation with the analysis of the resource lens has been mentioned (Gu, 2019; Halfacree, 1995). Horizontal gender segregation usually makes men acquire more economic resources from the perspective of better working conditions (Gu, 2019). Thus, men make more economic contributions to their families. The principle of capitalism prioritizes proﬁts and economic resources, which indicates that gender segregation makes men in an advantaged position at home. Men’s higher position at home indicates women’s lower position such as in Jordan, which might inﬂuence women’s job experience (Al- Dajani and Marlow, 2010). However, the experience of certain women in Jordan critiques the comprehensiveness of the argument (Al-Dajani and Marlow, 2010). Because some women generate loads of wealth through entrepreneurship, nevertheless, their subsidiary position is still inevitable in the whole society (Al-Dajani and Marlow, 2010).

However, Bazaz and Akram (2021) stated the appearance of gender segregation usually accompanies other intersected characteristics by critiquing the homogeneity of women. This indicates that women endure diﬀerent levels of burden caused by gender segregation due to

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intersected identities. The intersection of patriarchal inﬂuence is becoming increasingly popular, and the main focus for the intersection involves in class and race etc. (Canham and Maier, 2018; Liu, 2023a; Shung-King et al., 2018). Patil (2013) has started to consider the complexity of the diversiﬁed and intersected factors and deﬁned it as intersectionality. It is argued that intersectionality refers to the intertwining among sex, gender, class and culture, and the diversiﬁed factors have cross-inﬂuence among each other (Patil, 2013). According to the critique of essentialism, even though the essence of patriarchy always refers to women subsidiary position and men dominated position, women experience varies in diﬀerent places and periods (Duncan, 1994). Thus, the homogenization of the female population ignores the dynamic diﬀerences of patriarchal practices, which simpliﬁes the patriarchy concept and makes it static in gender relations (Duncan, 1994; Patil, 2013). Therefore, the intersected factors are worth considering to adding the complexity and deepness (Patil, 2013).

Taking the example of medical industry, women tend to work in lower level of job such as caring job rather than being highly skilled doctors (Shung-King et al., 2018). Because highly skilled occupations are usually prepared for men in the medical industry (Shung-King et al., 2018). Even worse, coloured women are in a lower position in the hierarchal order, thus, they endure disadvantaged treatment not only results from gender but also from race (Shung-King et al., 2018). Hence, not all women experience the same level of discrimination inﬂuenced by patriarchy, so that demonstrating the intersection of discrimination caused by patriarchy and the heterogeneity of women. However, economic level might inﬂuence the level of negative patriarchal impacts, and women who have strong economic basis are supposed to be less inﬂuenced (Shung-King et al., 2018). Further, when it comes to research perspective of intersectionality, it is reported that most of the research pertaining to intersectionality focuses on national angle, meaning that the diﬀerential complexity of interrelation among diﬀerent countries with international lens are usually being ignored (Salem and Yount, 2019).

However, merely considering the current gender relations fails to grasp a holistic tendency for understanding gender segregation in organizations, thus, it is necessary to consider gender relations from the perspective of tendency for reshaping gender relations. Raghuram (2004) studied the inﬂuence of migrant behaviour to men and women for reshaping hierarchal position in organizations. Based on maximization of family utility, it is more beneﬁcial to sacriﬁce individuals who contribute less to family (Halfacree, 1995). Thus, it is more common for a family to prioritise men’s employment choices and ignore women’s employment needs in the migrant behaviour (Halfacree, 1995; Halfacree, 2004). Because scarifying women’s needs has the lowest opportunity costs for a family (Halfacree, 1995; Halfacree, 2004). Therefore, even though employment changes for immigrants provide women a second chance to reshape their career, it is usually diﬃcult for women to reshape their hierarchal position due to the low staring point. Further, racial discrimination also needs to be considered, which

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might cause intersected discrimination for women (Halfacree, 1995; Machado et al., 2023). Overall, from the perspective of gender segregation, not only does the current organization climate blocks women’s employment in organizations, but it also has negative inﬂuences on reshaping unshakable gender relations in another country in migrant behaviour.

Even if the patriarchal system has the conditions to be maintained in the society based on historical materialism, however, it is evidenced that some women tend to rebel against patriarchal rules in the labour market such as China (Evans, 2021). This resistance is deﬁned as patriarchal bargaining (Gu, 2019). Speciﬁcally, women might delay pregnancy time to reduce the negative impacts on their employment (Liu, 2023b). However, Evans (2021) argued that the deﬁnition ignores the long-lasting patriarchal awareness embedded in the society due to its excessive emphasis on behavioural resistance. Thus, the ﬁghting might only be viewed as a way to alleviate the negative impacts caused by patriarchy rather than ease the controlling mechanism of patriarchy. Though in western Berlin, it is reported that some single mothers refuse to accept the dependence on their husband, which to some extent demonstrates that women’s willingness to break out of the patriarchal bondage (Mädje and Neusüss, 1994).

* 1. **The Evolution of Patriarchy**

After demonstrating that the application of historical materialism could explain the concept of patriarchy maintenance in society and illustrating the legitimacy of patriarchy, however, it is worth noting that the mismatch between productive forces and relations of production promotes the update of productive forces so that promoting the development and evolution of patriarchy (Farrelly, 2011). According to diachronic materialism, the changes of productive forces are supposed to be signiﬁcant attribution of the evolution of patriarchy and also facilitate social development (Farrelly, 2011; Ross, 2008). Taking the example of capitalism, capitalism society prioritises capital in society, thus, productive forces from the gender viewpoint in capitalism society needs to be adaptable to the prioritization. Speciﬁcally, the way in which labour is distributed in capitalist relations of production is obviously more liberalized as opposed to the earlier entrenched male bread-winner female caring job model. Thus, unshackling women’s reproduction stimulates more women to create more economic value for national market so that following the value and prioritization of capitalism society (Cohen and Hartmann, 2023). The stimulus usually refers to lowering the threshold of entering national labour market to increase the opportunities of women in employment and adapt to the development of productive forces (Cohen and Hartmann, 2023). Though neoliberalism reduces the introduction of policy favouring women and still maintains the disadvantaged position for women in employment (Cohen and Hartmann, 2023). Further, technology also

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makes a diﬀerence (Farrelly, 2011). The advancement of technology promotes medical level leading to the reduction of child mortality (Farrelly, 2011). The reduction of child mortality results in the fact that women’s role in the labour market produces more beneﬁts in society than reproduction (Farrelly, 2011). However, for the relatively undeveloped countries with limited medical resources, women are supposed to take caring responsibility at home so that facilitating reproduction issue (Farrelly, 2011). Because under-developed medical level reduces population health and needs more reproduction (Farrelly, 2011). Therefore, the changes of productive forces promote the update of gender relations by adjusting certain national policies with the intervention of technology so that making it possible to reshape the pattern of patriarchy over time.

However, as mentioned above, when it comes to the relationship between patriarchy and capitalism, discussions pertaining to the independence of capitalism and patriarchy are popular and disputable in the academia and fail to reach consensus (Gottfried, 1998; Walby, 1989; Pollert, 1996). Even though the above capitalism example to some extent indicates the co- existence of capitalism and patriarchy when explaining the evolution process of patriarchy, Gottfried (1998) stated that the two has dualist relationship. The dualist ideology between capitalism and patriarchy demonstrates mutual independence of the two (Gottfried, 1998). Mitchell might also agree with the independence because Mitchell emphasized the two systems with diﬀerent focused dimensions while analysing capitalism and patriarchy system, which involves economic and unconscious dimension respectively (Walby, 1989). The separation of analysis angle admits the independence of capitalism and patriarchy and believes that these two systems belonging to diﬀerent dimensions. Further, Pollert (1996) also mentioned the diﬀerence of the two systems and argued that capitalism and patriarchy have diﬀerent intrinsic motivation. Speciﬁcally, capitalism views the pursuit of capital itself as intrinsic motivation while the intrinsic motivation of patriarchy has not been mentioned (Pollert, 1996).

Apart from the independent relationship between patriarchy and capitalism, the causal relationship is also a signiﬁcant point of criticism (Walby, 1989). Walby (1989) stated that patriarchy is not derived from capitalism, which could be demonstrated by the fact that the shadow of patriarchy can be found in feudalistic society and socialist countries. For instance, China, as a socialist country, also has certain patriarchal traditions and customs embedded in social structure, and patriarchal culture exits in Chinese society (Liu, 2024). From the viewpoint of family, gender division of labour is most commonly characterised by traditional type which means that women take caring roles and men take the breadwinner role (You, Yi and Chen, 2021). Thus, the imposed caring responsibility for women blocks their opportunities to achieve individual development which reﬂects patriarchal ideology. However, family angle is not the only angle that reﬂects patriarchal culture, organizational behaviour

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also manifests women’s disadvantaged position compared with men (Tatli and Ozturk and Woo, 2017). It has been evidenced that the number of female managers in Chinese organizations is less than male managers, which could infer less resources women acquired in organizations and their subsidiary position (Tatli and Ozturk and Woo, 2017). Hence, it is demonstrated that China as a socialist country exists patriarchal cultures, and the patriarchy has been practically manifested in family and organizational dimensions. Therefore, the above demonstration critiqued the argument that patriarchy is derived from capitalism.

The above analysis emphasized the signiﬁcance of productive forces towards the evolution of patriarchy and discussed the relationship between capitalism and patriarchy. Moreover, national natural resources are also a useful analysis angle when it comes to the evolution of patriarchy (Farrelly, 2011). Farrelly (2011) believed that national natural resources inﬂuence productive forces so that making eﬀects on gender relations of production, thus, it could infer that natural resources might have something to do with the evolution of patriarchy. Speciﬁcally, in middle east countries, the abundance of oil resources results in increasing the intensiveness of export mining industry (Farrelly, 2011). The intensiveness indicates that women’s reproduction work is less eﬀective than entering the labour market in the mineral sector (Farrelly, 2011). Because natural resources create huge economic development opportunities (Farrelly, 2011). However, common sense tells us that mining industry is physically demanding which indicates that the industry increases entry threshold for women. The higher threshold to some extent stimulates the subsidiary position of women in paid work especially the mainstream job that requires high level of physical labour (Norris, 2009). In addition, the female disadvantages also indirectly result in less national political election rights for women (Farrelly, 2011). Thus, natural resources to some extent inﬂuence gender relations which reﬂect in the evolution of patriarchy characteristics in a particular country and even negatively block women political position such as election rights. However, not all natural resources have negative impacts on women in the labour market (Farrelly, 2011). For instance, in Canada Alberta, gender relations fail to be negatively inﬂuenced by plenty of natural resources because Alberta has reported high level of female engagement of economic development (Farrelly, 2011). In addition, the enactment of the act in Canada regarding women protection also indicates the inclusion of women in society (Farrelly, 2011). Therefore, natural resource is a signiﬁcant angle to analyse the evolution of patriarchy, though the inﬂuence of natural resources on the direction of patriarchal shaping remains regionally diverse.

The above analysis elaborated patriarchy evolution from the angle of natural resources. However, Duncan (1994) stated that the evolution of patriarchy is highly diﬀerentiated. The diﬀerentiation means that patriarchy does not evolve in a ﬁxed pattern but varies from region to region in diﬀerent historical periods (Duncan, 1994). Pollert (1996) stated that the

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diﬀerentiation reduces the usefulness of patriarchy because it makes patriarchy fail to explicitly respond to actual practices in diﬀerent places and periods. However, diﬀerentiation does reﬂect the extent to which typical patriarchy is being adapted in diﬀerent places. Thus, the diﬀerentiation of patriarchy research indeed helps to deepen the understanding of modes of embedded patriarchal relations so that contributing to minimize the negative impacts of historical remaining. Hence, further academic understanding and research regarding patriarchy and its diﬀerentiation is still necessary. Sharabi (1987) deﬁned typical patriarchy in Arab as neopatriarchy. The neopatriarchy seems to superﬁcially summarize the features of patriarchy in Arab, however, it actually exposes the necessity to consider diﬀerences of typical patriarchy in diﬀerent geographical places and historical periods (Sharabi, 1987). Apart from neopatriarchy, the diﬀerentiation of patriarchy due to diﬀerent level of adaptation to local customs and cultures has attracted many scholars’ attention, and many countries are being studied such as Islamic, Pakistan and Sandi Arab (Haghighat, 2005; Habiba, Ali and Ashfaq, 2016; Adham, 2022). Nevertheless, it needs to mention that there is little research pertaining to the adaptation of the typical patriarchal system in China. But Evans (2021) proposed patchy patriarchy in China, which captures typical characteristics of Chinese patriarchy. This can be viewed as a successful research attempt in China that could catch Chinese diﬀerentiated features of patriarchy.

It has been evidenced that characteristics of patriarchy in China to some extent make impacts on women’s lifecourse. Taking the example of education factor, educational level for Chinese women might be largely impacted by patriarchal ideas, and it is believed that female oﬀspring in a family receives fewer educational resources (Wang, 2005). Speciﬁcally, if viewing the allocation of educational resources as family investment, it would be more economically beneﬁted to invest resources on boys due to male privilege in the labour market in their future career development. Thus, overall, Chinese women’s educational experience is not as rich as men’s so that inﬂuencing women’s lifecourse trajectory and personal development; in turn, women’s less educational opportunities acquired might result in the disadvantaged position in the labour market and less labour remuneration (Wang, 2005). Even worse, women’s unfair treatment in the labour market might to some extent legitimizes parents’ male preference in terms of gender diﬀerences in educational decisions so that leading to vicious circle. This education diﬀerence by gender is therefore considered to be a concrete manifestation of the patriarchal ideology that inﬂuences women’s lifecourse (Wang, 2005). However, women’s educational impediments are merely passive choices which depends on their parents’ patriarchal ideas and gender consciousness. Thus, it is still necessary to consider the subjective level of lifecourse trajectory while exploring patriarchy. It has been evidenced that women are in favour of caring responsibility at home rather than career development, meaning that women tend to sustain their family by abandonment of individual development while facing conﬂict of interest (Halfacree, 1995; Halfacree, 2004). However, how patriarchy shapes women’s subjective choices are still a research gap, though it is still undeniable that

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some scholars have studied how women navigate work and life domain through the exploration of work-life interface theory (Ezzedeen and Zikic, 2017; McMillan, Morris and Atchley, 2011; Rosa, 2022). Overall, most research emphasizes passively accepted negative inﬂuences on women manifested in personal development, family and organizations. However, how patriarchy theoretically shapes women’s subjective choices needs further exploration.

1. **Research Questions**

Main question: How is patriarchy implicated in women’s subjective control of personal development trajectory in China?

Sub question 1: How do patriarchal ideologies embedded in political, social and legal structures shape women’s lifecourse in China?

Sub question 2: How do women’s career choices reﬂect the inﬂuence of patriarchy in China?

1. **Methodology**

The study will adopt an interpretivist approach as philosophical position (Saunders, Lewis and Thornhill, 2007). Firstly, the study assumes that the essence of reality is subjective and diversiﬁed, meaning that human beings’ subjective feelings and perceptions of the world are deemed the truth in the world. Accordingly, in the patriarchal research, the reality is considered to be the subjective patriarchal understanding and perceptions in legal, political and social perspectives. The subjective nature means that the results of the study depend

heavily on participants‘ feelings and viewpoints. Additionally, large number of participants (40

interviewees in the research) might increase the complexity and richness of research analysis due to diﬀerences in the personal background of interviewees. Even though the research lacks numeric data, the research does contain textual data that responds to human beings’ mindset pertaining to the shape of patriarchy in society at the level of human subjective ideology. It is the subjective ideology that increases the complexity and depth of research results rather than the experimental results of the single factor correction yielded (Saunders, Lewis and Thornhill, 2007). The exploration of numeric data and causal factors is more related to quantitative research rather than focusing on the long-term shaping and multidimensional impact of patriarchy in society (Saunders, Lewis and Thornhill, 2007). Therefore, the assumption regarding subjectivity and diversity of reality nature is appropriate for the research topic.

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Secondly, after illustrating the essence of reality, it is necessary to discuss the acquisition of reality. The research assumes that the reality could be acquired from communication and interaction with participants. The study will capture reality that has been shaped by patriarchy thinking especially in the domains of lifecourse and employment. However, the interpretivism philosophical position makes it diﬃcult to examine research reliability (Saunders, Lewis and Thornhill, 2007). This is because it would be diﬃcult to break through respondents’ psychological defences during the interview and open up their personal feelings and viewpoints because participants might subconsciously answer questions based on researcher’s expectations. Even though the reliability and truthfulness of the answer can be guaranteed, it is still diﬃcult to verify the research from a rigorous scientiﬁc methodological perspective. Compared with interpretivism, positivism is easier to test the validity of research because positivism aims to emphasize universal laws from an empirical perspective using rigorous scientiﬁc reasoning (Saunders, Lewis and Thornhill, 2007). However, it is undeniable that it is unrealistic to generalize rules and even test how patriarchy shapes women’s career and lifecourse choices. This is because there are diﬀerences in each person’s upbring and educational experiences and even in their genes in terms of how they perceive emotions. Therefore, the research is not appropriate to adopt positivism philosophical position. Comparatively, functionalism focuses more on social structures and functional shaping of the society in diﬀerent aspects and attaches signiﬁcance to the functionality of the components of the social structure (Saunders, Lewis and Thornhill, 2009). Even though it is undeniable that the adoption of functionalism might help to analyse the embeddedness of patriarchy from the perspective of social structure, the motivation of the research emphasizes patriarchy’s shaping of the subjective dimension of femininity. Therefore, it would be comparatively suitable for the research to apply interpretivism as philosophical position. To sum up, the interpretivist philosophical position assumes that the reality is subjective and diversiﬁed, and the reality could be acquired through communication and interaction with human beings.

1. **Research Design**

Typology of research design could be divided into two research strategies including general interest and contextual interest (Klopper, 2008). The research will apply contextual interest because the study view China as research context to characterize the typology of patriarchy in China pertaining to how patriarchy shapes working women ‘s lifecourse and employment choices.

* 1. **Sampling**

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The research will apply purposive sampling in data collection and will use typical case sampling (Van den Bulck, 2019). This is because the research expects to draw a picture of the typical ways in which patriarchy shapes women’s lifecourse and employment trajectory in China. In doing so, target samplings are supposed to fulﬁl the following standards. First and foremost, participants should be Chinese working women. Secondly, the Chinese working women should take on dual responsibilities in the family and organizations simultaneously, meaning that this part of women might have the concern of balancing work and life. However, it needs to mention that purposive sampling is relatively diﬃcult to implement (Van den Bulck, 2019). In comparison, the deﬁciency could be remedied by convenient sampling because the process of convenient sampling is voluntariness without complicated standard setting (Van den Bulck, 2019). Nevertheless, it might be diﬃcult to guarantee that volunteers’ personal situation is deeply in line with the topic that patriarchy shapes working female mindset (Van den Bulck, 2019). Therefore, comparatively, the advantage of purposive sampling is obvious compared with convenient sampling.

Even though purposive sampling largely guarantees that sample is highly adaptable to the research topic, the purposive sampling still has its drawbacks (Van den Bulck, 2019). It might be diﬃcult for purposive sampling to target and get access to the appropriate women (Van den Bulck, 2019). Comparatively, snowballing sampling might reduce the diﬃculty to get access to interviewees because participants would recommend the next person (Van den Bulck, 2019). Nevertheless, it is doubtful that participants are willing to recommend, additionally, once the snowball trajectory is broken it will be diﬃcult to continue targeting candidates. Additionally, whether the recommended candidates are suitable for the research still needs to be considered. Therefore, it seems that purposive sampling is more reasonable for the research. Further, the research will accept the support of friends and relatives to introduce eligible candidates and set economic stimulus such as 100 CNY shopping voucher to encourage potential candidates to participate.

* 1. **Data collection**

The study will use biographical semi-structured in-depth interview to collect data from Chinese women in Zibo China in line with the research aims and the project interest in the lifecourse and employment lens. The chosen city Zibo is located in the east of China, thus, the research could represent women’s patriarchal ideologies in small cities in eastern China. On the one hand, semi-structured interview provides a ﬂexible framework to systemize answers from interviewees (Saunders, Lewis and Thornhill. 2007). Thus, semi-structured interview

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leads the direction of communication and facilitates to collect targeted data to explore how patriarchy shapes women’s lifecourse and employment trajectory. On the other hand, biographical method requires participants to share personal stories and values the distinctiveness of participants so that deepening the understanding of women’s motivation regarding lifecourse and employment choices (Merrill and West, 2009). Thus, not only does the integration of biography and semi-structured interview provides participants with narrative directions but also allows participants to freely recall personal stories and trajectory (Rosenthal, 1993; Merrill and West, 2009). Speciﬁcally, from the perspective of hermeneutic reconstruction, narrative biographical interview includes two types of principles including reconstructive analysis principle and the principle sequentiality (Rosenthal, 1993). The research will apply the principle of sequentiality because the principle considers the sequences of diﬀerent stages in women’s lifecourse so that making the interview process more coherent. The interview questions will be drafted around the following three themes including the educational trajectory, personal development in the labour market and motherhood choices. But it needs to mention that the theme sequence of interview questions in the data collection process would be diﬀerent from the sequence of themes in data analysis process. This is because the recategorization of themes needs to be carried out in the coding process which lays foundation for the application of thematic analysis (Rosenthal, 1993).

The data collection will be set in a face-to face format because face-to-face data collection increases visual stimulation and catches visual details (Novick, 2008). The capture of visual information allows researcher to drive the continuation or terminal of interview through some subtle gestures of demeanour; additionally, researcher could also aﬃrm or question the truthfulness of what is being discussed in some unexpected gesture. These advantages are not available in non-face-to-face interviews such as telephone interview (Novick, 2008). Nevertheless, it could argue that applying technology such as Zoom to collect data could also catch visual information and is more convenient (Latkovikj and Popovska, 2019). We cannot deny that the advantages of applying technology in data collection such as signiﬁcantly reducing the cost of time and money (Latkovikj and Popovska, 2019). However, it has been evidenced that whether using technology to conduct interviews is eﬃcient depends on whether participants are heavy media users (Kazmer and Xie, 2008). Only when interacting with participants who are heavy media users can the research eﬃciency being increased (Kazmer and Xie, 2008). Additionally, it is reported that young people are more acceptable to media and technology which makes them more likely to be heavy media users (Kazmer and Xie, 2008). This could infer that applying technological software such as Zoom might merely increase the eﬃciency of young participants. Further, researcher might spend more time on teaching older participants so that reducing the eﬃciency of the research. It also needs to consider that older participants who are not patient enough might drop out of the study, which makes the study skew towards the young (Kazmer and Xie, 2008). To sum up, it is more appropriate to apply oﬄine interview to collect data.

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The research will interview 40 Chinese working women. It is reported that the appropriate number for participants is around 30 in single organizations and is 50 in multiple organizations (Saunders and Townsend, 2016). Since the research would focus on diﬀerent organizations, thus, it seems that 50 should be appropriate. However, it is evidenced that too many participants might result in the diﬃculty to analyse in depth so that leading to superﬁcial discussions in data analysis (Saunders and Townsend, 2016). Thus, the research will interview 40 participants to deepen exploration of patriarchy with high saturation. In addition, as to the age of participants, the research will select women between the ages of 25-50 years of age. As to the lower limit, it is reported that it takes time for people to make the transition from being a student to being a social worker (Peng, 2020). Thus, the study believes that only employees who have been working for a few years can be used as participants. As to the upper limit, the highest age for the selected participants is 50 years of age. It is reported that the retirement age for white-collar women in China is 55 years of age (Giles t al., 2023). However, it is evidenced that employees have less engagement and commitment level when they are approaching retirement (De Wind et al., 2017). Thus, the study set 50 years of age as the upper limit. Therefore, the study will interview Chinese working women who are 25-50 years of age. After explaining the number and age of participants, it is necessary to consider the target industry. The target participants will focus on employees in ﬁnancial industry because the competitiveness of ﬁnancial industry might intensify contradiction between patriarchy and women’s subjective control in work and lifecourse trajectories, and the ﬁnancial industry has high level of gender inequality (Baeckström, 2022; He and Wei, 2023). However, it is still necessary to set the boundary of so called ‘ﬁnancial industry’ because the scope of the deﬁnition of ‘ﬁnancial industry’ is broad. To be more speciﬁc, the research anticipates interviewing three people per week (with the participation sheets signed before interview). The location of interview depends on collective decision-making between the interviewee and interviewer. Data collection is expected to be completed within three months.

* 1. **Data analysis**

The research will adopt thematic analysis. Firstly, from the viewpoint of the ﬁtness of methodology and thematic analysis, it has been demonstrated that thematic analysis could be integrated with any methodologies, thus, it is appropriate for the interpretivist research to adopt thematic analysis (Ciesielska and Jemielniak, 2018). Compared with template analysis, the thematic analysis provides data analysis with enough freedom so that reducing negative interference of predeﬁned templates that set boundaries for analysis process (Saunders, Lewis and Thornhill. 2007). However, the freedom might increase the implementation diﬃculty

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especially in categorizing and extracting diﬀerent themes in large amount of data. Comparatively, qualitative content analysis could save research time and is easier to operate compared with thematic analysis (Vaismoradi and Snelgrove, 2019). But qualitative content analysis focuses more on describing and summarising data rather than deep interpretation (Vaismoradi and Snelgrove, 2019). Since the research expects to interpret and explore how patriarchy shapes women’s subjective choices based on narratives. Thus, it could infer that applying thematic analysis is more possible to acquire deep analysis and insights. Further, when it comes to the speciﬁc angles to implement thematic analysis, the research will integrate ‘literal’, ‘interpretive’ and ‘reﬂexive’ angles to analyse the shaping of patriarchy reﬂected in women’s mindset (Welsh, 2002). Speciﬁcally, not only does the research explain women’s life trajectory from the literal level, but it also interprets deeper meanings through making connections between women subjective decision-making and patriarchal ideology. Further, the inﬂuence of interviewer to the research will also be analysed based on the reﬂexive angle.

The research will adopt NVivo software to analyze data because NVivo is a software specializing in handling qualitative data (Van den Bulck et al., 2019). NVivo’s clear layout such as appropriate setting of function buttons and coloured bar promotes the eﬃciency of data analysis so that reducing the occurrence of accidental errors (Van den Bulck et al., 2019). However, researcher still needs to manually code data to diﬀerent themes which might be time-consuming (Sotiriadou, Brouwers and Le, 2014). In comparison, Leximancer has the function of automatically coding based on the frequency of diﬀerent keywords (Sotiriadou, Brouwers and Le, 2014). The automatic coding without doubt reduces labour and time costs, but it reduces the contribution of human intelligence to the research (Sotiriadou, Brouwers and Le, 2014). Further, it has been evidenced that the positive eﬀects of software on the eﬃciency of research is inﬂuenced by the familiarity of researcher to the software (Paulus et al., 2017). This indicates that I need to have high familiarity with the NVivo software. With the foundation of the NVivo elective in the ﬁrst year of the PhD, I plan to familiarise myself further with NVivo during the data collection period so that laying foundation for future data analysis. Nevertheless, it needs to mention that qualitative analysis software is merely auxiliary tool and cannot dominate the analysis process. It is still necessary to value the subjective judgemental steps.

To be more speciﬁc, the detailed steps to analyse data are as followed. I will ﬁrst familiarize myself with the imported data and categorize the data into three primary themes including the educational trajectory, personal development in the labour market and motherhood choices. In the process of categorization, I will take notes of keywords in diﬀerent stages to lay foundation for the ﬁnal readjustments of themes. After that, I need to reconsider the themes and make adjustments based on the notes. This process is signiﬁcant because it sets the ﬁnal

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themes. The setting of the ﬁnal themes will be based on a standard which is ’recurrent and distinctive features of participants’ accounts, characterize particular perceptions and/or experience which the researcher sees as relevant to the research questions’ (King and Herrocks, 2010). Lastly, I need to interpret and abstract data in diﬀerent themes (Ciesielska and Jemielniak, 2018; Lester, Cho and Lochmiller, 2020).

1. **Ethical Consideration**

Ethical issue of the research might involve participants, related organizations and the society. Firstly, the research might make negative impacts on participants because the interview questions will be related to women’s individual life and employment experience, and the questions might involve certain unfair working treatment and negative trajectory choices. The reminder of these issues might cause psychologically negative impacts on participants. Secondly, the research might also have implicit conﬂict of interest. The distinguished one is that the disclosure of unfair and non-conforming regulation settings mentioned in the narrative of participants might conﬂict the interests of related organizations. On the one hand, from the standpoint of the research, disclosure of unethical organizations contradicts the principles of protecting the researched organization. On the other hand, from the standpoint of the whole society, the rejection of disclosure means the condonement of wrongful acts that have negative implications for society. The research will be benchmarked against local laws. As long as participants’ narratives do not involve law-breaking phenomena, the study will view them as reasonably analyzable data.

The research will undergo full ethical review by the University of Manchester’s University Research Ethics Committee (UREC). The researcher is currently in the process of preparing the application for ethical approval.

1. **Expected Research Implications and Limitations**

The expected research implications of the research are to ﬁgure out the typical appearance of patriarchy in China through exploring how patriarchy shapes women’s personal choices. However, the research still exists limitation. The research will collect data in Zibo China, meaning that it might not be able to reﬂect diﬀerences across regions. However, it is undeniable that it would be unrealistic to use 40 samples to represent diﬀerent cities in the whole China. Therefore, it might be appropriate for this research to represent small eastern cities in China pertaining to patriarchy’s shaping of women’s mindset.

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**From Individual to Team Recovery：A Comprehensive Review**

**Abstract：**In contemporary organizational settings, the ability to recover from work- related stress is essential for employees for maintaining well-being, sustaining

motivation, and improving job performance. While recovery at the individual has been extensively studied, the mechanism of recovery at the team level remains underexplored. With the increasing prevalence of team-based work structures, recovery at the team level not only influences individual well-being but also plays a crucial role in enhancing team effectiveness and promoting organizational development. This study firstly comprehensively reviews the employee recovery research at the individual level with its concept , theoretical foundations, as well as its antecedents and outcomes. Then this research expands the discussion of the recovery at the team level, by discussing how team members collectively unwind and restore their psychological and physical resources. The study provides preliminary discussions of recovery at the team level regarding conceptualization, mechanisms, antecedents, and outcomes, and addresses some key research themes for future research.

1. **Theoretical Foundations of Recovery**
   1. **Concept and Range of Employee Recovery**

Within the organizational literature, recovery is defined as "the unwinding process of reducing or eliminating strain caused by work stress" (Sonnentag,et al , 2017). The recovery process is essential for employees, as they encounter various job demands that induce psychological and psychological strain, such as distress, anxiety and exhaustion (Bennett et al., 2016). As a result, recovery from work is a critical process that enables employees to sustain their well-being and performance in demanding work environments.

Recovery process can occur across multiple temporal and spatial contexts. Within the workplace, employees may experience recovery through micro-breaks between tasks

such as nutrition taking and relaxing(Kim et al., 2017),or during designated break periods such as lunch break (Trougakos et al., 2014). Beyond the work setting, recovery also takes place during evening leisure time (Ouyang et al., 2019), weekends (Fritz et al., 2010), or extended periods such as vacations (Chan et al., 2022). Each of these recovery opportunities vary in duration and effectiveness, offering distinct mechanisms for replenishing depleted psychological and physiological resources.

* 1. **Two Research Streams：Recovery Activities and Experience**

Research on recovery processes has been approached from two distinct yet complementary perspectives: recovery activities and recovery experiences. Firstly, extensive literature has examined specific activities individuals engage in during non- work time and their effects on recovery outcomes. Sonnentag (2001) classified these activities into two broad categories based on their duty profile. Recovery activities are categorized as low-duty activities, such as physical exercise, socializing with friends, and engaging in relaxation. They are theorized to facilitate resource replenishment and alleviate strain through mechanisms such as psychological detachment, positive affect induction, and the cessation of work-related demands (Sonnentag, 2001). In contrast, high-duty activities, including work-related tasks undertaken during leisure time and household responsibilities, are posited to hinder recovery by perpetuating cognitive and emotional demands, thereby depleting personal resources and impeding the restoration process(Sonnentag, 2001).

Sonnentag and Fritz (2007) further introduced the concept of recovery experiences, arguing not the specific recovery activities, but the specific psychological experiences that occur during these activities are crucial for understanding the recovery process. They suggest that the effective recovery underlying four core subjective recovery experiences: psychological detachment (mentally disconnecting from work), relaxation (low levels of mental or physical activation and little physical or intellectual effort), mastery (engaging in challenging or skill-building activities), and control (to choose activities that best meet their recovery needs). Specifically, according to the meta-

analyses, psychological detachment is the recovery experience that has been most extensively studied, while some research utilises the combination of the four recovery experiences to evaluate the effectiveness of recovery(Bennett et al., 2016).

* 1. **Theoretical Foundations**

Current recovery research relies mainly on the Effort Recovery Model (ERM) (Meijman & Mulder, 1998), the Conservation of Resources (COR) theory (Hobfoll, 1989, 2002) and the Job Demands-Resources (JD-R) model (Demerouti et al., 2001) to shape the understanding of the recovery process.

Firstly, the ERM emphasizes that the high work demands require effort expenditure, which leads to employees’ load reactions in physiological and psychological symptoms, such as increased cortisol levels and fatigue (Meijman & Mulder, 1998). According to ERM, recovery occurs when work demands cease, allowing these load reactions to return to baseline levels. If the recovery is insufficient, employees must exert additional effort to compensate for their suboptimal state, potentially leading to a negative spiral of increasing strain.

In addition, COR theory (Hobfoll, 1989) provides a recovery-based lens to view the recovery process. COR proposes that individuals are motivated to obtain, maintain, and protect their resources (Hobfoll,2002). While work demands consumer resources, employee recovery functions as the process through which depleted resources are restored. Moreover, COR theory suggests individuals greater resource reserves are more likely to gain additional resources, which leads to positive "gain spirals" that can enhance the recovery process (Hakanen et al., 2008).

The JD-R model (Demerouti et al., 2001) integrates above perspectives by positioning demands and resources as parallel processes that influence employee well-being. Resources can buffer the impact of demand, and recovery may serve as a mechanism that mediates the relationship between these factors and various outcomes. The model suggests that the constellation of demands and resources (e.g., high demands-low

resources vs. high demands-high resources) has implications for whether employees develop strain outcomes.

* 1. **Predictors of Recovery**

Research has identified multiple factors that influence employee recovery processes, with job demands and resources emerging as primary predictors within the JD-R framework (Bakker & Demerouti, 2017). Additionally, individual differences and organizational factors have been recognized as important predictors of recovery experiences.

* + 1. **Work Demands**

Work demands are work characteristics that require sustained physical, emotional or cognitive effort (Demerouti et al., 2009). Work demands play a crucial role in determining an employee's ability to recover after work, aligning with the Effort- Recovery (E-R) model. This model suggests that work demands can consume energy, heighten stress levels, and extend feelings of strain, ultimately hindering the recovery process (Sonnentag et al., 2014; Sonnentag & Fritz, 2015). Given the complexity of these demands, ten Brummelhuis and Bakker (2012) categorize them into four distinct types: overload, physical, emotional, and cognitive. Each demand uniquely influences recovery by reducing available downtime and sustaining heightened activation levels. Overload demands, for instance, often blur the boundaries between work and personal life, making detachment difficult (Sonnentag & Bayer, 2005). Similarly, emotional and cognitive demands prolong stress, preventing employees from fully unwinding (Bennett et al., 2016). However, physical and cognitive demands, while generally hindering recovery, may also offer employees a sense of accomplishment or control, which can mitigate their negative effects to some extent (Crawford, LePine, & Rich, 2010; Michel et al., 2016).

While all forms of work demand have the potential to obstruct recovery, emotional and overload demands are particularly detrimental due to their persistent psychological burden(). Understanding these distinctions can help organizations develop strategies

that promote employee well-being by mitigating excessive demands and encouraging effective recovery practices.

While work demands can deplete employees' resources and necessitate recovery, their effects vary depending on the nature of the demands and employees’ perceptions. The Challenge-Hindrance-Stressor framework (Cavanaugh et al., 2000) provides a nuanced perspective, categorizing job demands into challenge demands, which have the potential to foster personal growth and development, and hindrance demands, which obstruct goal achievement and contribute to strain.

Challenge demands are job characteristics that, while requiring substantial effort, can also offer opportunities for individual development and achievement (Crawford et al., 2010). These demands may enhance recovery experiences, especially with when they lead to a sense of accomplishment and motivation: For instance, high workload, when perceived as challenging rather than overwhelming, can contribute to positive recovery experiences by fostering a sense of achievement (Tadić et al., 2015). Job responsibility levels exhibit mixed effects on recovery; while they may be energizing during work, they often require substantial recovery time afterward (Webster et al., 2011). Learning demands can stimulate personal growth but may simultaneously increase cognitive recovery needs (Van den Broeck et al., 2010).

In contrast, hindrance demands are work characteristics that obstruct personal development and goal attainment, creating strain and impeding recovery (Cavanaugh et al., 2000). These demands tend to drain energy without offering the motivational benefits associated with challenge demands: For instance, role ambiguity and conflict strongly impair psychological detachment and diminish recovery quality (Sonnentag & Fritz, 2015). Job insecurity has particularly strong negative effects on recovery, leading to persistent stress and impaired well-being (De Witte et al., 2016). Organizational politics generate emotional strain that disrupts recovery processes (Chang et al., 2009).

* + 1. **Resource**

While the Effort-Recovery (E-R) model (Meijman & Mulder, 1998) posits that recovery

primarily occurs following the cessation of work demands, the Conservation of Resources (COR) theory (Hobfoll, 1989, 2002) provides a more comprehensive framework for understanding recovery processes. COR theory suggests that resources serve dual functions: they not only buffer against stress but actively contribute to psychological replenishment and adaptive resilience. Contemporary research has advanced the understanding of resource dynamics in recovery, distinguishing between contextual and personal resource categories (ten Brummelhuis & Bakker, 2012).

Contextual resources are external factors that support recovery and can be categorized into work-domain and non-work-domain resources (Hobfoll, 2002).

Work-domain resources include job-related factors that enhance autonomy and reduce stress, such as supervisor support, job control, and organizational flexibility (Demerouti et al., 2001). Employees with greater job control can structure their work schedules to allow for recovery activities (Rodriguez-Muñoz et al., 2012). Additionally, supportive work environments reduce work-related rumination at home, fostering a more effective recovery process (Bakker et al., 2005). However, some research suggests that while work resources contribute to relaxation and a sense of control, they may not necessarily facilitate psychological detachment from work (Kinnunen et al., 2011).

Non-work domain resources refer to resources from family and social support—critical for effective unwinding. A supportive home environment can enhance recovery activities by making them more enjoyable and restorative (Park & Fritz, 2015; Shimazu et al., 2014). These resources help mitigate the lingering effects of work stress and act as key determinants of an individual’s ability to achieve psychological recovery.

Beyond external factors, personal resources also play a crucial role in recovery. Personal resources include stable individual characteristics and psychological traits, such as self-efficacy and self-esteem, that enable individuals to navigate work-life balance more effectively (ten Brummelhuis & Bakker, 2012). Employees with strong personal resources often perceive greater control over their time, which helps them

engage in recovery activities more readily (Kinnunen et al., 2011). Additionally, individuals with high personal resources tend to experience gain spirals—a phenomenon where existing resources help generate new ones, further supporting recovery over time (Hobfoll et al., 2018).

* 1. **Outcomes of Individual Recovery**

Recovery experiences and processes have been associated with a wide range of significant outcomes across multiple domains, with particularly robust evidence in the areas of psychological well-being and performance (Sonnentag & Fritz, 2015). In this section, we will discuss these outcomes in terms of psychological well-being, psychosomatic well-being, and performance.

* + 1. **Psychological Well-being Outcomes**

Successful recovery has been consistently linked to enhanced mental health and emotional states. Studies demonstrate increased positive effects and decreased negative effects following successful recovery periods (Demerouti et al., 2009). Enhanced life satisfaction has been documented, particularly when recovery experiences include both physical and psychological detachment (Fritz & Sonnentag, 2006). Additionally, reduced emotional exhaustion and burnout symptoms are observed with regular recovery practices (Bakker et al., 2013).

* + 1. **Psychosomatic Well-being**

In terms of psychosomatic well-being, improved sleep quality is one of the most consistently reported benefits of effective recovery (Wendsche & Lohmann-Haislah, 2017). Research shows reduced physical complaints and psychosomatic symptoms following recovery periods (Geurts & Sonnentag, 2006). Moreover, lower levels of fatigue and enhanced energy levels are associated with successful recovery experiences (Zijlstra & Sonnentag, 2006). Physiological indicators such as reduced cortisol levels and improved heart rate variability have also been documented, further supporting the positive impact of recovery (Rook & Zijlstra, 2006).

* + 1. **Performance Outcomes**

The impact of recovery on employees’ performance is also substantial. Several studies indicate positive relationships between recovery and task performance (Fritz et al., 2010). Enhanced cognitive functioning, including improved attention and decision- making capabilities, has been linked to successful recovery (Binnewies et al., 2010). Creative performance and problem-solving abilities show improvement following recovery periods (de Bloom et al., 2015). Additionally, recovery contributes to contextual performance, with research documenting increases in organizational citizenship behaviors, improved interpersonal behaviors, and enhanced communication effectiveness (Sonnentag, 2003; Volman et al., 2013). Moreover, recovery is positively associated with higher levels of work engagement and proactive behaviors (Bakker et al., 2016).

In conclusion, recovery experiences positively influence a range of outcomes that are essential for employee well-being, effective performance, and positive social interactions. These findings highlight the importance of promoting recovery practices in organizational settings to enhance overall health and productivity.

1. **Team-Level Recovery**
   1. **Emergence of Team-Level Recovery**

While the individual recovery has been extensively studied, the current research has largely overlooked the possibility that recovery activities may arise and develop within team settings (Sonnentag et al., 2017). As organizations are increasingly relying on teams as fundamental units for achieving strategic goals, tackling complex tasks and adapting to dynamic environments (Marks et al., 2001), understanding recovery mechanisms at the team level has become essential. As work boundaries become increasingly blurred, team members may build strong social connections (Jia et al., 2014). Moreover, the rise in mobile teams that eliminate geographic barriers to team composition (Franzoni et al., 2017), which increases the possibility of collective

recovery. These increased reliance on teams raises the question of how team members recover from work stress collectively.

In real-world work contexts, evidence shows that collective recovery takes various forms across both formal and informal settings, during and after work hours. Within formal on-the-job settings, organisations may adopt structured approaches such as scheduled team breaks and coordinated recovery periods. For example, some Japanese companies mandate group exercise sessions(), while certain hospital emergency departments employ team-based shift rotations that alternate between periods of high and low intensity(). Additionally, some teams can schedule regular micro-breaks such as group happy hours or team stretching sessions. In contrast, informal on-the-job recovery emerges from spontaneous interactions among team members. Common examples include conversations in the coffee area, walking meetings, or group lunch, which naturally provide opportunities for collective decompression during the workday.

Beyond the workplace, formal off-job recovery can take the form of company- sponsored team retreats or organized sports activities. Such as hiking expeditions and corporations establishing sports teams, which offer structured settings for collective recuperation. Similarly, informal off-job recovery is observed in spontaneous after- work gatherings and virtual social activities. This mode of recovery has become particularly relevant in today’s distributed work environments, where teams often sustain their connections through online gaming sessions or virtual social hours.

* 1. **Range of Team-Level Recovery Activities**

Team-level recovery activities can be categorized along three key dimensions: formal vs. informal, on-the-job vs. off-job, and self-initiated vs. formally planned interventions.

* + 1. **Formal/Informal Recovery**

Formal recovery activities could include team-building retreats, mandatory wellness programs, structured relaxation (e.g., mindfulness sessions), scheduled team debriefs after intense work periods.

Informal recovery activities could include casual social gatherings (e.g., after-work

drinks, coffee breaks),

unstructured chatting in the workplace, impromptu stretching or relaxation moments during work.

* + 1. **On-Job vs/ Off-Job Recovery**

On-job team recovery activities include short breaks between tasks, job crafting (adjusting tasks for personal well-being), work-related socialization that provides emotional support.

Off-job recovery activities include company-sponsored team outings or sports activities, voluntary team participation in wellness programs outside work (e.g., weekend yoga), engaging in non-work-related social activities with colleagues.

* + 1. **Self-Initiated / Formal Plan/Intervention**

Self-initiated recovery activities include personal socializing with colleagues, informal team recovery moments (e.g., suggesting a walk together)

Formal plan/intervention-based recovery could be implemented as part of organizational policies or leadership-driven strategies, HR-driven well-being initiatives (e.g., mental health days, structured breaks) Leadership-initiated recovery strategies (e.g., rotating lighter workloads after intense projects), Team coaching, professional recovery workshops.

* 1. **Current Research Gaps**

While substantial progress has been made in understanding individual recovery processes (Sonnentag & Fritz, 2015), significant gaps remain in exploring recovery dynamics at the team level. This section identifies key research gaps and provides a theoretical rationale for advancing team-level recovery research.

* + 1. **Limited Focus on Team Recovery**

Researchers predominantly examine recovery as an individual-level phenomenon

(Bennett et al., 2018). However, in contemporary team-based work environments characterized by high interdependence and frequent interactions (Mathieu et al., 2017), team members' recovery states likely exhibit reciprocal influences. Drawing from theories of emotional contagion (Hatfield et al., 1993) and shared experiences (Kelly & Barsade, 2001), collective recovery activities—such as synchronized breaks or team- building events—may significantly shape team dynamics and recovery outcomes.

* + 1. **Insufficient Understanding of Team-Level Recovery Dynamics**

As organizations increasingly adopt team-based structures (Kozlowski & Bell, 2013), limited attention has been directed toward understanding how team characteristics, resources, and demands influence recovery processes. For instance, teams exhibiting strong cohesion may develop distinctive synchronized recovery patterns, yet these collective phenomena remain largely unexplored. Moreover, the role of team leadership in facilitating or impeding recovery requires systematic investigation. Leadership behaviors—including recovery practice modeling, fostering recovery-supportive norms, and promoting psychological safety—likely play pivotal roles in shaping team recovery processes (Schaufeli & Taris, 2014).

* + 1. **Missing Team-Level Recovery Mechanisms**

Current recovery frameworks predominantly emphasize individual-level strategies, such as psychological detachment and relaxation (Sonnentag & Fritz, 2015), while neglecting team-specific recovery mechanisms. A fundamental question remains whether team recovery experiences emerge as an aggregation of individual recovery experiences or involve distinct collective processes. Potential team-level mechanisms—including synchronized rest periods, coordinated time-off policies, and structured collective recovery activities—warrant empirical investigation.

Furthermore, the bidirectional relationship between individual and team recovery requires theoretical elaboration. Questions persist regarding whether well-recovered teams facilitate enhanced individual recovery, or whether highly recovered individuals

contribute to superior team-level recovery outcomes (Costa et al., 2014). Understanding these mechanisms could inform evidence-based workplace policies and interventions.

* + 1. **Social Embeddedness and Contemporary Context**

Recovery processes are inherently embedded within broader organizational and social contexts (Hobfoll et al., 2018). Research on supervisor support and transformational leadership indicates that recovery is significantly influenced by social structures (Inceoglu et al., 2018), while studies on interpersonal crossover effects suggest that recovery states exhibit contagious properties that shape team dynamics over time (Westman, 2001). Emerging evidence highlights the benefits of collective recovery experiences, such as shared breaks and peer support, in enhancing overall recovery outcomes (de Bloom et al., 2017).

The increasing prevalence of virtual and hybrid team structures introduces novel challenges related to collective engagement, disconnection, and recovery synchronization (Gilson et al., 2015). These contemporary work arrangements amplify the urgency of understanding team-level recovery processes. Given the established links between individual recovery experiences and social contexts (Sonnentag et al., 2017), as well as evidence of recovery crossover effects and collective recovery benefits, team-level recovery likely operates through distinct mechanisms that cannot be fully captured through an individual-level analytical lens alone.

This theoretical rationale, combined with the identified research gaps, underscores the critical need for advancing team-level recovery research. Such investigations could yield valuable insights into enhancing organizational well-being, productivity, and resilience in contemporary work environments.

* 1. **Theoretical Support and Research Themes**

In addition to existing theoretical framework, several team-related theoretical perspectives also provide compelling rationales for expanding this investigation to the team level and proposed relevant research themes.

* + 1. **Social Attributes of Team Level Recovery**

The social nature of recovery manifests through multiple theoretical mechanisms and empirical evidence, supporting the necessity of team-level investigation.

Firstly, research has demonstrated that recovery experiences are shaped by social contexts and interactions (Sonnentag & Fritz, 2015). Studies examining workplace recovery have shown that supervisor support significantly influences employees' recovery experiences (Bennett et al., 2020), while coworker support can buffer the negative effects of work stress on recovery (Naseem et al., 2020). For instance, when supervisors model good recovery practices and support their subordinates' recovery efforts, employees are more likely to experience successful psychological detachment (Sonnentag & Schiffner, 2019). These findings indicate that recovery is not merely an individual process but is embedded within a broader social context.

Secondly, the effectiveness of recovery activities is often enhanced through social interaction. Research has shown that shared break activities and collective recovery experiences tend to be more beneficial than solitary ones (Pereira & Elfering, 2014). Studies examining leisure activities have found that social activities during off-job time are particularly effective for recovery (Oerlemans et al., 2014), especially when these activities are voluntary and enjoyable. This social enhancement of recovery benefits suggests that recovery might be inherently social in nature, with collective experiences providing additional resources beyond individual recovery efforts.

Thirdly, recovery experiences have been shown to transfer between individuals in close relationships. Studies of couples have demonstrated significant crossover effects in recovery experiences, with one partner's recovery state influencing the other's well- being (Rodríguez-Muñoz et al., 2018). Similarly, Hahn et al. (2014) found that psychological detachment from work can transfer between spouses, indicating that recovery processes can be socially transmitted. These interpersonal effects suggest that recovery experiences are inherently interconnected within social systems.

Lastly, organizational climate and social norms significantly influence recovery practices. Research has shown that organizational cultures that support work-life balance and recovery are associated with better recovery experiences among employees (Foucreault et al., 2018). The presence of shared recovery rituals and collective break practices in organizations further demonstrates how recovery is embedded within social systems and cultural contexts.

To sum up, the social attributes of recovery provide strong justification for expanding recovery research to the team level, team level recovery research can examine the research questions like:

*How collective recovery experiences emerge from social interactions within teams The role of team dynamics in shaping recovery processes*

*The potential synergistic effects of shared recovery activities*

*The influence of team climate on recovery practices and outcomes*

Furthermore, the social attributes of recovery suggest that team-level recovery might offer unique benefits beyond individual recovery practices. Just as social support enhances individual recovery, team-based recovery initiatives might create collective resources and shared experiences that benefit all team members.

* + 1. **Emotional Contagion Theory**

Emotional contagion serves as a key mechanism for understanding team-level recovery. Emotional contagion theory suggests that recovery states—similar to emotions and energy—can spread among team members through both conscious and unconscious processes of social interaction and emotional transmission (Elfenbein, 2014). This perspective highlights the interdependent nature of recovery within teams, where one individual’s recovery experience may influence the well-being of others.

Research on emotional contagion in workplace settings has demonstrated that team members' emotional states and energy levels can transfer between individuals (Bakker

et al., 2015). For instance, studies have shown that leader emotions significantly influence follower affect and that engagement states can spread among team members. Extending this evidence to recovery, it is likely that recovery states follow similar contagion patterns. The crossover effects of recovery between spouses (Rodríguez- Muñoz et al., 2018) provide preliminary support for this idea, suggesting that recovery transmission processes could also operate within work teams.

Emotional contagion theory has several important implications for team-level recovery research:

*The recovery experiences of individual team members may influence their colleagues’ recovery states, potentially creating positive or negative recovery spirals.*

*Leaders’ recovery practices could shape team-level recovery norms, with well- recovered leaders fostering a recovery-supportive environment.*

*Collective recovery activities may amplify recovery benefits by facilitating shared emotional experiences that reinforce well-being.*

Team climate regarding recovery could develop and spread through emotional contagion processes, influencing the extent to which recovery is valued and practiced within teams. Understanding these contagion mechanisms is crucial for developing effective team-level recovery interventions. If recovery states are indeed contagious, organizations could strategically leverage this phenomenon to enhance collective recovery through well-designed team activities and recovery-supportive leadership practices. By fostering a culture that encourages team-level recovery, organizations may promote sustainable well-being and performance in team-based work environments.

* + 1. **The Resource Caravan**

The resource caravan principle, a key theoretical component within Conservation of Resources (COR) theory, provides a compelling framework for understanding collective resource dynamics in team recovery processes (Hobfoll et al., 2018). This theoretical perspective posits that resources tend to aggregate and travel in

interconnected patterns, creating resource caravans that can be amplified through social interactions and collective experiences (ten Brummelhuis and Bakker, 2012; Hobfoll, 2011).

In team contexts, the resource caravan principle suggests that recovery resources are not merely individual assets but can accumulate and propagate within collective settings (Chen et al., 2015). This aggregation occurs through various mechanisms, including social support, shared experiences, and collective recovery activities (Guchait et al., 2020). Recent empirical evidence supports this perspective, demonstrating that team- level recovery initiatives can generate collective resource pools that benefit all team members (Wayne et al., 2021).

1. **Influence Factors of Team Level Recovery**

Building upon the established understanding of individual-level recovery processes and theoretical support of team- level recovery , this chapter briefly explores how various predictors and outcomes may manifest at the team level, emphasizing the interplay between shared work demands, collective resources, leadership influences, and resulting outcomes. Therefore, provide possible research themes for future research.

* 1. **Team-Level Predictors of Recovery**

The predictors of team-level recovery can be broadly categorized into three main areas: team-level work demands, team-level resources, and leadership influences.

* + 1. **Team-Level Work Demands:**

In team-based work environments, members often encounter shared work demands, such as high team workload, time pressure, emotional demands, and coordination requirements, that can collectively influence their recovery experiences. For instance, teams working under tight deadlines or managing complex tasks may experience heightened stress and strain that necessitate coordinated recovery efforts. Additionally, emotional demands, such as dealing with challenging clients as a unit, can exacerbate collective fatigue and hinder the overall recovery process. Coordination requirements, where team members must synchronize their activities to achieve shared goals, may further contribute to cognitive overload, reducing the time and energy available for effective recovery. Moreover, team conflict can deplete collective resources, impeding the group’s ability to engage in restorative activities effectively.

* + 1. **Team-Level Resources:**

Conversely, teams possess collective resources that can facilitate recovery. These resources may include a supportive team climate that emphasizes work-life balance, a shared understanding of the importance of recovery, and the development of collective coping strategies. When teams establish norms and practices that promote recovery, such as allowing flexibility in break schedules or fostering open communication about well-being, they can enhance their capacity to restore depleted resources. Additionally, team-level autonomy in determining when and how to take breaks contributes to more effective recovery processes. Such collective resources are critical in buffering the negative effects of shared work demands and promoting sustained team performance.

* + 1. **Leadership Influence**

Leadership plays a pivotal role in shaping collective recovery experiences. Effective team leaders can model recovery-supportive behaviors, establish norms that prioritize well-being, and actively support collective recovery activities. Leadership styles that encourage open communication, psychological safety, and resource availability are particularly beneficial for fostering a recovery-conducive environment (Inceoglu et al., 2018b). Furthermore, leaders who actively manage team boundaries and workloads can enhance the group's capacity to engage in meaningful recovery processes. By promoting team-level recovery initiatives and demonstrating recovery-supportive behaviors themselves, leaders can contribute to positive recovery spirals within their teams.

* 1. **Outcomes of Team-Level Recovery**

Effective team-level recovery processes can yield a range of beneficial outcomes across performance, well-being, and social-related domains. Through the lens of multilevel theory and team effectiveness frameworks, these outcomes can be conceptualized as follows:

* + 1. **Team Performance**

Recovery at the team level has been shown to enhance various aspects of team performance, including task performance, innovation, creativity, and adaptability. By restoring collective energy and cognitive resources, teams are better equipped to tackle complex challenges, generate novel solutions, and adapt to changing circumstances. Additionally, well-recovered teams are more likely to exhibit positive organizational citizenship behaviors, contributing to a supportive and productive work environment.

* + 1. **Team Well-being**

Beyond performance metrics, team-level recovery processes also influence collective well-being. Successful recovery can improve team mood, enhance collective affect, and reduce shared stress levels. Moreover, teams that regularly engage in restorative activities are less prone to collective burnout and are more likely to experience elevated levels of engagement and vitality. Psychological safety within the team is also positively associated with effective recovery practices, as members feel more comfortable expressing their needs and participating in recovery activities.

* + 1. **Team Social-Related Outcomes:**

Recovery processes at the team level contribute to strengthened social bonds and improved interpersonal relationships. Teams that prioritize recovery often develop a stronger sense of cohesion, which enhances their ability to collaborate effectively and maintain a shared identity. Furthermore, promoting collective recovery experiences can enhance team members’ perceptions of psychological safety, making them more willing to support each other’s recovery needs.

* 1. **Cross-Level Outcomes**

Finally, team-level recovery processes can have cross-level implications for individual recovery experiences. A supportive team recovery climate can positively influence personal well-being and performance, particularly when individuals feel their recovery needs are respected and encouraged by their teammates. Conversely, poorly managed team-level recovery processes may exacerbate individual strain and undermine personal recovery efforts.

Overall, understanding the influence factors of team-level recovery requires an integrative approach that considers the complex interactions between shared work demands, collective resources, leadership dynamics, and resulting outcomes. Further research is needed to explore how these factors interact and contribute to effective recovery processes at the team level.

**4.Conclusion**

This comprehensive review synthesizes existing research on both individual and collective recovery, emphasizing the importance of recovery processes in enhancing well-being, performance, and organizational outcomes. At the individual level, recovery has been shown to significantly improve psychological well-being by reducing negative effects, emotional exhaustion, and burnout while promoting positive affect and life satisfaction. Additionally, psychosomatic benefits, such as improved sleep quality and reduced fatigue, underscore the physiological significance of

successful recovery practices. Furthermore, the positive impact on performance outcomes, including enhanced cognitive functioning, creative problem-solving, and proactive behaviors, highlights the critical role of recovery in sustaining productivity and engagement.

However, despite the extensive literature on individual recovery, research on team-level recovery remains relatively underdeveloped. As team-based work structures continue to dominate modern organizational settings, collective recovery has become increasingly relevant. This review identifies a growing need to investigate how team members collectively unwind and restore their resources. Understanding collective recovery mechanisms and their outcomes will not only advance theoretical knowledge but also inform practical interventions aimed at promoting team effectiveness and organizational resilience.

Future research should address the theoretical and empirical gaps identified in this review, particularly by examining the social dynamics and contextual factors that shape collective recovery. By integrating insights from social interaction theories, emotional contagion frameworks, and resource-based perspectives, scholars can develop a more holistic understanding of how recovery operates at the team level. Such insights will be invaluable for organizations striving to foster healthier, more resilient, and high- performing teams.

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