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Money for Taxes

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Abstract

We develop a model showing that monetisation and fiscal capacity are complements in imperfectly monetised economies. A positive shock to monetisation increases the efficiency of taxation, and hence the incentive to invest in fiscal capacity. We take this model to the data by investigating an exogenous shock to Europe's monetisation: the inflow of precious metals from the Americas during 1550-1790. Our causal estimates indicate that increases in monetisation led to gradual and persistent increases in fiscal capacity in England, France and Spain.

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Keywords: monetary capacity, fiscal capacity, monetization, inflation, taxation, quantity theory of money, monetary non-neutrality.

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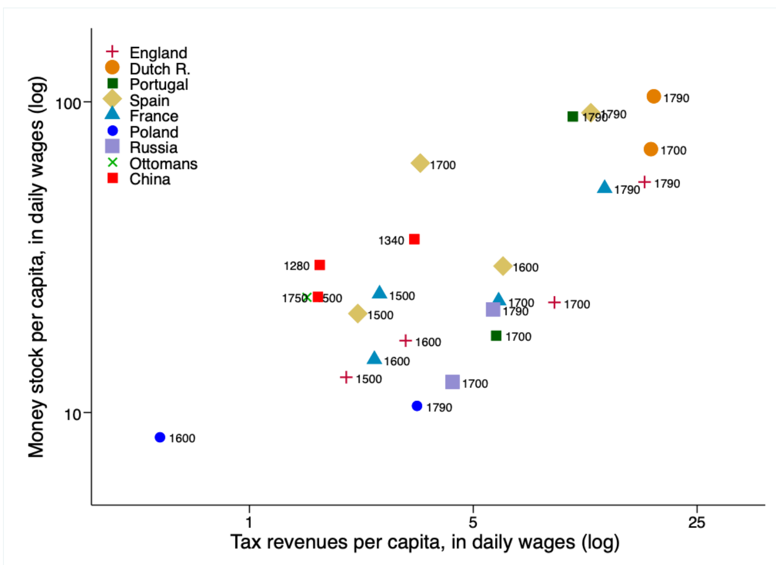
1 Introduction

The limited monetization of medieval and early modern states constrained their ability to raise taxes. In England, for example, only 40% of households relied primarily on wages in the early sixteenth century, a share that had remained broadly stable since the thirteenth century (Dyer, 2002, p. 364). In such weakly monetised economies, taxation relied largely on payments in kind and in labour (Spufford, 1988; Bonney, 1999). Such non-monetary forms of tax revenue were costly to store and re-allocate, constraining fiscal revenue collection and implying a positive relationship between money and taxes. Figure 1 confirms such a relationship between real per capita tax revenues and real per capita money stocks across 8 European countries and China over the early modern period. The variables are scaled by daily wages, and hence do not simply pick up a relationship that is driven by rising economic prosperity.

Figure 1: Per capita tax revenues and money stocks across time and countries



Note: See Section 3.2 for a data description.

Thus, limited monetisation constrains the immediate ability of an authority to collect taxes. A subtler point is that limited monetisation also has dynamic effects: it limits incentives to build up fiscal capacity over time. It thereby shapes the long-run trajectory of states towards a path to sustained growth, for which fiscal capacity is a main ingredient (Besley and Persson, 2011).

It is this dependence of fiscal-capacity investment on monetisation that we study in this paper. We analyze this theoretically and empirically. In terms of the former, we offer a model of imperfect monetisation that explicitly lays out the connection between monetisation and taxation, which runs in both directions. On the one hand, the state's capacity to raise taxes is an essential ingredient in determining the value, and hence the success, of a currency. Thus, strong fiscal capacity is an important pre-condition for strong monetisation. On the other hand, greater monetisation itself promotes the development of fiscal capacity by strengthening the incentives to invest in it. Exogenous increases in monetisation—such as those generated by inflows of silver—raise the returns to fiscal-capacity investment through two channels: they expand the size of the taxable economy and make economic activity easier to tax. As a result, monetisation fosters the emergence of stronger fiscal states.

We test this implication empirically by studying the largest monetary expansion of the early modern period: the inflow of precious metals from the Spanish colonies in the Americas between the sixteenth and eighteenth centuries, which increased European money stocks to unprecedented levels (Palma, 2020). As historians have repeatedly pointed out, for silver-starved European economies, these (overwhelmingly privately-owned) inflows meant an increased capacity of governments to issue money, and a dramatic increase in the share of transactions conducted using money. Moreover, as shown by Palma (2022), the discovery and production of precious metals in the Americas was exogenous to the short-term variations of the European economies. We thus study the causal effect of monetisation on fiscal capacity in Europe (proxied by, respectively, per capita real money stocks and per capita real tax revenues), using a Local Projection-Instrumental Variable Approach (Jordà, 2005) in which production of precious metals in the Americas is used to instrument for monetisation in Europe. For the sample of countries, we investigate England, France and Spain, as these countries were heavily impacted by the precious metals shock, and have detailed historical annual data for both monetisation and taxation.[1]

The empirical results identify a significant and substantial causal impact of monetisation on fiscal capacity. In the first stage, an increase in the production of precious metals in the

[1]In the Online Appendix, we provide additional historical evidence of a close relationship between precious metals, monetisation and fiscal capacity (again proxied by per capita real money stocks and tax revenues) for earlier periods and other parts of Europe, as well as for China.

Americas significantly increased per capita real money stocks across our sample of European countries. In the second stage, a 1 percent increase in per capita real money stocks increased per capita real tax revenues by 0.6-1.5 percent over a 20-year interval. Moreover, consistent with a gradual investment in fiscal capacity, the effect built up over a period of 14-17 years in England and France, and persisted over the course of subsequent decades in all countries considered. In contrast, the effect for Spain peaked earlier and was overall smaller, potentially related to the fact that part of the silver went directly to Spanish government coffers. These findings are robust to controlling for income and measures of warfare and the representativeness of political regimes. Likewise, the findings are robust to accounting for potential violations of the exclusion restriction through the adjusted impulse responses methodology of Jordà et al. (2020).

Our paper complements a large literature that investigates the origins of state capacity from an empirical and theoretical perspective. At least since Tilly (1990), the literature pointed to war pressure as the key driver of fiscal capacity (Besley and Persson, 2009, 2011; Dincecco, 2009). Our paper complements this view by suggesting that sufficient monetisation is a necessary condition that needs to be in place for an effective build-up of fiscal capacity. We hereby contribute to an emerging literature that explores alternative key drivers of fiscal capacity. In this vein, Dal Bó et al. (2025)'s examination of excise revenues in early modern Britain shows that the taxation of traded goods was more important for the build-up of fiscal capacity than previously thought.

The findings also shed new light on a central idea in macroeconomics: the long-run neutrality of money. The conventional view holds that money is neutral in the long run, in the sense that an increase in the money supply has no real effects and leads only to a proportional increase in the price level.[2] Our results do not challenge this view in its usual interpretation. Rather, they suggest a historically important qualification by showing that in imperfectly monetised economies, an increase in the money supply can have persistent real effects. This distinction is historically important, as large segments of pre-modern economies were insufficiently monetised. Following a positive monetary shock, money could penetrate previously under-monetised sectors. While prices would increase, they would do so less than proportionally, since a larger share of economic activity would now be conducted using money. The resulting expansion in monetisation would

[2] See, however, Brzezinski et al. (2024); Palma (2018a, 2022); Jordà et al. (2024).

facilitate market transactions and broaden the tax base, thereby increasing fiscal capacity. In this way, an increase in the money supply could have lasting economic and political consequences.

In the same vein, our findings relate to the literature on the trade-off between monetary expansion and taxation (Sargent and Wallace, 1981; Sims, 1994; Mankiw, 1987). The common wisdom in the literature is that states can raise revenue by either increasing taxes or increasing money supply, the latter of which in turn increases the price level. Hence, in the short run, increasing taxes and increasing money supply are substitutes. We find in this study that, over the long run, the relationship is more complex. In under-monetised economies, if the money supply expands in a way that provides liquidity to new regions or sectors, it also improves the tax collection, triggering a virtuous cycle of monetisation and fiscal capacity building (Capie, 2004; Desan, 2014, p.256). Hence, in the long run, taxation and money supply are complements.

The remainder of the paper is structured as follows. Section 2 sets out our model, giving a precise definition to the notion of imperfect monetisation and exploring its link to fiscal capacity. Section 3 discusses the new dataset and causal empirical results relating to the effect of increases in monetisation on fiscal capacity in early modern Europe. Section 4 concludes.

2 Model

We first describe and discuss the model setup (Sections 2.1–2.2), then identify its equilibrium (Section 2.3). Our main result is stated in Section 2.4, while Section 2.5 reflects on the applicability of our model to a fiat-money environment.

2.1 Baseline setup

Our model consists of two types of agent: citizens, who engage in market transactions, and a government, which finances public expenditure through taxes. We discuss each type of agent in turn.

Citizens. Consider an economy inhabited by a unit mass of atomistic citizens. There are two private goods, a consumption good (c) and silver bullion (b), and one public good, public expenditure (g). The utility of citizen i is

$$U_i = c_i + b_i + \tilde{\alpha} g, \tag{1}$$

where $\tilde{\alpha} \geq 0$ is a parameter capturing the relative importance of public expenditure. Each citizen is initially endowed with one unit of the consumption good and $(1-\lambda)\sigma$ units of silver bullion (henceforth, simply "silver"), where $\lambda \in [0, 1]$ and $\sigma > 0$. An additional $\lambda\sigma$ units of silver are owned by the government. Thus, the economy's total endowment of silver is σ.

Citizens are part of a market economy in which they can exchange goods with one another. Silver is a homogeneous good, and citizens are indifferent between consuming their own endowment and that of others. The consumption good, however, is different: citizens derive utility only from the consumption good of others (as in Diamond 1982 and Kiyotaki and Wright 1989). They therefore wish to engage in transactions in order to sell their own consumption good.

We distinguish between two types of transactions. In the first, citizens exchange their own consumption good for another agent's consumption good. In the second, they exchange their own consumption good for another agent's silver. We refer to the former as *barter transactions* and to the latter as *monetary transactions*. Barter transactions are subject to search costs: to arrive at the exchange with one unit of the consumption good, an agent must leave home with $\phi > 1$ units. By contrast, monetary transactions are frictionless (in the absence of taxes).[3]

For agents wishing to sell silver in monetary transactions (henceforth, "sellers of silver"), silver must first be converted into "coins". Conversely, agents who acquire silver in monetary transactions (henceforth, "buyers of silver") must convert those coins back into silver before consuming it. Both transformations take place at the "mint". While the conversion process is itself costless, the government levies a seigniorage tax $s \geq 1$ on silver passing through the mint.

[3]The assumption that barter transactions involve higher search costs than monetary transactions could be micro-founded by explicitly modelling the consumption good as heterogeneous in preferences. A simple example is as follows. Suppose there are three varieties of the consumption good (A, B, and C), and three corresponding types of consumers. Type-A consumers derive utility only from variety A, type-B consumers only from variety B, and so on. Let an agent of type XY be one who is endowed with variety X and consumes variety Y, and suppose that agents of the six possible types (AB, AC, BA, BC, CA, and CB) have equal mass. In this setting, search costs are naturally higher in barter transactions. For example, an agent of type AB must find an agent of type BA. In a monetary transaction, by contrast, it would be sufficient to find either a type-BA or a type-BC agent.

Thus, $s = 1$ corresponds to the absence of seigniorage, whereas any $s > 1$ implies a positive tax. Specifically, for each unit of silver that sellers of silver bring to the mint, they receive coins containing $1/s$ units of silver, while the remaining $(s-1)/s$ units are appropriated by the government. Similarly, for each unit of silver embedded in coins (henceforth, "monetary silver") that buyers of silver bring to the mint, they receive $1/s$ units of silver.

To capture a situation in which silver is scarce, as it was in early-modern economies (i.e. there was not enough silver to conduct all transactions using silver coins), we assume that silver can be exchanged only once in monetary transactions. This is a stark way of modelling a low velocity of money, such that some transactions must be conducted through barter.

In addition to the seigniorage tax, citizens are subject to a transaction tax $t \geq 1$. Both barter and monetary transactions are subject to this tax. Specifically, after each transaction, agents must stop by the "tax collector". For every unit of consumption good or silver with which they leave the transaction, they retain only $1/t$ units, while the remaining $(t-1)/t$ units are appropriated by the government.

To summarise, the key difference between barter and monetary transactions is that the former are subject to a search friction ϕ, whereas the latter are not. Instead, monetary transactions are subject to the seigniorage tax s (which is levied at the mint). Both types of transactions are subject to the transaction tax t. The seigniorage and transaction taxes are policy variables chosen by the government, as we now describe.

Government. The government has three sources of income with which to finance public expenditure g. First, it owns a fraction $\lambda \in [0, 1]$ of the total silver endowment σ. Denoting the price of silver in terms of consumption goods by p, this gives the government wealth equal to $\lambda\sigma p$. Second, the government receives revenues R_t from the transaction tax t described above, which applies uniformly to all transactions. Finally, the government receives revenues R_s from the seigniorage tax s, which is levied on monetary transactions. Part of the silver collected through taxation (the portion taxed from buyers of monetary silver) has already been exchanged, whereas the remainder (the portion taxed from sellers of silver) has not. This distinction is relevant because we have assumed a limited velocity of silver: the government can exchange only silver that has not yet been exchanged.[4]

The transaction tax has two additional features. First, to allow for the possibility that barter transactions are harder to tax than monetary transactions, we assume that, for every unit of revenue generated by the transaction tax on barter transactions, a fraction $\delta \in [0, 1]$ is lost before reaching the government. Second, following the fiscal capacity literature (Besley and Persson, 2009), we assume that the transaction tax rate cannot exceed the government's fiscal capacity, $t \leq \tau$, where $\tau \geq 1$. Fiscal capacity must be developed in advance, and developing it costs $\xi C(\tau)$ units of public expenditure. The function $C(\cdot)$ is continuous, increasing, and convex, with $C'(1) = 0$ and $C'(\tau) \to \infty$ as $\tau \to \infty$. The parameter $\xi > 0$ is a cost shifter governing the cost of investing in fiscal capacity.

Putting everything together, the government's overall optimisation problem is given by:

$$\max_{g,\tau,s,t} W = c + b + \alpha g, \tag{2}$$

$$\text{subject to: } g + \xi C(\tau) \leq R_t + R_s + \lambda \sigma p \tag{3}$$

$$t \leq \tau \tag{4}$$

where $c = \int_{i \in [0,1]} c_i \, di$, $b = \int_{i \in [0,1]} b_i \, di$, and α is the weight that the government places on public expenditure g. In other words, the government chooses public expenditure, fiscal-capacity investment,[5] and taxes so as to maximise the sum of citizens' utilities, while valuing public expenditure at rate α. Comparing this objective with citizens' utility in equation (1), the key difference is that the government's valuation of public expenditure, α, need not coincide with citizens' valuation, $\tilde{\alpha}$.

We make two assumptions on α: $\alpha > 1$ and $\alpha \geq \tilde{\alpha}$. The former assumption allows us

[4] In particular, the government's stock of yet-to-be-exchanged silver includes the $\lambda\sigma$ units it initially owns, as well as the $(s-1)(1-\lambda)\sigma/s$ units it collects from sellers of silver.

[5] That investment in fiscal capacity is financed out of current revenues is only a simplifying assumption. Models of fiscal capacity often have two periods, with investment in period-2 capacity financed out of period-1 revenues (generated through exogenously given initial capacity). Extending the model along these lines would not yield additional insights in our context: the only difference would be that investment would be weighed against its period-1 opportunity cost (say α_{initial}), rather than against the opportunity cost of period-2 revenues (α). If the opportunity cost of revenues were constant over time ($\alpha_{\text{initial}} = \alpha$), the equilibrium of the extended model would coincide with that of the current one.

to focus on the case of interest, namely one in which tax revenues are valuable, at least from the government's perspective. The latter assumption nests a continuum of government "types" within the model, subject to the restriction that the government values public expenditure at least as much as citizens do. As $\alpha \to \tilde{\alpha} > 1$, the government type approaches a benevolent utilitarian planner who maximises aggregate citizen utility. At the opposite extreme, as $\alpha \to \infty$ and $\tilde{\alpha} \to 0$, the government type approaches one that cares only about public expenditure, even though citizens derive little or no benefit from it. For example, this could represent a government that entirely embezzles public revenues for private consumption.[6]

Timeline. The timing of the game is as follows:

1. The government sets fiscal capacity, τ.
2. The government sets the transaction and seigniorage taxes, t and s.
3. Transactions take place, taxes are collected, public expenditure takes place. After this, payoffs realise.

2.2 Discussion and extensions of baseline setup

The model described in the previous section is one in which commodity money arises endogenously as a means to reduce the frictions associated with specialisation, in the tradition of Kiyotaki and Wright (1989). Our framework departs from Kiyotaki and Wright (1989), however, in a key respect. In their model, a commodity becomes a medium of exchange as a result of strategic interaction among agents, that is, because it is expected to be accepted in future transactions. In contrast, in our model silver emerges as a medium of exchange merely due to the lower search frictions associated with monetary transactions. In reduced form, this assumption reflects the idea that silver is valued for consumption by a broader set of agents than other commodities (as discussed in footnote 3). There are two main reasons for adopting this approach. First, we focus on a historical setting in which money predominantly took the form of commodity money

[6] It would be straightforward to make α and $\tilde{\alpha}$ stochastic in order to capture fiscal shocks (for example, those arising from war). Doing so, however, would neither alter our qualitative results nor generate significant new insights.

based on precious metals, and it is natural to assume that such metals were widely valued in consumption. Second, abstracting from strategic interaction and equilibrium beliefs allows us to work with a simpler environment. This enables us to isolate the mechanism of interest and present it in a transparent way.

For the equilibrium to feature an imperfectly monetised economy, we assume a low supply of silver combined with a low velocity of money. For tractability, in the baseline model, we fix the velocity of money at an arbitrarily low level by assuming that silver can be exchanged only once. While this assumption is stark, we relax it in Online Appendix A.1.1 by allowing silver to be exchanged a finite integer number $v \geq 1$ of times. As one would expect, the economy remains imperfectly monetised as long as v is not too large. Moreover, the comparative statics of the extended model are qualitatively the same as in the baseline model, implying that our results do not hinge on the assumption of a velocity of money equal to one.

Beyond the assumptions discussed above, imperfect monetisation requires not only silver scarcity in physical terms, as ensured by a limited supply of silver and a low velocity of money, but also scarcity in transaction-value terms. In particular, the price of silver must be bounded from above. Otherwise, the equilibrium price of silver could rise to a level at which even a very small quantity would suffice to monetise the entire economy, regardless of how scarce silver is or how slowly it circulates.[7] In our baseline model, such an upper bound arises naturally because the liquidity value of silver is tied to contemporaneous fundamentals. In particular, such value cannot exceed the gains from avoiding barter, captured by the parameter ϕ. As long as barter is not arbitrarily inefficient, the price of silver is therefore bounded. This feature is specific to our simple microfoundation of money. In a model where silver is also valued because it is expected to be accepted in future transactions, as in Kiyotaki and Wright (1989), silver would command an additional liquidity premium. In that case, the upper bound implied by ϕ would be relaxed, though not necessarily eliminated.[8]

[7]To consider an extreme example, if one gram of silver were worth as much as nominal GDP, a single transaction using that gram would suffice to monetise the entire economy.

[8]Our extension with a velocity of money greater than one (Online Appendix A.1.1) moves in this direction, since silver acquires value not only from its intrinsic consumption value and its role in current exchange, but also from its ability to facilitate future transactions. Unlike in Kiyotaki and Wright (1989), however, this liquidity value is pinned down by a finite sequence of future uses rather than by equilibrium beliefs about future acceptability.

For this reason, Online Appendix A.1.2 develops a more fundamental microfoundation for a bounded price of silver based on indivisibilities. Specifically, we show that if transactions are bounded above and there exists a physical lower bound on the amount of silver that can be embedded in a coin,[9] then the price of silver remains bounded even if its intrinsic value is arbitrarily high. Intuitively, if the price of silver were to rise sufficiently, the smallest physically mintable coin would become too valuable to function in everyday transactions. This mechanism captures one aspect of the "big problem of small change" studied by Sargent and Velde (1999, 2002).[10]

We view both mechanisms as plausible. While they differ in their microfoundations, they share the same reduced-form implication: they place an upper bound on the purchasing power of silver and hence on the amount of monetary exchange that a given stock of silver can support. Accordingly, when we refer to imperfect monetisation as arising from silver scarcity in the remainder of the paper, this should be understood as encompassing either mechanism. We return to this distinction in Section 2.3.

Note also that all agents face the same search costs in the baseline model. One implication is that, when the economy is imperfectly monetised, the model is silent about which transactions are monetary and which are barter. A natural extension—sketched in Online Appendix A.1.3—introduces heterogeneity in search costs. This extension captures the idea that some transactions, such as the sale of highly specialized goods or services in urban settings, or the purchase of specialized or luxury goods by wealthier individuals, are inherently more costly to conduct through barter and therefore more likely to be monetary. We describe the equilibrium of this extended model in Section 2.3 below and argue that our baseline results remain qualitatively unchanged in this more general environment.

[9] In practice, minting coins with very low silver content was infeasible for two complementary reasons. First, coins made entirely of silver would have to be extremely small, making them difficult to handle and easy to lose. Second, alloying small quantities of silver with base metals was not a viable alternative, as the metallic content—and thus value—of such coins would be difficult to verify reliably.

[10] In these studies, a decline in the price level (equivalently, an increase in the price of silver in our model) tends to raise the supply of large coins more than that of small coins, since the latter are costlier to mint. This can generate shortages of small denominations, distorting the economy away from transactions that rely on them. A key difference from our setting is that, in Sargent and Velde (1999, 2002), the economy remains fully monetised.

2.3 Equilibrium

We now solve the model by backward induction. We first characterize equilibrium in the silver market (Period 3), then derive the government's optimal tax choices conditional on fiscal capacity (Period 2), and finally determine optimal fiscal capacity (Period 1).

Period 3. The share of monetary transactions in total transactions is determined by equilibrium in the silver market. Unlike the consumption good, silver can be consumed directly by its owner. Nevertheless, agents are willing to sell silver in monetary transactions whenever the utility obtained from the consumption good received in exchange exceeds the utility from consuming the silver directly. This supply of silver meets demand from agents who wish to acquire silver in order to avoid the search costs associated with barter transactions. The silver market clears when the price of silver in terms of the consumption good, p, equates supply and demand.

We begin by deriving silver supply. This comes from both the government and private agents. For every unit of silver that the government sells in monetary transactions, it obtains p units of the consumption good. Since one unit of silver can finance as much public expenditure as one unit of the consumption good, the government sells all its silver if $p > 1$, whereas it retains all of it and transforms it directly into public expenditure if $p < 1$. For every unit of silver that private agents sell in monetary transactions, they ultimately receive $p/(st)$ units of another agent's consumption good, and hence obtain the same amount of utility.[11] Since the alternative is to consume the silver directly, yielding one unit of utility, private agents sell all their silver if $p > st$, whereas they retain all of it and consume it directly if $p < st$. Intuitively, the threshold price st is increasing in the taxes that must be paid in order to exchange silver for consumption goods. This is because the alternative of consuming silver directly is untaxed, beyond the proportion λ

[11] Having to stop at the mint, agents arrive at the exchange with $1/s$ units of silver. There, they obtain p/s units of the consumption good. Having to stop by the tax collector on the way back, they arrive home with $p/(st)$ units of the consumption good.

that directly goes to the government. In summary, the aggregate supply of silver is

$$B^s = \begin{cases} 0 & \text{if} \quad p < 1 \\ z \in [0, \lambda\sigma] & \text{if} \quad p = 1 \\ \lambda\sigma & \text{if} \quad 1 < p < st \\ z \in [\lambda\sigma, \sigma] & \text{if} \quad p = st \\ \sigma & \text{if} \quad p > st \end{cases},$$

and is illustrated in Figure 2.[12]

We next turn to the demand for silver, also illustrated in Figure 2. For every unit of their own consumption good that agents exchange in barter transactions, they ultimately receive $1/(\phi t)$ units of another agent's consumption good. If instead they exchange that unit for silver in a monetary transaction, they ultimately receive $1/(pts)$ units of silver.[13] Since another agent's consumption good and silver enter utility symmetrically, aggregate demand for silver is

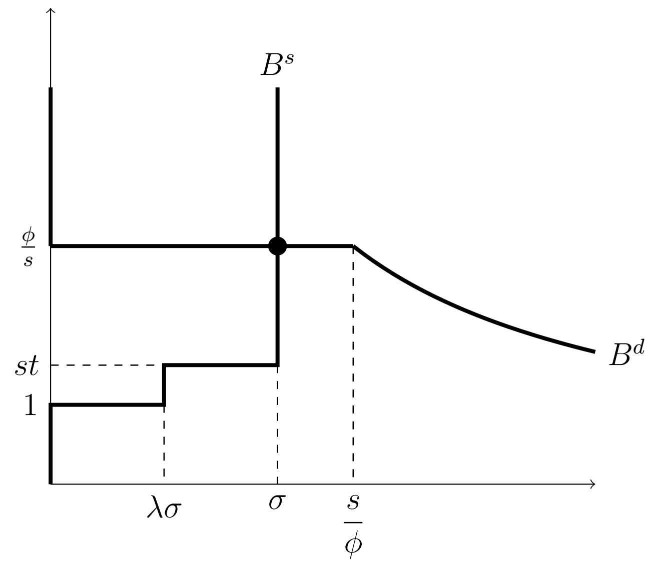
$$B^d = \begin{cases} \frac{1}{p} & \text{if} \quad p < \frac{\phi}{s} \\ z \in \left[0, \frac{1}{p}\right] & \text{if} \quad p = \frac{\phi}{s} \\ 0 & \text{if} \quad p > \frac{\phi}{s} \end{cases}.$$

If $p < \phi/s$, an agent's own consumption good yields greater utility when exchanged in a monetary transaction than when exchanged in a barter transaction. Agents therefore exchange their entire endowment of the consumption good in monetary transactions, resulting in a demand for $1/p$ units of silver. The opposite is true if $p > \phi/s$. Intuitively, ϕ/s captures the value of silver to those who demand it. This value is increasing in the search costs avoided by using monetary transactions, as captured by ϕ, and decreasing in the seigniorage tax s, which applies only to monetary transactions.

[12]Note that supply equals the economy's total endowment of silver if $p > st$, that is $B^s = \sigma$. This is because the government finds it optimal to sell not only its own silver, but also the silver it collects from sellers of silver.

[13]In barter transactions, agents arrive at the exchange with $1/\phi$ units of their own consumption good. They receive in exchange $1/\phi$ units of another agent's consumption good, of which only $1/(\phi t)$ units remain after stopping by the tax collector. In monetary transactions, agents arrive at the exchange with one unit of their own consumption good. They receive in exchange $1/p$ units of silver, of which only $1/(pt)$ units remain after stopping by the tax collector, and $1/(pts)$ units after stopping at the mint.

Figure 2: Silver market equilibrium



In equilibrium, the price of silver equates demand and supply. For some parameter values, however, the equilibrium may involve either no "private" monetary transactions (that is, monetary transactions in which private agents sell silver) or only monetary transactions. To exclude these cases, which are of limited relevance to the historical setting under consideration, we impose

Assumption 1.

$$st < \frac{\phi}{s}. \tag{5}$$

Assumption 2.

$$\sigma < \frac{1}{\phi}. \tag{6}$$

Assumption 1 requires taxes not to be so high as to induce a collapse of the private market for silver. (At this stage, the assumption must be stated in terms of endogenous variables, but we later show that it holds in equilibrium.) Under this assumption, the tax burden faced by private agents when bringing silver to the exchange is lower than the value of silver to those who demand it. In terms of Figure 2, the upper horizontal segment of the supply curve lies below the horizontal segment of the demand curve, ensuring that private monetary transactions take place. Assumption 2 ensures that silver is scarce: even if the entire endowment of silver is used in monetary transactions, some transactions must still be conducted through barter. In other words, the economy remains imperfectly monetised. In terms of Figure 2, the market-clearing equilibrium always lies on the horizontal segment of the demand curve.

Under Assumptions 1 and 2, equilibrium in the silver market is as depicted in Figure 2. The equilibrium price of silver is therefore

$$p^* = \frac{\phi}{s}.$$

At this equilibrium, the economy is imperfectly monetised and the price of silver equals its valuation by buyers. As a result, all surplus generated by monetary exchange accrues to sellers of silver. In equilibrium, all endowments are exchanged. Agents use all of their yet-to-be-exchanged silver to purchase consumption goods in monetary transactions, including both privately owned silver and silver owned or collected by the government. At the same time, agents sell part of their consumption-good endowment in exchange for silver in monetary transactions and exchange the remainder for other consumption goods through barter. Consequently, agents consume only silver acquired from others, despite silver being a perfectly substitutable good in utility terms. The reason is that yet-to-be-exchanged silver commands a premium over its consumption value, reflecting its ability to reduce the search costs associated with barter transactions.

Before moving on, we note two peculiar features of the model. First, p^* is not decreasing in σ, implying that a greater abundance of silver does not generate inflation (i.e. a decline in the price of silver). This result is a by-product of our simplifying assumption of homogeneous search costs. In Online Appendix A.1.3, we develop a simple extension in which agent $i \in [0, 1]$ faces search costs equal to $\phi - \theta i$, where $\theta \geq 0$ and $\phi - \theta > 1$. In that model, and in the equilibrium in which the economy is imperfectly monetised, only agents with sufficiently high search costs engage in monetary transactions. These agents now capture part of the surplus generated by monetary exchange. This feature accords well with the historical observation that, during the early modern period, money was used disproportionately in cities and by more affluent social groups. Being involved in the exchange of more specialised goods and services, these regions and groups arguably faced higher costs of barter. In this more general model, the equilibrium price of silver is given by $\phi/(\theta\sigma + s)$, which is decreasing in σ whenever $\theta > 0$. Intuitively, a greater abundance of silver allows monetary transactions to be adopted by agents for whom silver is less valuable because the search frictions associated with barter are lower. We show that the comparative statics of the extended model are qualitatively identical to those of the baseline model, implying that our results do not hinge on the assumption of homogeneous search costs.

Second, since the intrinsic value of silver is ϕ, Assumption 2 can alternatively be interpreted as requiring that the intrinsic value of silver not be too large. If the value of silver were to become arbitrarily large, its equilibrium price would increase accordingly, and even a minuscule quantity of silver would suffice to monetise the entire economy. As anticipated in Section 2.2, Online Appendix A.1.2 develops an alternative foundation for imperfect monetisation based on indivisibilities. Specifically, we show that if no more than $d \in (0, 1]$ units of the consumption good can be exchanged in a single transaction, if no more than $f \in (0, \sigma]$ units of silver can be embedded in a single coin, and if transactions cannot be bundled, then the equilibrium price of silver is bounded above by $\max[d/f, 1]$.[14] Under these conditions, the requirement for imperfect monetisation can be relaxed to $\sigma < \max(1/\phi, 1/(d/f))$, implying that the economy can remain imperfectly monetised even as the intrinsic value of silver becomes arbitrarily large ($\phi \to \infty$). The intuition is that, in the presence of indivisibilities, the equilibrium price of silver cannot rise without bound, since otherwise even the smallest mintable coin would become too valuable to be used in ordinary transactions. This result implies that a bounded value of ϕ can be interpreted as capturing either a limited intrinsic value of silver or the classic small-change problem.

A citizen's indirect utility before the transaction tax and public expenditure, which we also refer to as "private utility", is

$$\frac{(1-\lambda)\sigma}{s}p^* + \frac{1}{\phi} = \frac{(1-\lambda)\sigma\phi}{s^2} + \frac{1}{\phi}. \tag{7}$$

[14]This model converges to the baseline model as $d = 1$ and $f \to 0$.

Expression (7) has an intuitive interpretation.[15] If silver were not used as a means of exchange, private utility would equal $(1-\lambda)\sigma + 1/\phi$, since all privately owned silver would be consumed directly by its owners and all consumption goods would be exchanged through barter. Absent the seigniorage tax, the ability to use silver as a means of exchange would increase private utility to $(1-\lambda)\sigma\phi + 1/\phi$, since each unit of silver used in monetary transactions prevents $\phi - 1$ units of the consumption good from being lost to search frictions.[16] There are two ways in which the seigniorage tax reduces these gains from monetisation, as reflected in the quadratic term in expression (7). First, by taxing sellers of silver, it reduces the amount of silver that private agents bring to the exchange. Second, by reducing the demand for silver and hence its equilibrium price, it lowers the amount of consumption goods transacted through the monetary economy.

Period 2. At this stage, the government takes fiscal capacity, τ, as given and chooses the seigniorage and transaction taxes. Since all endowments are exchanged in equilibrium, expression (7) equals the amount of silver and consumption goods that citizens bring home after transactions but before the transaction tax is levied. Because all such goods are subject to the transaction tax, private utility after taxation is equal to $1/t$ times expression (7). Given the unit mass of citizens, this amount also equals aggregate private utility, that is, $c + b$ in equation (2).

Since public expenditure is determined by the government's budget constraint in Period 3, and since the budget constraint binds in equilibrium, we can write

$$g = R_t + R_s + \lambda\sigma p^* - \xi C(\tau).$$

[15] To derive expression (7), note that agents sell $(1-\lambda)\sigma/s$ units of silver in exchange for $(1-\lambda)\sigma p^*/s$ units of the consumption good (call this amount A). Since all silver is exchanged in equilibrium (including that owned by the government), agents also sell σp^* units of their consumption good in exchange for σ units of silver, which become σ/s units after passing through the mint (call this amount B). They are left with $1-\sigma p^*$ units of their own consumption good, which they barter for $(1-\sigma p^*)/\phi = 1/\phi - \sigma p^*/\phi$ units of another agent's consumption good (call this amount C). Summing A, B, and C yields expression (7).

[16] To see this, note that, absent the seigniorage tax, each unit of silver purchases ϕ units of another agent's consumption good, which can then be consumed without further loss. Had those units instead been exchanged through barter, only one unit would ultimately have been consumed, with the remaining $\phi - 1$ units lost to search frictions.

Substituting this expression into (2) yields the government's period-2 problem:

$$\max_{s,t} W(s,t) = \frac{1}{t}\left[\frac{(1-\lambda)\sigma\phi}{s^2} + \frac{1}{\phi}\right] + \\ + \alpha\left\{\underbrace{\frac{t-1}{t}\left[\frac{(1-\lambda)\sigma\phi}{s^2} + \frac{1}{\phi} - \delta\frac{1}{\phi}\left(1-\sigma\frac{\phi}{s}\right)\right]}_{R_t} + \underbrace{\frac{s-1}{s}\sigma\left[(1-\lambda)\frac{\phi}{s}+1\right]}_{R_s} + \lambda\sigma\frac{\phi}{s} - \xi C(\tau)\right\}, \tag{8}$$

subject to $t \leq \tau$.

The first term in curly brackets represents transaction-tax revenues, R_t. These equal the tax rate, $(t-1)/t$, multiplied by private utility (the taxable base of the transaction tax), minus a positive term equal to δ times the value of barter transactions. This adjustment reflects the fact that a share δ of revenues raised from taxing barter transactions is lost before reaching the government. The second term represents seigniorage revenues, R_s, and equals the tax rate, $(s-1)/s$, multiplied by the taxable base, $\sigma[(1-\lambda)\phi/s+1]$. This expression reflects the fact that the government taxes silver both when privately owned silver is brought to the mint to be converted into coins and when silver coins are brought back to be converted into silver. Only in the former case, however, can the government subsequently sell the silver on the exchange, increasing its value by a factor $p^* = \phi/s$.

It is shown in Online Appendix A.2 that the seigniorage tax which solves the government's problem is

$$s^* = s(t) = \max\left[1, (1-\lambda)\frac{2\phi(\alpha-1)}{\alpha[t(\phi-1)+(t-1)\delta]}\right]. \tag{9}$$

For our purposes, the key comparative static is that s^* is weakly decreasing in the transaction tax t. Intuitively, while the seigniorage tax helps finance public expenditure, it is distortionary because it reduces demand for silver and hence both its price and the share of monetary transactions in the economy. By contrast, the transaction tax is levied on private utility, and its effectiveness increases with monetisation. As a result, a higher transaction tax raises the relative cost of relying on seigniorage, leading the government to set a lower s^*. This effect is particularly strong when barter transactions are difficult to tax (high δ).

The optimal seigniorage tax is also decreasing in the government's share of silver ownership, λ. Intuitively, the more silver the government owns, the more costly it becomes to depress the monetary value of silver through taxation.

For some parameter values, the optimal seigniorage tax is zero ($s^* = 1$) for all $\tau \geq 1$ and $\lambda \in [0, 1]$. This occurs, for example, when search costs are high and the government places little value on public expenditure (high ϕ and low α). Intuitively, in this case the gains from monetisation are large relative to the value of the public expenditure financed by seigniorage, making any positive seigniorage tax unattractive. To rule out this uninteresting case, we impose

Assumption 3.

$$\frac{2\phi(\alpha - 1)}{\alpha(\phi - 1)} > 1,$$

which ensures that the government finds it optimal to use the seigniorage tax, at least when τ and λ are sufficiently low.

Turning to the optimal transaction tax, it is straightforward to verify that, if δ is sufficiently low, the government's objective (equation 8) is increasing in t, implying that $t^* = \tau$. Intuitively, the transaction tax is non-distortionary because it applies equally to all transactions. In the extreme case of $\delta = 0$, each additional unit of private utility collected through taxation translates into one additional unit of public expenditure. Since the government values the latter more than the former, its objective is increasing in t. If δ is sufficiently large, however, the objective may instead be decreasing in t, because too large a share of revenues from barter transactions is lost before reaching the government. In that case, $t^* = 1$. To rule out this uninteresting possibility, we impose

Assumption 4. $\delta < \frac{\alpha-1}{\alpha}$.

Assumption 4 ensures that enough revenues reach the government even in the extreme case in which all transactions are barter. It is therefore sufficient to guarantee that

$$t^* = \tau. \tag{10}$$

We define monetisation, m, as the share of the consumption good that is exchanged in monetary transactions. Since σp^* units of the consumption good are exchanged in monetary transactions, and the total endowment of the consumption good is one, monetisation is given by

$$m = \sigma p^* = \sigma \frac{\phi}{s(\tau)} \equiv m(\sigma, \tau). \tag{11}$$

Under Assumption 2, the economy is not fully monetised, that is, $m < 1$.

In Online Appendix A.1.1, we develop a more general model in which silver can be exchanged a finite integer number of times, $v \geq 1$. In that framework, monetisation is given by $\sigma\phi(v)/s(\tau)$, where $\phi(v) = \phi$ when $v = 1$ and is increasing in v. Thus, a higher velocity of money raises monetisation, but the economy remains imperfectly monetised provided that v is not too large. Reassuringly, the comparative statics of the extended model are qualitatively identical to those of the baseline model, implying that our results do not hinge on the assumption that each unit of silver can be exchanged only once.

Equation (11) formalizes the idea that a low silver supply (low σ) leads to imperfect monetisation, provided the intrinsic value of silver (ϕ) is not too high. The former captures a supply-side constraint on monetisation, while the latter reflects a demand-side one. As discussed earlier and shown formally in Online Appendix A.1.2, a bounded ϕ can be interpreted either literally, as reflecting a limited intrinsic value of silver, or as arising from indivisibilities that restrict the use of small coins when the price of silver becomes sufficiently high.

Equation (11) also identifies a second demand-side determinant of monetisation: the government's fiscal capacity, τ. A first key result of the model is therefore that monetisation is weakly increasing in fiscal capacity. Intuitively, a government with greater fiscal capacity relies less on the seigniorage tax to finance public expenditure. This raises monetisation because seigniorage reduces the equilibrium price of silver and hence the amount of consumption goods that silver can purchase.

Period 1. In this period, the government chooses fiscal capacity, τ, anticipating that, in Period 2, taxes will be set according to the policy functions (9) and (10). Thus,

$$\tau^* = \arg\max_{\tau} W[s(\tau), \tau].$$

It is shown in Online Appendix A.2 that there exists a finite solution to this problem, which is greater than one and implicitly characterized by

$$\frac{1}{\tau^2}\left\{\left[\frac{\alpha-1}{\alpha}\frac{1-\lambda}{s(\tau)}+\frac{\delta}{\phi}\right]m(\sigma,\tau)+\left(\frac{\alpha-1}{\alpha}-\delta\right)\frac{1}{\phi}\right\}=\xi\frac{dC(\tau)}{d\tau}, \tag{12}$$

which equates the marginal benefit of investment in fiscal capacity to its marginal cost.

Since $m(\sigma, \tau)$ appears in the marginal benefit of investment, expression (12) makes it clear that monetisation affects incentives to invest in fiscal capacity. Greater monetisation makes the economy larger and transactions easier to tax, thereby increasing the returns to fiscal-capacity investment. Indeed, this remains true even for a rapacious government that entirely embezzles public revenues for personal consumption (a case captured by $\alpha \to \infty$).

Having characterized the equilibrium of the model, it is now straightforward to show (see Online Appendix A.2) that Assumptions 1–4 can simultaneously hold.

2.4 Main theoretical result

Having characterized the equilibrium of the model, we now turn to our main result: fiscal capacity and monetisation are complements. To establish this, we examine the comparative statics of the equilibrium with respect to two parameters: the endowment of silver (σ) and the cost of investing in fiscal capacity (ξ). Changes in σ directly affect monetisation (equation 11) but not fiscal capacity for a given level of monetisation (expression 12). Studying the comparative statics with respect to σ therefore isolates the effect of an exogenous shock to monetisation on fiscal capacity. Conversely, changes in ξ directly affect fiscal capacity but not monetisation for a given level of fiscal capacity, allowing us to isolate the effect of an exogenous shock to fiscal capacity on monetisation. These results are summarized in Proposition 1, whose proof can be found in

Online Appendix A.2.

Proposition 1. *An exogenous positive shock to monetisation (an increase in the endowment of silver, σ) weakly increases fiscal capacity, and strictly increases it if $\lambda < 1$ or $\delta > 0$. Likewise, an exogenous positive shock to fiscal capacity (a decrease in the cost of investment ξ) weakly increases monetisation.*

That an exogenous positive shock to fiscal capacity weakly increases monetisation is unsurprising, since $m(\sigma, \tau)$ is weakly increasing in τ. The main novelty of Proposition 1 is that the reverse effect also holds: an exogenous increase in monetisation—such as a rise in the endowment of silver, σ—raises fiscal capacity. The intuition can be seen from expression (12), which equates the marginal benefit of investing in fiscal capacity to its marginal cost. In particular, monetisation enters the marginal benefit through the term in square brackets. An increase in monetisation raises this marginal benefit through two channels. First, greater monetisation increases the value of the private economy and thus expands the taxable base of the transaction tax. This "income channel" operates only if silver is at least partly privately owned ($\lambda < 1$). If all silver were owned by the government, an increase in its endowment would not make citizens wealthier and would therefore not increase the returns to fiscal-capacity investment. Second, greater monetisation reduces the share of transactions conducted through barter, increasing the efficiency with which the transaction tax can be collected. This "efficiency channel" operates only if barter transactions are more difficult to tax than monetary ones ($\delta > 0$). The strength of the income channel is governed by the privately owned share of silver, $1 - \lambda$, while the strength of the efficiency channel is governed by the difficulty of taxing barter transactions, δ.

The result that an increase in the endowment of silver raises fiscal capacity may at first seem surprising. In line with the fiscal-capacity literature, one might expect a larger natural-resource endowment to reduce investment in fiscal capacity by lowering the need for fiscal revenues. Part of the discrepancy stems from the fact that, unlike much of the existing literature, we allow silver to be at least partly privately owned ($\lambda < 1$). This distinction matters. Even in our model, setting $\lambda = 1$ eliminates the income channel through which an increase in σ raises fiscal capacity. However, our result does not hinge on private ownership. As argued above, even when the income channel is shut down, an increase in σ still raises fiscal capacity through the efficiency channel (provided $\delta > 0$). The key reason is that silver is a particular type of natural resource: it can be used as money. Regardless of who owns it, a larger silver endowment increases the share of monetary transactions in the economy, thereby improving the efficiency of taxation and strengthening the incentive to invest in fiscal capacity.[17]

Proposition 1 suggests that, in an imperfectly monetised economy such as the one we study, taxation and the money supply are positively related in the long run. This contrasts with the fiscal theory of the price level and related frameworks, in which taxation and money creation are alternative instruments for financing government expenditure. The key difference is that we endogenise the economy's degree of monetisation, whereas these frameworks typically take full monetisation as given. Our mechanism is therefore particularly relevant for imperfectly monetised economies, such as those prevailing in the early modern period.

2.5 Credibility and fiat money

In our model, silver emerges endogenously as money because its intrinsic consumption value makes it a natural instrument for mitigating the frictions associated with specialization. The framework is therefore well suited to describing a monetary system based on full-bodied commodity money. Even in such systems, however, money may trade above the intrinsic value of the underlying metal because it provides liquidity services, as in search models such as Kiyotaki and Wright (1989) or cash-in-advance models. This is the case in the equilibrium we consider, where $p^* > 1$.

The historical and theoretical environments studied by Sargent and Velde (2002), however, go considerably further. They show that even within a commodity money system governments can sustain forms of token whose exchange value exceeds their intrinsic value by a very large margin. In theory, the government can suspend the free minting of small coins and replace existing small

[17] For simplicity, we assume that utility is linear in public expenditure. If utility from public expenditure were concave, an increase in the endowment of government-owned silver would have an additional negative effect on investment in fiscal capacity, because it would reduce the marginal value of public expenditure. In the extreme case in which all silver is government-owned and barter transactions are no more difficult to tax than monetary ones (that is, $\lambda = 1$ and $\delta = 0$), an increase in σ could then reduce fiscal capacity. Even in that setting, however, the positive relationship between silver endowments and fiscal capacity would continue to hold for sufficiently low values of λ and sufficiently high values of δ.

denominations with token coinage in quantities sufficient to support small transactions, but not so large as to generate excessive inflation (which could induce agents to melt full-bodied large coins). Convertibility of token coinage into full-bodied coins at a fixed rate—consistent with the "standard formula" that prevailed from the nineteenth century onward—tends to stabilize the system, but is not strictly required. Thus, such an arrangement allows the government to economize on scarce precious metals while maintaining a well-functioning monetary system.

Empirically, Sargent and Velde (2002) show that Castile experimented with inconvertible copper *vellón* from 1596: this token coinage circulated above its metallic value for several decades, but repeated overissue ultimately generated inflationary instability and a return toward a metallic anchor. Castile was not unique. Sargent and Velde also document related seventeenth-century experiments with overvalued small coinage in France, Catalonia, Germany, Russia, and the Ottoman Empire. Later paper-money experiments display the same fragility: French Revolutionary assignats ended in hyperinflation and abolition (Sargent and Velde, 1995), while Sweden's repeated fiat episodes in 1716–1719, 1745–1776, 1789–1803, and 1809–1834 were each followed by devaluation or the restoration of convertibility (Edvinsson, 2010).

The key implication is that scarcity of silver need not mechanically imply imperfect monetisation: a credible and institutionally constrained issuer could economise on precious metal by supplying token or paper money. In low-credibility settings, however, these instruments are fragile because expectations of overissue undermine their value.

Because our model does not explicitly incorporate credibility, it is not well suited to analysing inconvertible fiat money regimes whose stability depends primarily on expectations about future issuance.[18] Nevertheless, we believe it remains a useful framework for studying the co-evolution of money and taxation in the early modern period, since the historical episodes discussed above—such as token money in Castile—were typically fragile and ultimately transitory. The scarcity and small-change constraints we emphasize can be interpreted as reduced-form representations of the limitations prevailing in low-credibility environments, where governments could not credibly commit to refrain from exploiting the monetary system for fiscal purposes.

[18]Our model could more straightforwardly be extended to accommodate convertible token or paper money. In that case, the supply of money would remain constrained by metal availability, as convertibility disciplines issuance.

While our model is not intended to analyse inconvertible fiat money regimes, the complementarity between monetisation and fiscal capacity identified in the paper may have analogues in such environments. One possibility is that greater fiscal capacity reduces the government's reliance on monetary financing and thus the incentive to overissue, enhancing credibility. In turn, increased confidence in the currency may shift transactions from informal or black markets into the formal sector, expanding the tax base and strengthening incentives to further develop fiscal capacity. This suggests a mutually reinforcing relationship between fiscal capacity and monetisation that could extend beyond the commodity-money setting we consider. Historical episodes such as England during the Napoleonic Wars and Yuan China, discussed in Online Appendix D, are broadly consistent with this interpretation.

3 Empirical analysis

Our framework argues that an exogenous positive shock to monetisation should increase fiscal capacity, and a positive shock to fiscal capacity should increase monetisation (Proposition 1). This section tests the first of these predictions, that is the causal impact of monetisation on fiscal capacity. The reason why we focus on this prediction is that the impact of monetisation on fiscal capacity is less well-understood and has received less attention in the empirical literature than the impact of fiscal capacity on monetisation.[19] Moreover, the natural experiment associated with the discovery and exploitation of massive amounts of precious metals in the Americas allows for a unique opportunity to identify the impact of monetisation on fiscal capacity.

3.1 Mapping from theory to empirics

We begin by describing the mapping between the theoretical variables and their empirical counterparts. Table 1 provides an overview.

[19] For the early modern period, empirical support for the argument that fiscal capacity had a positive impact on monetisation is provided by Karaman et al. (2020). For 11 European states between 1500 and 1900, this paper finds that a higher fiscal capacity stabilized monetary units, as states no longer depreciated their currencies for seigniorage. This impact breaks down only at very low levels of fiscal capacity, because weak states lacked the capacity to circulate currency, and could not generate seigniorage revenues in the first place. As for the modern period, empirical support for the impact of fiscal capacity on monetary stability is provided, among others, by

Table 1: Mapping between main theoretical and empirical variables

Description	**Theory**	**Empirics**	**Relationship**
Precious metals	σ	$metals_t$	σ is the per capita metal stock; $metals_t$ is production of American silver and gold (a flow), and is treated as an exogenous shifter of the per capita metal stock.
Monetisation	$m^* = \sigma p^*$	$monetary_{i,t}$	m^* is the equilibrium purchasing power of the per capita metal stock; $monetary_{i,t}$ is the per capita real money stock.
Fiscal capacity	τ^*	$fiscal_{i,t}$	τ^* is a policy variable (fiscal capacity) which directly maps into equilibrium per capita real tax revenues; $fiscal_{i,t}$ is per capita real tax revenues.
Causal prediction	$\sigma \to m^* \to \tau^*$	$metals_t \to monetary_{i,t} \to fiscal_{i,t}$	The empirical design implements the model's causal chain.

The model features stock variables, flow variables, and policy variables. The endowment of silver, σ, is a *stock*, representing the quantity of monetary metal available per capita at a point in time. Monetisation, $m^* = \sigma p^*$, is also a stock-like object, as it measures the purchasing power of that stock of monetary metal in equilibrium. In contrast, fiscal capacity, τ, is a *policy variable* that governs the flow of tax revenues, while realised tax revenues themselves are *flows*.

In the empirical analysis, we map these theoretical objects into observable counterparts as follows. Monetisation is proxied by the per capita real money stock, a stock variable measured at annual frequency.[20] As an exogenous driver of monetisation, we use annual precious-metal production in the Americas, which is observed as a flow. One feature of this mapping is that the model's exogenous variable, σ, is a stock, whereas its empirical counterpart is a flow. Our empirical strategy addresses this by exploiting the fact that precious-metal flows accumulate into the stock of money. Accordingly, the first-stage regression relates current money stocks to lagged precious-metal production, so that metal flows serve as shocks to the evolution of the underlying stock.

Finally, as standard in the literature, fiscal capacity is proxied by per capita real tax revenues, which are also flows measured over a year. Equation (25) in Online Appendix A.2 shows that, in the model, equilibrium per capita real tax revenues can be written as:

Sargent (1982) and Catao and Terrones (2005).

[20]The per capita real money stock is an appropriate proxy for monetisation in our baseline model, where monetisation is given by σp^*, the per capita purchasing power of the money stock. In the extension developed in Online Appendix A.1.1, monetisation becomes $\sigma v p^*$, where $v \geq 1$ denotes the velocity of money. The proxy therefore remains valid provided that velocity does not display a strong long-run trend. This is not an unreasonable assumption for the period under consideration: while velocity was at times volatile between 1550 and 1790, it exhibited no clear secular trend (Palma, 2018c, p. 391). The baseline model also abstracts from economic growth. Unlike changes in velocity, however, balanced growth does not invalidate the proxy. If all real quantities in the model grow proportionally, equilibrium monetisation remains characterised by σp^*. Empirically, we further account for potential scale effects by controlling for real GDP per capita in the baseline specification.

$$\text{pc real tax revenues} = \overbrace{\frac{\tau^*[\underset{+}{m^*}(\underset{+}{\sigma})]-1}{\tau^*[\underset{+}{m^*}(\underset{+}{\sigma})]}\left[\underbrace{Y(\underset{+}{\sigma})}_{\substack{\text{real GDP}\\\text{per capita}}} - \underbrace{L(\underset{-}{\sigma})}_{\substack{\text{inefficiency of}\\\text{taxation (due to the}\\\text{existence of barter)}}}\right]}^{\text{Revenues from the transaction tax}} + \overbrace{R_s(\sigma)}^{\substack{\text{Revenues from}\\\text{seigniorage}}} + \overbrace{R_\sigma(\underset{+}{\sigma})}^{\substack{\text{Revenues from}\\\text{government's own metals}}} \tag{13}$$

Since revenues from the transaction tax are increasing in τ^*, per capita real tax revenues are indeed a valid proxy for fiscal capacity.

The model's key causal prediction is that an increase in σ raises monetisation, $\uparrow m^*$, which in turn increases fiscal capacity, $\uparrow \tau^*$. Our empirical design studies this causal chain by estimating the relationship $monetary_{i,t} \rightarrow fiscal_{i,t}$, while instrumenting for $monetary_{i,t}$ using $metals_t$. Equation (13), however, highlights several channels through which an increase in σ may affect observed tax revenues even in the absence of any increase in fiscal capacity. First, it may mechanically raise revenues from the transaction tax by expanding the taxable base, since it increases real GDP per capita, Y, and reduces the inefficiency of taxation, L, by reducing the importance of barter transactions. Second, it may affect revenues from seigniorage, R_s, and from direct taxes on metals, R_σ, both of which may be included in observed per capita real tax revenues.[21] We return to each of these potential confounding channels in Section 3.5.2 below.

3.2 Variables and data

We now explain how our three main empirical variables (annual precious metal production in the Americas and the per capita real money stock and real tax revenues) are constructed. As

[21]Seigniorage revenues may be either increasing or decreasing in σ. The latter is possible because, as shown in the detailed version of equation (13) (see equation (25) in Online Appendix A.2), an increase in σ, while expanding the taxable base of the seigniorage tax, may reduce the equilibrium seigniorage rate, $s(\tau^*)$, by increasing fiscal capacity, τ^*. In the context of our empirical analysis, however, the main concern is that seigniorage revenues may be increasing in σ, since this could generate a positive relationship between monetisation and observed tax revenues even in the absence of any increase in fiscal capacity. By contrast, if seigniorage revenues were decreasing in σ, this would bias our estimates downward and lead us to underestimate the effect of m^* on τ^*.

with other variables, the data sources are discussed in detail in Online Appendix C.

The yearly precious metal production in the Americas (our instrument for monetisation) is measured as the sum of silver and gold production in metric tons, with the latter translated to silver units. These privately-extracted and owned outputs,[22] which peaked in the early 17th and late 18th century respectively for Potosí and Mexican silver, and in the mid 18th century for Brazilian gold, resulted in exogenous variation in European money stocks (see Palma 2022). Because we rely on a natural experiment for identification, we focus on the period in which this experiment was most relevant, between 1550 and 1790.[23] We also restrict the sample to England, France and Spain, the only countries for which detailed monetary and fiscal data is available. These countries were also among the most affected by the inflow of metals from the Americas (Palma, 2022).

To calculate the per capita real money stock (our proxy for monetisation), we first collect the data on the money stocks of different countries. We then convert the money stock from local currency into silver, the universal measure of value for the early modern period. We next divide the money stock by the population to get the per capita money stock in grams of silver. Finally, we divide the per capita money stock by the daily cost of a standard consumption basket in grams of silver to arrive at the per capita real money stock.[24]

Per capita real tax revenues are calculated by dividing central government revenues by population and by the daily cost of a standard consumption basket in each country. Consequently, tax revenues are measured in standard consumption baskets, the same unit as monetisation. In principle, fiscal revenues could include both payments in kind and payments in money. In practice,

[22]Among the countries considered, only for Spain was there a direct effect of metal outputs on government revenues, since the industry was taxed by the Spanish Crown. We take this issue into account in Section 3.3.

[23]The year 1550 marks the beginning of the arrival of American precious metals in Europe in large quantities, whereas the year 1790 marks the growing importance of paper money and a weakening relationship between precious metals and money stocks. For France we stop at 1788, before the French Revolution.

[24]Money stocks, which for premodern Europe were predominantly composed of coin stocks, have been reconstructed using a combination of data and assumptions. Data on annual observation of mint output flows was combined with occasionally observed stocks (usually at the moment of total or partial recoinages) and other supporting information, such as rates of annual depreciation of coins through wear and tear, based on ranges established by numismatic research. For methodological details on the reconstruction methods of money stocks, see Palma (2018b) and Chen et al. (2021). We focus on state-issued money because private forms of money rarely circulated at the national level, did not last long without government backing, and complemented, rather than displaced, state-issued money.

however, the revenues accruing to the central government in the early modern states we study were overwhelmingly monetary, since taxes collected in kind were costly to transport, store, and redeploy across the territory, and therefore could not easily finance expenditure undertaken by the centre (Ardant, 1975; Bonney, 1999). This is consistent with a high δ in the model, that is, a situation in which barter is difficult to tax.[25]

Figure 3 shows the per capita real money stock and real tax revenue series for the three countries in our sample. The two series appear to be closely related, and both increased significantly through the early modern period. This close relationship, however, does not by itself imply a causal relationship between the two, since monetary and fiscal capacity may both be determined by other variables.

3.3 Empirical strategy

The empirical specification follows the Local Projection-Instrumental Variable (LP-IV) methodology (Jordà, 2005). This methodology uses an excluded instrument to estimate the causal effects for different time horizons. The methodology is well-suited for our aim of estimating long-run effects, as it yields consistent estimates even at long horizons.[26]

Following the LP-IV methodology, we proceed in two stages. In the first stage, we use the production of precious metals in the Americas as an instrument for monetisation. In the second stage, we estimate the causal effect of monetisation on real tax revenues, using only the exogenous variation in the former variable that was generated by the production of precious metals.

The first-stage equation, estimated separately for each country i, is of the following form:

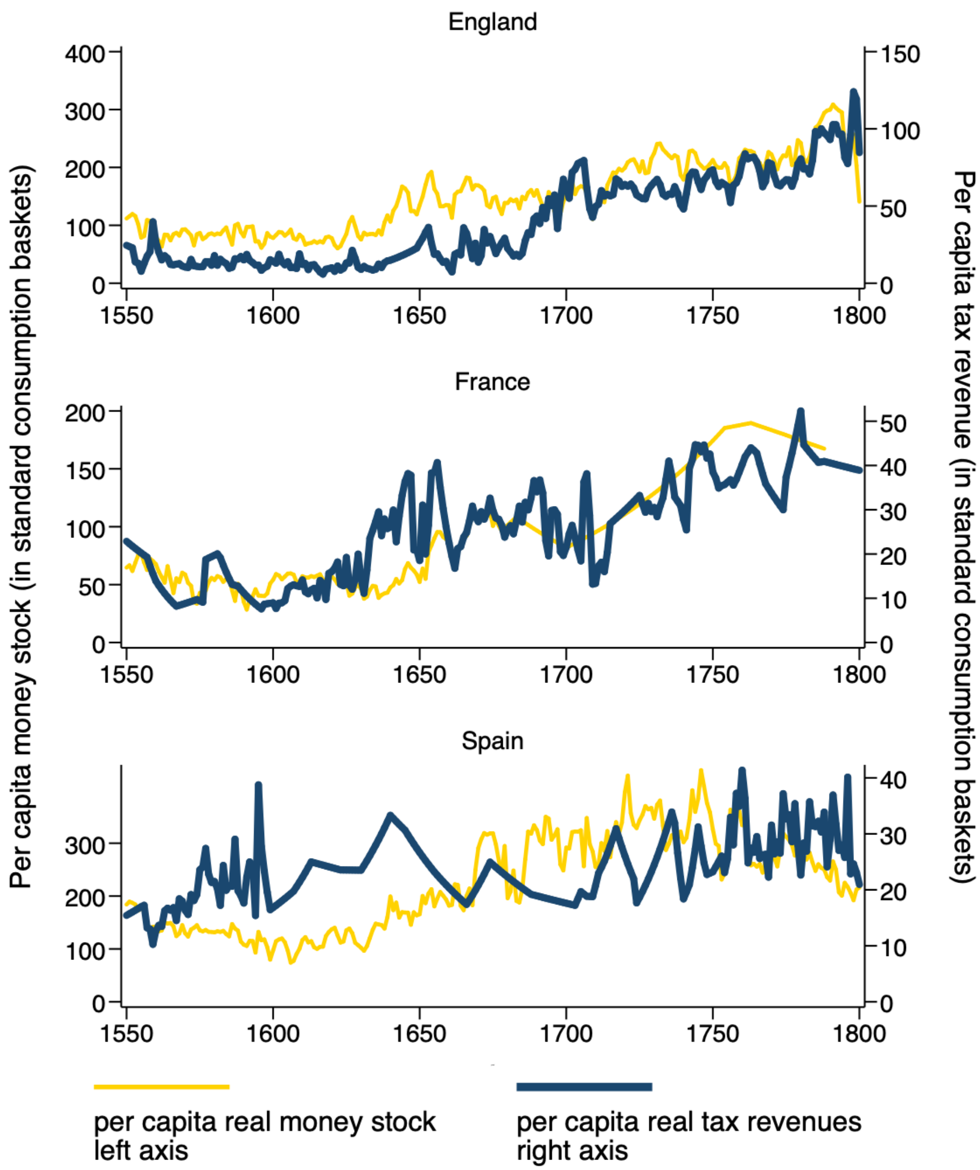
$$ln(monetary_{i,t}) = \alpha_i + \gamma_i ln(metals_{t-1}) + \boldsymbol{\phi_i} \mathbf{x_{i,t}} + e_{i,t}, \tag{14}$$

where $monetary_{i,t}$ is the per capita real money stock (our proxy for monetisation) in country i and year t, and $metals_{t-1}$ is total production of precious metals in the Americas in year $t-1$,

[25]Ideally, one would further net out seigniorage revenues and focus on non-seigniorage tax revenues only. This is possible only for England, the only case for which sufficiently detailed mint revenue data are available, and doing so leaves the results virtually unchanged. The country-specific sources underlying the tax revenue series are listed in Online Appendix C.

[26]See Jordà et al. (2024) for a general discussion of the methodology and the consistency of the estimates.

Figure 3: Money Stock and Tax Revenues Per Capita (in standard consumption baskets)



Note: See Online Appendix C for data sources.

expressed in grams of silver.[27]

The second-stage relationship is estimated separately for each country i and time horizon h:

$$\ln(fiscal_{i,t+h}) - \ln(fiscal_{i,t-1}) = \alpha_{i,h} + \beta_{i,h} \ln(\widehat{monetary}_{i,t}) + \boldsymbol{\psi_{i,h}} \mathbf{x_{i,t}} + u_{i,t+h}. \tag{15}$$

The outcome variable on the left-hand side is the cumulative growth of real per capita tax revenues (our proxy for fiscal capacity) in country i, between years $t-1$ and $t+h$. The main explanatory variable on the right-hand side, $ln(\widehat{monetary}_{i,t})$, is the log of the per capita real money stock, instrumented with the production of precious metals in the first stage. The vector $\mathbf{x_{i,t}}$ is a vector of control variables whose components are described below for each local projection result; at baseline, these include lags of the dependent variable, as well as contemporaneous and lagged values of the log of real GDP per capita.[28] The term $u_{i,t+h}$ is a horizon-specific error term. To address the potential serial correlation in the error term (Jordà, 2005), we use HAC-robust standard errors based on Newey and West (1987) throughout.[29]

The main coefficient of interest is $\beta_{i,h}$, estimated for each time horizon h in the second stage. This coefficient captures the impact of exogenous changes in monetisation in year t on the cumulative growth of fiscal capacity in country i, between years $t-1$ and $t+h$. For example, $\beta_{i,0}$ measures the impact of monetisation on real per capita tax revenues between years $t-1$ and t; $\beta_{i,1}$ the impact between years $t-1$ and $t+1$; and so on.

One concern with the empirical strategy is whether the proposed instrument, precious metal production in the Americas, satisfies the two requirements of the instrumental variable approach. The first requirement is relevance: the instrument should be sufficiently correlated with European money stocks after controlling for other variables. As discussed in the next section, both the historical evidence and the first-stage results support this condition. The second requirement is the exclusion restriction: conditional on controls, American precious metal production should

[27] Note that the excluded instrument has no i-subscript, since it is the same for all countries in the analysis.

[28] As explained in more detail further below, we explicitly control for real GDP per capita to account for a potential effect of the instrument on fiscal capacity via increased economic activity. Our results are unaffected by excluding this control variable.

[29] Montiel Olea and Plagborg-Møller (2021) note that the inclusion of lagged variables in the estimation can eliminate the need to use HAC-robust standard errors. In our specification, we include lagged variables and additionally allow for autocorrelation in the error term.

affect fiscal capacity only through monetisation. Potential violations of this restriction are discussed in detail in Section 3.5.2, where we consider alternative channels and conduct additional robustness exercises.

3.4 Main empirical results

Table 2 reports the first-stage results.[30] The F-statistic is above the rule-of-thumb value of ten for all three countries in the sample. Likewise, the elasticity of the per capita real money stock with respect to metal production in the Americas is positive and significant for all three, with a higher point estimate for Spain. In particular, a one percent increase in the production of precious metals in the Americas is estimated to have increased Spanish real per capita money supply by 0.5 percent after one year. This greater impact on Spanish money supply is expected, since the precious metals from the Americas first arrived in Spain, and diffused to England and France only indirectly through capture or trade.

Table 2: First-stage results

Dependent variable: real money p. c.	England (1550-1790)	France (1550-1788)	Spain (1550-1790)
lagged metals production	0.189***	0.243***	0.495***
	(0.058)	(0.053)	(0.077)
Observations	241	239	241
First-stage F	10.42	20.76	41.27

Note: The table shows the first-stage results, where the endogenous variable is the log real per capita money stock. Regressions control for two lags of log per capita real tax revenues, as well as contemporaneous and lagged per capita real GDP. The LP-IV approach uses Newey-West standard errors throughout. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure 4 presents the second-stage results. For each country i and horizon h, the vertical axis reports the point estimate of the coefficient $\beta_{i,h}$, together with the confidence intervals. For all three countries in our sample, an exogenous increase in monetisation increased real tax revenues. For the timing of impact, it was fastest in Spain, where the effect of an increase in the real per capita money stock in year t was already visible in the same year, and peaked 5 years

[30] France has two observations fewer, because we end the sample before the French Revolution; doing this across all countries would yield similar results.

later. In contrast, in England and France, the effect built up more slowly over time, peaking respectively 17 and 14 years after the increase in monetisation. For the magnitude of the effect, it was stronger in England and France than in Spain; over the course of 20 years, a one percent increase in the per capita real money stock increased per capita real tax revenues by between 1 and 1.5 percent in England and France, but by only 0.6 percent in Spain. As for the persistence of the effect, in all three countries, the impact was quite persistent over the 20-year time horizon considered in Figure 4. In Online Appendix Figure B.2, we extend the time horizon to 30 years, and show that the coefficient is remarkably stable even over this longer period of time.

3.5 Mechanisms

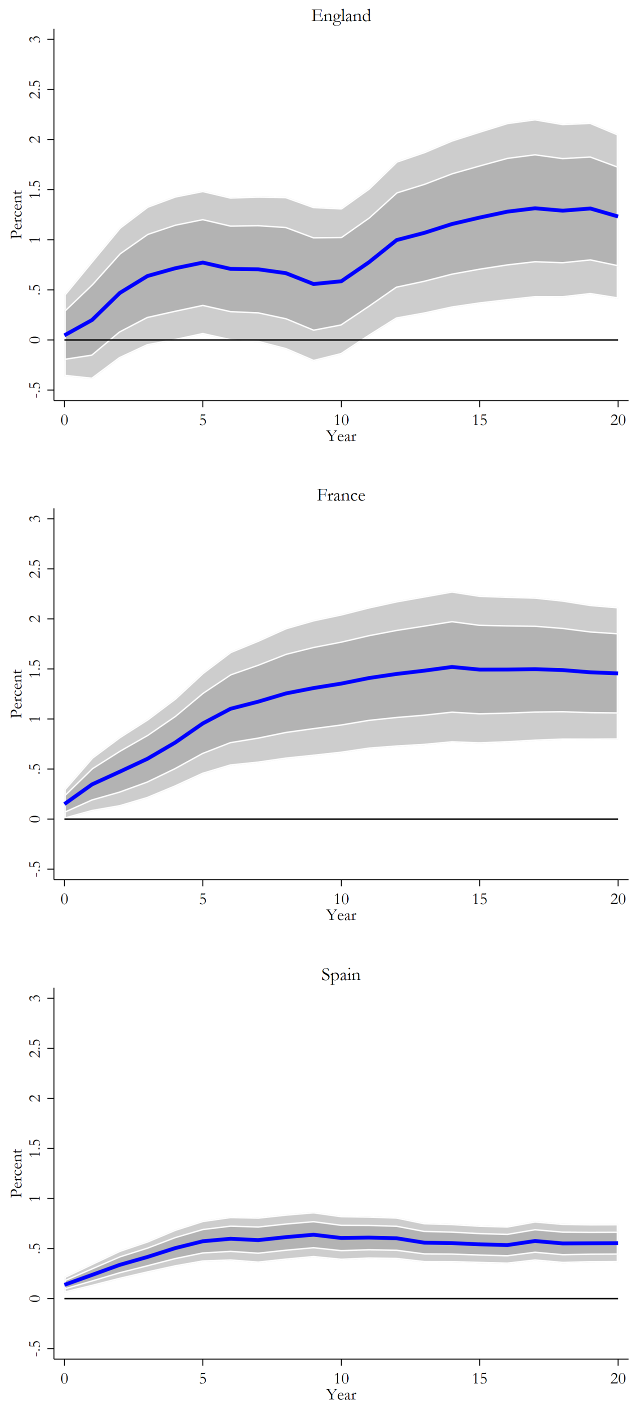
The previous section established that an increase in monetisation, instrumented using American precious-metal production, led to an increase in real tax revenues. We now discuss the mechanisms that may account for this result. We begin in Section 3.5.1 with the main mechanism highlighted by our model—investment in fiscal capacity—and then turn to alternative explanations in Section 3.5.2.

3.5.1 Investment in fiscal capacity

Our model highlights one possible mechanism underlying the results in the previous section: greater monetisation ($\uparrow m^*$) strengthens incentives to invest in fiscal capacity, thereby increasing the equilibrium level of fiscal capacity ($\uparrow \tau^*$) and, in turn, observed real tax revenues (see expression 13). The gradual build-up of the estimated effect of monetisation—taking up to 17 and 14 years to peak in England and France, respectively—is consistent with this interpretation. In the model, fiscal capacity adjusts only gradually for two reasons. First, building fiscal capacity is costly and takes time. Second, the model features a positive feedback loop: higher fiscal capacity increases monetisation, which in turn further strengthens incentives to invest in fiscal capacity.

As discussed in Section 2.4, incentives to increase τ^* strengthen as m^* rises through two channels: an income channel, whereby greater monetisation expands the size of the economy and hence the taxable base of the transaction tax; and an efficiency channel, whereby it increases

Figure 4: % change in per capita real tax revenues due to a 1% exogenous increase in per capita real monetary stock



Note: LP-IV impulse responses showing the cumulative response of per capita real tax revenues to a 1% increase in per capita real money stock, instrumented with the production of precious metals. 90% (light gray) and 1 standard deviation (dark gray) Confidence Intervals shown, based on Newey-West standard errors. The regressions control for two lags of log of per capita real tax revenues, as well as contemporaneous and lagged per capita real GDP. See Online Appendix C for data sources.

the efficiency with which the transaction tax can be collected. Both channels raise the returns to investing in fiscal capacity. While we cannot fully disentangle these mechanisms, our baseline regressions control for contemporaneous real GDP per capita (measured at time t, the year of the monetary expansion). Moreover, Figure B.4 in Online Appendix B.2 shows that our results are robust to including five leads of real GDP per capita. This approach is motivated by evidence that the positive income effects of precious-metal inflows dissipated within 4–9 years of their arrival (Brzezinski et al. 2024; Palma 2022). At the same time, as fiscal capacity takes time to build up, in the short run, expansions of GDP will occur before expansions in fiscal capacity. To the extent that these controls account for the expansion in economic activity induced by monetisation, the baseline coefficients primarily reflect the efficiency channel. Consistent with this interpretation, omitting contemporaneous real GDP per capita from the regressions (see Online Appendix Table B.1, column 4, and Figure B.3) leaves the estimated effect of monetisation on tax revenues essentially unchanged for France and Spain, but substantially increases it for England—the only country in our sample to experience sustained economic growth, including the Industrial Revolution, during this period (see Broadberry et al. 2015).[31]

Historical evidence also supports the view that, in the period under consideration, greater monetisation made taxation more efficient, leading to the development of new taxation tools. Although continuous series for the share of transactions conducted in money are not available for the period 1500–1800, the historical record indicates a marked expansion of monetary exchange in England, France, and Spain. At the same time, states increasingly taxed activities that had become monetised. As market transactions shifted toward money and money-denominated instruments, tax collection became easier, as governments could target observable fiscal choke points—such as stamped paper, excisable manufactures, notarised contracts, and recorded payments. These generated auditable paper trails and enabled administrative economies of scale (Ashworth, 2003; White, 1989; Torres-Sánchez, 2012). As a result, governments developed fiscal tools specifically designed to exploit these monetary choke points.

In England, the rise of monetised exchange is evident in both litigation and payment in-

[31] On the heterogeneous effects of precious-metal inflows on income growth across countries, see Charotti et al. (2025); Chen et al. (2026).

frastructure. From the mid-sixteenth to early seventeenth century, a large share of civil suits concerned debts from ordinary market transactions, indicating widespread monetised exchange at the household and firm level (Muldrew, 1993). By the late eighteenth century, payment technology had shifted further toward cashless instruments: London bankers established the Clearing House in 1773 to net cheques and bills, settlement increasingly relied on Bank of England notes rather than coin, and country banks spread rapidly (Boel, 2019; Turner, 2015). These developments point to a growing share of transactions conducted through money and money-denominated claims. They also help explain why British governments relied increasingly on taxes collected at monetary choke points, including customs, excises, and stamp duties (Brewer, 1988; Ashworth, 2003).

For France, Parisian notarial records document dense money and credit contracting from the late seventeenth century onward, consistent with highly monetised urban transactions visible to authorities (Hoffman et al., 2000). By 1740, France had a large notarial credit market: roughly 1.7 million notarized debt contracts were outstanding, equal to about 15.8 percent of GDP, and the system enabled nearly one-third of French families to borrow. By 1780, the stock had risen to 22.8 percent of GDP (Hoffman et al., 2019). Because these contracts financed purchases, mortgages, dowries, and working capital, they reflect the growing use of money in everyday exchange. Consistently, the *Ferme Générale* centralized major cash-based levies, including the *gabelle*, *aides*, customs, and later tobacco taxes, enabling greater scale and enforcement (White, 1989).

For Spain, comparable evidence comes from the expansion of inland bills of exchange and notarial credit markets. Inland bills became the main instrument for channeling domestic transfers and grew more efficient as clearing practices developed, indicating that an increasing share of payments passed through money denominated paper (Maixé-Altés and Iglesias, 2009). Notarial studies likewise show active short term credit markets in Spanish cities (Martínez Moutón et al., 1995). On the fiscal side, the Spanish monarchy increasingly targeted monetised purchases through the *alcabala*, *millones*, customs, and the tobacco monopoly. By the late eighteenth century, New Spain's tobacco monopoly had become the largest single source of public revenue, with net income around three million pesos a year in the 1790s (Marichal, 1999).

3.5.2 Alternative mechanisms

We now consider alternative mechanisms that could account for our results. For each, we discuss evidence suggesting that it is unlikely to be the primary driver of the observed increase in real tax revenues following an increase in monetisation.

Mechanical effects through increases in the taxable base Real tax revenues may increase following a monetary expansion not because of investment in fiscal capacity, but mechanically through an expansion of the taxable base. Such an increase may arise either from overall economic growth or from a larger share of transactions being conducted in forms that are easier to tax. In terms of the model, even if τ^* does not respond to an increase in m^*—for instance, because the cost of investing in fiscal capacity is sufficiently high—real tax revenues would still increase following a rise in σ. This is because a higher σ increases real GDP per capita and reduces the inefficiency of taxation associated with barter (Y and L in the first term in expression 13).

Several features of our results suggest that they are not mechanically driven by increases in income or improvements in the efficiency of taxation. Consider first the role of income. Our baseline regressions control for contemporaneous and lagged real GDP per capita, thereby accounting for the immediate expansion in economic activity that our model predicts would follow an inflow of precious metals and that has been documented for our period of study by Palma (2022) and Brzezinski et al. (2024).

Second, the timing of the estimated effects further suggests that they are unlikely to be mechanically driven by increases in real GDP per capita. Palma (2022) (for six early modern European countries) and Brzezinski et al. (2024) (for early modern Spain) show that increases in monetisation led to rises in real GDP that persisted for several years but dissipated after approximately 4–9 years, depending on the country. If this income effect were driving our results, we would expect a similar pattern: fiscal revenues rising rapidly and temporarily, before declining as real GDP reverted toward its previous level. Instead, we find that the effects of monetisation accumulate gradually and remain highly persistent. As discussed above, this pattern is consistent with a mechanism in which monetisation strengthens incentives to invest in fiscal capacity, leading states to undertake a gradual process of capacity building with lasting effects (an increase in τ^*).

Finally, to further assess the role of changes in real GDP per capita, we re-estimate our baseline specification including five leads of GDP growth. Since fiscal capacity takes time to expand, short-term GDP responses occur before such an expansion takes place. Figure B.4 in Online Appendix B.2 presents the results. Flexibly controlling for future GDP expansions does not materially affect our estimates. This exercise is only indicative; nevertheless, the results provide additional evidence that the increase in fiscal revenues is driven by enhanced fiscal capacity rather than by higher levels of economic activity alone.

Consider next the possibility that our results are driven by a mechanical increase in the efficiency of taxation (a fall in L in equation 13). Although we are unable to directly control for this channel, the timing of the estimated effects again suggests that it is unlikely to account for our findings. If a monetary expansion raised real tax revenues purely by increasing the efficiency of taxation, one would expect a rapid response, as existing fiscal instruments targeting monetary choke points would immediately capture a larger taxable base. Instead, we find an effect that builds up only gradually over time. This pattern is more consistent with the gradual development of new fiscal tools designed to exploit these choke points, such as the expansion of excise, customs, and stamp duties in England, and the centralisation of cash levies under the *Ferme Générale* in France.

Effect via expanded seigniorage. Another potential channel through which a metal inflow could increase real tax revenues is via higher seigniorage (i.e. mint revenues). In terms of the model, as long as $s(\tau^*) > 1$, an increase in σ may raise seigniorage revenues, and hence total revenues, even if τ^* remains constant (see the second term in expression 13). We investigate this channel directly for England, the only country for which sufficiently detailed data on mint revenues are available.[32] Figure B.5 in Online Appendix B.2 re-estimates our baseline specification after deducting mint revenues from total tax revenues. The results are virtually unchanged. This reflects the fact that, aside from the 1540s, mint revenues constituted only a negligible share of total tax revenues.

The broader historical evidence points in the same direction: the fiscal importance of seignior-

[32]The sources are taken from O'Brien and Hunt (1995).

age declined over time, as states increasingly relied on broad-based taxation and public debt. England provides the clearest example. Although Tudor rulers occasionally raised substantial revenue through debasement—most notably during the Great Debasement of 1544–1551—this ceased to be a meaningful fiscal strategy by the late seventeenth century. The Free Coinage Act of 1666 effectively ended the Mint's role as a revenue-generating institution by abolishing mint charges on private bullion; thereafter, mint expenses were financed from general taxation rather than contributing to it (Challis, 1992). Eighteenth century public finance instead relied on excise, customs, and land taxes (O'Brien and Hunt, 1993).

France and Spain exhibit a similar long-run pattern. In France, seigniorage could be important during earlier monetary crises, but by the seventeenth and eighteenth centuries mint profits were modest relative to the overall budget (Bonney, 1999). Even the major recoinage of 1689–1693 under Louis XIV generated annual mint profits of only about 3 to 6 percent of total royal revenues, despite being an exceptional episode (Jambu, 2015; Velde, 2008). In Spain, the late sixteenth-century silver windfall benefited the Crown primarily through taxes on remittances rather than through coinage seigniorage. The largest true seigniorage gains arose later from episodic copper *vellón* issues and restampings in the seventeenth century, which generated substantial but temporary windfalls rather than a stable revenue base (Motomura, 1994, 1997; Andrés Ucendo and Lanza García, 2008). By the late eighteenth century, mint-related extraordinary revenues had declined to low single-digit shares of total income (Andrés Ucendo and Comín Comín, 2021).

Taken together, this evidence indicates that the rise in tax revenues over our period was not driven by increasing seigniorage. If anything, the fiscal importance of seigniorage declined over time as broader and more regular fiscal instruments expanded. This pattern is consistent with our proposed mechanism: as monetisation deepened, governments found it easier to tax ordinary economic activity, reducing their reliance on mint profits. In terms of the model, as σ and hence m^* increase, τ^* rises (by Proposition 1), which in turn reduces the seigniorage tax $s(\tau^*)$ (by equation 9). Once fiscal capacity becomes sufficiently high, $s(\tau^*)$ converges to one and seigniorage revenues become negligible.

Effect via direct taxes on silver. Another potential mechanism is that tax revenues increased directly through taxes levied on the silver arriving from the Americas. In terms of the model, if $\lambda > 0$ (i.e. the government appropriates a positive share of incoming silver), then an increase in σ raises total revenues even if τ^* remains constant (see the last term in expression 13). This channel, however, does not apply to England and France, which could not directly tax bullion remittances upon arrival (i.e. $\lambda = 0$ in both cases). The fact that the estimated effects are largest for these two countries already suggests that this mechanism is unlikely to play a central role in explaining our results.

It is nevertheless informative to consider Spain. Consistent with this channel, only Spain displays a statistically significant contemporaneous effect, followed by a much flatter dynamic profile and, consequently, a smaller long-run effect compared to England and France. This pattern is consistent with the model. Using the detailed version of expression (13) (expression 25 in Online Appendix A.2), it is straightforward to show that a higher λ mechanically amplifies the immediate effect of an increase in σ on revenues (before τ^* adjusts), while simultaneously weakening the income channel through which monetisation raises fiscal capacity (see Section 2.4). Intuitively, when the government can directly tax incoming metals, larger inflows generate an immediate increase in revenues but reduce the incentive to develop the administrative capacity required to tax monetised transactions, resulting in a smaller increase in revenues over time.

Institutional change and wars. The inflow of precious metals may have also directly affected institutions, in particular in the case of the Spanish Crown which received part of the total inflow of precious metals as a direct revenue stream. This changed the Crown's reliance of having to go through parliament to raise taxes, or indeed to build fiscal capacity for these purposes. It thereby may also have changed the Crown's willingness and ability to wage war.

Towards investigating the role of these changes in our results, we re-estimate our main specification after adding controls for warfare and for parliamentary meetings. The results are in Appendix Table B.1, Columns 5–7, and Online Appendix Figures B.9. Controlling for war does not change the results significantly for any of the three countries. Controlling for parliamentary meetings, our proxy for institutional quality, leaves the estimates unchanged for England and

France. For Spain, by contrast, the inclusion of the parliamentary control roughly doubles the estimated effect of monetisation on tax revenues, and the impulse response shifts from peaking on impact to peaking around ten years after the shock. This pattern is consistent with the long-standing argument that American silver generated an "institutional resource curse" in Spain (see Charotti et al., 2025, for a recent overview), by sustaining the Crown's wartime ambitions and reducing its dependence on parliamentary tax bargains. If monetisation reduced institutional quality to the detriment of fiscal capacity, controlling for deteriorating institutional quality may lead to larger effect sizes of monetisation on tax revenues. This exercise of controlling for contemporary warfare and institutional quality is only indicative; nevertheless, Spain's smaller and earlier-peaking response is what one would expect when the executive can substitute the precious metals windfall directly for fiscal capacity rather than build on top of it.

3.6 Further robustness

In Online Appendix B.1, we present a detailed evaluation of the robustness of the results. For this purpose, we estimate the impulse responses with different sets of control variables and different time horizons. We also estimate adjusted impulse response functions that take into account potential violations of the exclusion restriction, following the methodology of Jordà et al. (2020). The results remain similar.[33] In Online Appendix D, we also put the theoretical model and empirical analysis in the text into a broader historical context by reviewing comparative evidence since antiquity.

4 Conclusion

Monetisation and fiscal capacity are jointly determined. Our theoretical framework shows that, in imperfectly monetised economies, greater monetisation increases the incentives to invest in fiscal capacity by enlarging and formalising the taxable economy, while greater fiscal capacity supports monetisation by reducing reliance on distortionary seigniorage. Consistent with this

[33]The main takeaway is that, for the results to be meaningfully different from our baseline, the violation of the exclusion restriction would have to be large relative to our main proposed mechanism.

mechanism, our empirical analysis exploits exogenous variation in precious metal inflows to show that increases in monetisation led to gradual and persistent increases in fiscal capacity in early modern Europe.

Our results have implications for macroeconomics, and more tentative implications for the study of economic development. In macroeconomics, higher taxes and monetary expansions are generally modeled as substitutes (Mankiw 1987; Sargent and Wallace 1981; Sims 1994). In contrast, we argue that, in undermonetised economies, they are complements: monetisation is a precondition for the building of fiscal capacity, and, in turn, countries with high fiscal capacity are capable of building more efficient monetary systems. This co-dependence also suggests that, in the context of under-monetised economies, money is not neutral, even in the long run.

Our theoretical and empirical analysis is grounded in premodern economies operating under commodity-money systems and characterised by relatively low levels of monetisation. As such, it cannot be applied mechanically to contemporary developing economies, which differ in important institutional and monetary dimensions. Nevertheless, as discussed in Section 2.5, the broader logic of the model may extend beyond the historical setting we study. In particular, complementarities between monetisation, credibility, and fiscal capacity may also arise in modern fiat-money economies characterised by informality, limited state capacity, and weak monetary credibility. Exploring these mechanisms in contemporary settings remains an important avenue for future research.

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Online Appendix

to *"Money for Taxes"*

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A Theory Appendix

A.1 Model extensions

A.1.1 General velocity of money

Suppose that, at the exchange—that is, after silver has been converted into coins and before it is converted back—silver can be exchanged a finite integer number $v \geq 1$ of times. In each round, agents may either exchange silver for consumption good or choose not to trade. If all consumption good is exchanged for silver before the end of the final round, agents return home immediately. Otherwise, if some consumption good remains unexchanged, agents barter it for other consumption good before heading home.[5]

We begin by assuming that, after the final round, some consumption good remains unexchanged, and we characterize the equilibrium by backward induction. We then derive a condition under which this initial assumption is satisfied. Specifically, we assume

$$\sigma \sum_{r=1}^{v} p_r < 1, \tag{16}$$

where p_r denotes the price of silver in round r. This condition ensures that the total amount of the consumption good exchanged for silver—the left-hand side of (16)—is strictly less than the aggregate endowment.

In round v (the last one) agents anticipate that, if they do not exchange their silver, they will bring it home and receive per-unit utility $1/(st)$. If they exchange it, they instead obtain per-unit utility p_v/t (where p_v is the price of silver in round v). Then, silver supply in round v is zero for $p_v < 1/s$, perfectly elastic and taking value between 0 and σ for $p_v = 1/s$, and equal to σ for $p_v > 1/s$. As for silver demand, agents anticipate that if they do not exchange their yet unexchanged consumption good for silver, they will barter it and obtain per-unit utility $1/(\phi t)$; if instead they exchange it for silver, they obtain per-unit utility $1/(p_v st)$. It follows that silver demand in round v is zero for $p_v > \phi/s$, perfectly elastic and taking value between zero and

[5] For simplicity, we also assume that consumption good that has already been exchanged cannot be exchanged again. To assume otherwise would complicate the silver demand functions without affecting the equilibrium described above, since buyers of silver would not sell any ready-exchanged silver at equilibrium prices.

$c_v/(\phi/s)$ for $p_v = \phi/s$, and equal to c_v/p_v for $p_v < \phi/s$. By Assumption 16, $c_v/(\phi/s) > \sigma$ (or else all consumption good would be exchanged for silver). It is then $p_v^* = \phi/s$, and all silver is exchanged in round v.

In round $v-1$, agents anticipate that if they do not exchange their silver for consumption good in the current round, they will exchange it in round v and receive $p_v = \phi/s$ units of consumption good per unit of silver. If they instead exchange it in round $v-1$, they obtain p_{v-1} units of the consumption good per unit of silver, where p_{v-1} is the price of silver in round $v-1$. Then, silver supply in round $v-1$ is zero for $p_{v-1} < \phi/s$, perfectly elastic and taking value between zero and σ for $p_{v-1} = \phi/s$, and equal to σ for $p_{v-1} > \phi/s$. As for silver demand, agents anticipate that if they do not exchange their yet unexchanged consumption good for silver, they will barter $c_{v-1} - \sigma p_v$ of it after round v, and obtain per-unit utility $1/(\phi t)$; if instead they exchange it for silver, they obtain per-unit utility

$$\frac{1}{p_{v-1}}\frac{\phi}{s}\frac{1}{t}$$

that is the amount of silver they receive in period $v-1$ ($1/p_{v-1}$) times the amount of consumption good they will receive per unit of silver in round v (ϕ/s), times one over the transaction tax they will pay on the consumption good ($1/t$). It follows that demand for silver in round $v-1$ is zero for $p_{v-1} > \phi^2/s$, perfectly elastic and taking value between zero and $(c_{v-1} - \sigma p_v)/(\phi^2/s)$ for $p_{v-1} = \phi^2/s$, and equal to $(c_{v-1} - \sigma p_v)/p_{v-1}$ for $p_{v-1} < \phi^2/s$. By Assumption 16, $(c_{v-1} - \sigma p_v)/(\phi^2/s) > \sigma$ (or else all consumption good would be exchanged for silver). It is then $p_{v-1}^* = \phi^2/s$, and all silver is exchanged in round $v-1$.

Extending this logic recursively across rounds, we obtain that the equilibrium price of silver in round $r \in \{1, ..., v\}$ is $p_r^* = \phi^{v-(r-1)}/s$.[6]

[6]Since $p_1^* = \phi^v/s > 1$ (by Assumption 1, or, more generally, by the weaker condition $st < \phi^v/s$ required to induce agents to bring their silver to the exchange in the general model), the government sells all of its silver in round 1 and exits the exchange.

We can now re-write condition 16 as

$$\sigma \sum_{r=1}^{v} \frac{\phi^{v-(r-1)}}{s} < 1$$
$$\sigma \frac{\phi}{s} \frac{\phi^v - 1}{\phi - 1} < 1.$$

A sufficient condition for this to hold is

$$\sigma\phi \frac{\phi^v - 1}{\phi - 1} < 1$$
$$\sigma < \frac{1}{\phi} \frac{\phi - 1}{\phi^v - 1}, \tag{17}$$

which is a general version of Assumption 2. Relative to that assumption, condition 17 additionally requires that v is not too large.

In this extended model, monetisation is equal to

$$\sigma \frac{\phi(v)}{s},$$

where $\phi(v) \equiv \phi(\phi^v - 1)/(\phi - 1)$. It is easy to verify that the comparative statics of monetisation with respect to σ, ϕ, and s are qualitatively the same regardless of the value of v.

Let p^* denote the equilibrium average price of silver across rounds,

$$p^* = \frac{1}{v} \sum_{r=1}^{v} \frac{\phi^{v-(r-1)}}{s}$$
$$= \frac{1}{v} \frac{\phi}{s} \frac{\phi^v - 1}{\phi - 1}.$$

Then, monetisation can alternatively be expressed as $\sigma v p^*$.

A.1.2 Indivisibilities

To isolate the role of indivisibilities, we abstract from taxation by setting $s = t = 1$, and from government ownership of silver by setting $\lambda = 0$. Consider the following indivisibilities. First, the maximum size of an individual transaction is $d \in (0, 1]$. If $d < 1$, this implies that agents, in order to sell and purchase one unit of the consumption good (as they do in equilibrium), must engage in multiple transactions. For simplicity, we assume that $1/d$ is an integer (for example, suppose $d = 0.2$, so that each agent must engage in at least $5 = 1/0.2$ different transactions). We assume that transactions cannot be bundled: in other words, one cannot have multiple transactions at the same time, neither with the same counterpart nor with different ones. Rather, one must complete the current transaction - whether monetary or barter - before being able to move to the next one. Second, the minimum silver content that can be physically embedded into a coin is $f \in (0, \sigma]$, and we similarly assume, for simplicity only, that σ/f is an integer (e.g. $\sigma = 0.1$ and $f = 0.05$, implying that each agent can obtain at most $0.1/0.05 = 2$ coins).[7] One or more coins can be used in a single transaction. We further assume $f < d$: this ensures that, at least for the lowest possible price of silver ($p = 1$) the amount of consumption good that the smallest coin can buy is less than the maximum that can be sold in a single transaction. In our running example, if $p^* = 1$, then the smallest coin can buy $0.05 * 1 = 0.05$ units of the final good, and each seller of silver can therefore conduct either two transactions worth 0.05 units of the consumption good each, or one transaction worth 0.1 (all these transactions are feasible, since they are less than 0.2).[8]

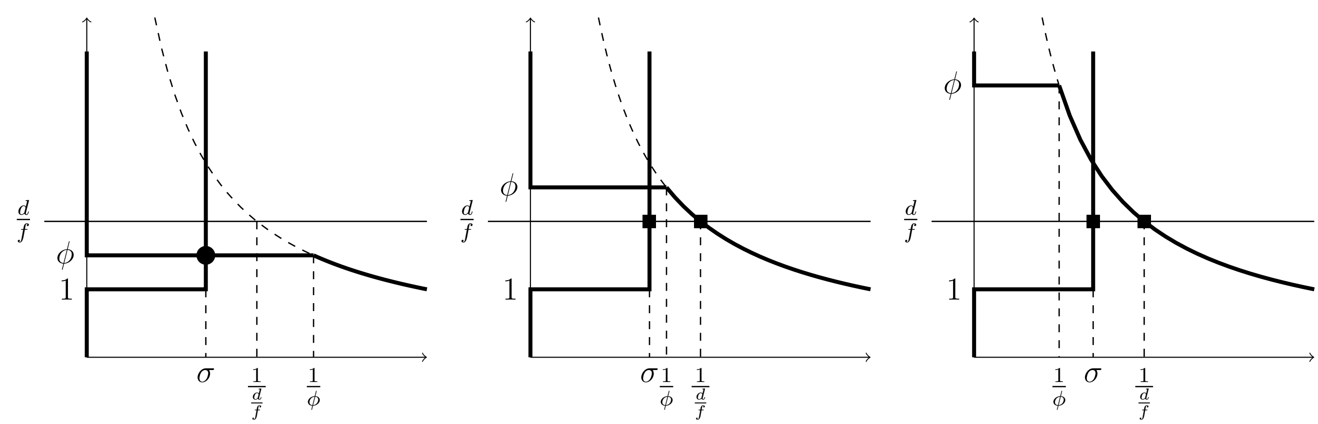
Under these assumptions, the maximum consumption good that can be physically exchanged for silver is $(\sigma/f) * d$. To see this, note that the maximum amount of consumption good that a single coin can buy is d, and there are at most σ/f coins overall. In our running example, two coins can buy at most $2*0.2 = 0.4$ units of the consumption good. In other words, indivisibilities create a physical limit to the possibility that even a minuscule quantity may be enough to monetise the entire economy: if $(\sigma/f) * d < 1$, this can never be the case. Note that, since $\sigma/f \geq 1$, the last inequality requires $d < 1$: intuitively, since people have at least one coin, and since prices can in principle increase to the point that a single coin is worth as much as the total endowment of the consumption good, then for a fully monetised economy to be a physical impossibility, the largest possible transaction must be lower than the total endowment of the consumption good. In other words, the model boils down to the baseline model for $d = 1$.

[7] They could alternatively obtain one coin worth 0.1 units of silver.

[8] The latter transaction can be carried out either using two coins, each containing 0.05 units of silver, or a single coin containing 0.1 units of silver.

An equivalent way to state this result is that there is a physical upper bound of $\max\{d/f, 1\}$ on the equilibrium price of silver. Since the minimum amount of silver that sellers can bring to a transaction is f, and the maximum amount of the consumption good that buyers can offer in return is d, the highest price buyers can possibly pay for silver is d/f. Figure A.1 illustrates this mechanism. In panel A, where the intrinsic value of silver ϕ is low, the upper bound does not bind, and the equilibrium in the silver market (marked by a black circle) coincides with the baseline outcome ($p^* = \phi$). Moving to panels B and C, ϕ increases, and so does the baseline equilibrium price of silver. In both panels, however, the upper bound binds, and the price of silver is therefore equal to $p^* = d/f$. In panel C, ϕ is sufficiently large that the economy would be fully monetised in the baseline model, but the presence of indivisibilities prevents this outcome. When the physical upper bound binds, the silver market is rationed: as indicated by the black squares in panels B and C, demand for silver exceeds supply at the realized price. Intuitively, because some silver is "wasted" in transactions that are excessively small, silver is exhausted before all transactions can be completed.

Figure A.1: Silver market equilibrium, indivisibilities



Panel A: $\frac{d}{f}$ not binding Panel B: $\frac{d}{f}$ binding Panel C: $\frac{d}{f}$ binding

In the alternative model, the sufficient condition for imperfect monetisation (Assumption 2) becomes

$$\sigma < \max\left(\frac{1}{\phi}, \frac{1}{\frac{d}{f}}\right).$$

This is evident in Figure A.1, where even if condition $\sigma < 1/\phi$ fails (as it does in panel C) imperfect monetisation realizes as long as $\sigma < 1/(d/f)$.

A.1.3 Heterogeneous transactions costs

Suppose that agents are heterogeneous in terms of their search costs, and ordered on the $[0, 1]$ interval in order of decreasing search costs. In particular, agent $i \in [0, 1]$ faces search costs equal to $\phi - \theta i$, where $\theta \geq 0$. For $\theta = 0$, this model is identical to the baseline. We assume $\phi - \theta > 1$, so that barter is inefficient even for the agent with the lowest cost of search.

Supply of silver is the same as in the baseline model. To derive demand for silver, note that for every unit of own consumption good that agent i exchanges in barter transactions, they bring home $1/[(\phi - \theta i)t]$ units of another agent's consumption good. If instead they exchange the unit for silver in monetary transactions, they bring home $1/(pts)$ units of silver. Since another agent's consumption good and silver have equal weights in utility, agent i opt for monetary transactions if and only if

$$\begin{aligned} ps &< \phi - \theta i \\ p &< \frac{\phi - \theta i}{s}. \end{aligned}$$

If follows that, if $p > \phi/s$, no agent opts for monetary transactions, and demand for silver is zero. At the opposite extreme, if $p < (\phi - \theta)/s$, all agents opt for monetary transactions, and demand for silver is $1/p$. For intermediate values of p, all and only the agents located to the left of agent $i(p)$ opt for monetary transactions, where

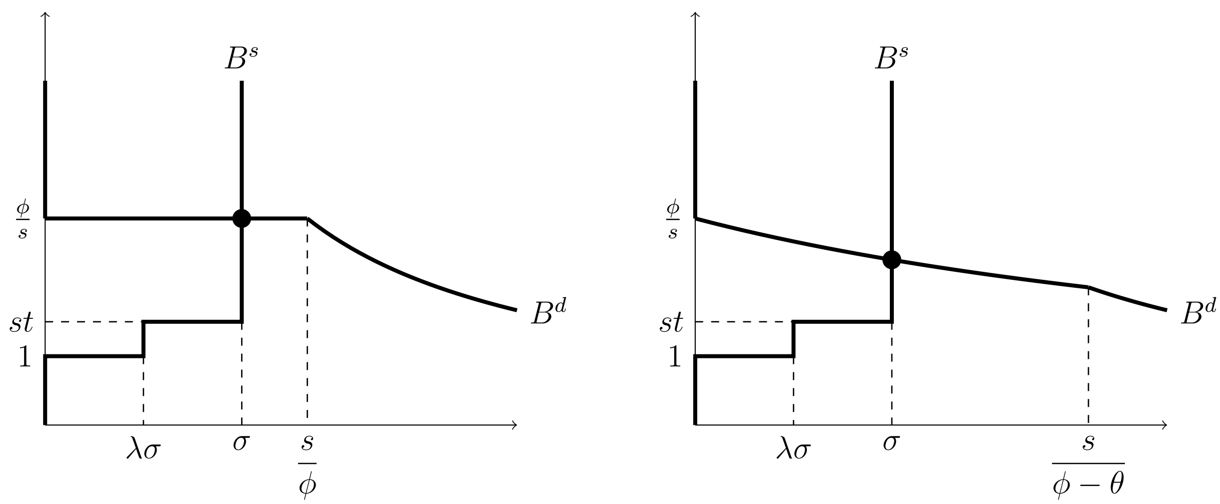
$$\begin{aligned} i(p) &= \arg\left[ps = \phi - \theta i\right] \\ &= \frac{\phi - ps}{\theta}. \end{aligned}$$

Note that agents to the left of $i(p)$ have mass $i(p)$, and they each demand $1/p$ of silver. It follows that, for intermediate values of silver, demand for silver is $i(p) * 1/p$.

Putting things together, aggregate demand for silver is then

$$B^d = \begin{cases} \frac{1}{p} & \text{if} \quad p < \frac{\phi-\theta}{s} \\ \frac{\phi-ps}{\theta}\frac{1}{p} & \text{if} \quad p \in \left[\frac{\phi-\theta}{s}, \frac{\phi}{s}\right] \\ 0 & \text{if} \quad p > \frac{\phi}{s} \end{cases} .$$

Figure A.2: Silver market equilibrium, heterogeneous agents



Panel A: $\theta = 0$ (baseline) Panel B: $\theta > 0$ (heterogeneous agents)

The equilibrium of the silver market is represented in Figure A.2, where panel A represents the baseline model ($\theta = 0$) and panel B the model with heterogeneous agents.

Under Assumption 1 and a weaker version of Assumption 2—that is $\sigma < 1/(\phi - \theta)$—supply meets demand at a price comprised between $(\phi - \theta)/s$ and ϕ/s. Then, the equilibrium price, found by equating demand and supply, is

$$\frac{1}{p}\frac{\phi - ps}{\theta} = \sigma$$

$$p^* = \frac{\phi}{\theta\sigma + s}.$$

As can be seen, provided $\theta > 0$, the equilibrium price is decreasing in the endowment of silver, σ.

monetisation is now

$$m = \sigma \frac{\phi}{\theta\sigma + s}.$$

It is straightforward to verify that the comparative statics of monetisation with respect to σ, ϕ, and s are qualitatively the same regardless of the value of θ.

A.2 Derivations and proofs

Derivation of optimal seigniorage tax. Let

$$\Gamma(t) \equiv \frac{1}{t} + \alpha \frac{t-1}{t}.$$

The government's objective function can be rewritten as

$$\begin{aligned} W(s,t) = {} & \Gamma(t) \left[\frac{(1-\lambda)\sigma}{s} p^* + \frac{1}{\phi} \right] - \alpha \frac{t-1}{t} \frac{\delta}{\phi} (1 - \sigma p^*) + \\ & + \alpha \left\{ \frac{s-1}{s} \sigma \left[(1-\lambda) p^* + 1 \right] + \lambda \sigma p^* \right\} - \alpha \xi C(\tau) \qquad (18) \\ = {} & A + \frac{\Gamma(t) + \alpha(s-1)}{s} (1-\lambda)\sigma p^* + \alpha \frac{t-1}{t} \frac{\delta}{\phi} \sigma p^* + \alpha\lambda\sigma p^* + \alpha \frac{s-1}{s} \sigma \\ = {} & A + \left[\frac{\Gamma(t) + \alpha(s-1)}{s} (1-\lambda) + \alpha \frac{t-1}{t} \frac{\delta}{\phi} + \alpha\lambda \right] \sigma p^* + \alpha \frac{s-1}{s} \sigma, \qquad (19) \end{aligned}$$

where the term A does not depend on s. It is

$$
\begin{aligned}
\frac{\partial W(s,t)}{\partial s} &= \frac{\alpha s - [\Gamma(t) + \alpha(s-1)]}{s^2}(1-\lambda)\sigma p^* + \\
&+ \left[\frac{\Gamma(t) + \alpha(s-1)}{s}(1-\lambda) + \alpha\frac{t-1}{t}\frac{\delta}{\phi} + \alpha\lambda\right]\sigma\frac{dp^*}{ds} + \alpha\frac{s-(s-1)}{s^2}\sigma \\
&= \frac{\alpha - \Gamma(t)}{s^2}(1-\lambda)\sigma p^* + \\
&- \left[\frac{\Gamma(t) + \alpha(s-1)}{s}(1-\lambda) + \alpha\frac{t-1}{t}\frac{\delta}{\phi} + \alpha\lambda\right]\sigma\frac{dp^*}{ds} + \alpha\frac{1}{s^2}\sigma \\
&= \frac{\alpha - \Gamma(t)}{s^2}(1-\lambda)\sigma\frac{\phi}{s} - \left[\frac{\Gamma(t) + \alpha(s-1)}{s}(1-\lambda) + \alpha\frac{t-1}{t}\frac{\delta}{\phi} + \alpha\lambda\right]\sigma\frac{\phi}{s^2} + \alpha\frac{1}{s^2}\sigma \\
&= \frac{\sigma\phi}{s^3}\left\{[\alpha - \Gamma(t)](1-\lambda) - [\Gamma(t) + \alpha(s-1)](1-\lambda) - \alpha\frac{t-1}{t}\frac{\delta}{\phi}s - \alpha\lambda s + \frac{\alpha s}{\phi}\right\} \\
&= \frac{\sigma\phi}{s^3}\left\{2[\alpha - \Gamma(t)](1-\lambda) - \alpha s(1-\lambda) - \alpha\frac{t-1}{t}\frac{\delta}{\phi}s - \alpha\lambda s + \frac{\alpha s}{\phi}\right\} \\
&= \frac{\sigma\phi}{ts^3}\left\{2(\alpha-1)(1-\lambda) - \alpha s\frac{(1-\lambda)\phi t + (t-1)\delta + \lambda\phi t - t}{\phi}\right\} \\
&= \frac{\sigma\phi}{ts^3}\left\{2(\alpha-1)(1-\lambda) - \alpha s\frac{t(\phi-1) + (t-1)\delta}{\phi}\right\}. \qquad (20)
\end{aligned}
$$

The government solves the constrained maximisation problem

$$\max_{s \geq 1} W(s,t).$$

Since $\partial W(s,t)/\partial s$ has the sign of $\tilde{s} - s$, where

$$\tilde{s} = (1-\lambda)\frac{2\phi(\alpha-1)}{\alpha[t(\phi-1) + (t-1)\delta]},$$

the unconstrained maximizer is $\tilde{s}$. If $\tilde{s} \geq 1$, this is also the constrained maximizer. If instead $\tilde{s} < 1$, then $\partial W(s,t)/\partial s < 0$ for all $s \geq 1$, so the constrained maximizer is $s = 1$. Hence,

$$s^* = \max[1, \tilde{s}].$$

□

Derivation of optimal transaction tax. The government's objective function can be re-written as in (18). Then,

$$\begin{aligned}
\frac{\partial W(s,t)}{\partial t} &= \frac{\alpha-1}{t^2}\left[\frac{(1-\lambda)\sigma}{s}\frac{\phi}{s}+\frac{1}{\phi}\right]-\alpha\frac{1}{t^2}\delta\frac{1}{\phi}\left(1-\sigma\frac{\phi}{s}\right)\\
&= \frac{\alpha}{t^2}\left\{\left[\frac{\alpha-1}{\alpha}\frac{(1-\lambda)\sigma}{s}\frac{\phi}{s}+\frac{\alpha-1}{\alpha}\frac{1}{\phi}\right]-\delta\frac{1}{\phi}\left(1-\sigma\frac{\phi}{s}\right)\right\}\\
&= \frac{\alpha}{t^2}\left\{\left[\frac{\alpha-1}{\alpha}\frac{1-\lambda}{s}+\frac{\delta}{\phi}\right]\sigma\frac{\phi}{s}+\left(\frac{\alpha-1}{\alpha}-\delta\right)\frac{1}{\phi}\right\}.
\end{aligned}$$

Clearly, a sufficient condition for $\partial W(s,t)/\partial t > 0$ is

$$\delta < \frac{\alpha-1}{\alpha}. \tag{21}$$

□

Identification of optimal fiscal capacity. The government's objective function given optimal policy can be found by plugging $t=\tau$ and $s=s(\tau)$ into (18):

$$\begin{aligned}
W[s(\tau),\tau] = {}& \frac{1+\alpha(\tau-1)}{\tau}\left[\frac{(1-\lambda)\sigma}{s(\tau)}\frac{\phi}{s(\tau)}+\frac{1}{\phi}\right]-\alpha\frac{\tau-1}{\tau}\delta\frac{1}{\phi}\left[1-\sigma\frac{\phi}{s(\tau)}\right]+\\
&+\alpha\left\{\frac{s(\tau)-1}{s(\tau)}\sigma\left[(1-\lambda)\frac{\phi}{s(\tau)}+1\right]+\lambda\sigma\frac{\phi}{s(\tau)}\right\}-\alpha\xi C(\tau)
\end{aligned} \tag{22}$$

To find optimal investment in fiscal capacity, set

$$\begin{aligned}
\frac{dW[s(\tau),\tau]}{d\tau} &= \frac{\partial W[s(\tau),\tau]}{\partial \tau}+\frac{\partial W[s(\tau),\tau]}{\partial s(\tau)}\frac{ds(\tau)}{d\tau}\\
&= \frac{\partial W[s(\tau),\tau]}{\partial \tau}\\
&= \frac{\alpha\tau-1-\alpha(\tau-1)}{\tau^2}\left[\frac{(1-\lambda)\sigma}{s(\tau)}\frac{\phi}{s(\tau)}+\frac{1}{\phi}\right]-\alpha\frac{\tau-\tau+1}{\tau^2}\delta\frac{1}{\phi}\left[1-\sigma\frac{\phi}{s(\tau)}\right]-\alpha\xi\frac{dC(\tau)}{d\tau}\\
&= \frac{\alpha-1}{\tau^2}\left[\frac{(1-\lambda)\sigma}{s(\tau)}\frac{\phi}{s(\tau)}+\frac{1}{\phi}\right]-\frac{\alpha}{\tau^2}\delta\frac{1}{\phi}\left[1-\sigma\frac{\phi}{s(\tau)}\right]-\alpha\xi\frac{dC(\tau)}{d\tau}\\
&= \frac{\alpha}{\tau^2}\left\{\left[\frac{\alpha-1}{\alpha}\frac{1-\lambda}{s(\tau)}+\frac{\delta}{\phi}\right]m(\sigma,\tau)+\left(\frac{\alpha-1}{\alpha}-\delta\right)\frac{1}{\phi}\right\}-\alpha\xi\frac{dC(\tau)}{d\tau}
\end{aligned} \tag{23}$$

where the second line follows from the fact that, if $s(\tau)=1$, then $ds(\tau)/d\tau=0$, and if $s(\tau)>1$, then by the optimal choice of $s(\tau)$, $\partial W[s(\tau),\tau]/\partial s(\tau) = 0$.

By Assumption 4, in (23), the term inside curly brackets is positive. Then, by the properties of $C(\tau)$, $dW[s(\tau),\tau]/d\tau > 0$ for $\tau = 1$. From (9), there exists $\overline{\tau} > 1$ such that, for $\tau \geq \overline{\tau}$, $s(\tau) = 1$. In this range,

$$\frac{dW[s(\tau),\tau]}{d\tau} = \frac{\alpha}{\tau^2}\left\{\left[\frac{\alpha-1}{\alpha}(1-\lambda) + \frac{\delta}{\phi}\right]\sigma\phi + \left(\frac{\alpha-1}{\alpha} - \delta\right)\frac{1}{\phi}\right\} - \alpha\xi\frac{dC(\tau)}{d\tau}.$$

The expression inside braces is a finite constant independent of τ. Since $C'(\tau) \to \infty$ as $\tau \to \infty$, it follows that

$$\frac{dW[s(\tau),\tau]}{d\tau} \to -\infty \quad \text{as } \tau \to \infty.$$

Hence there exists $\hat{\tau} \geq \overline{\tau}$ such that

$$\frac{dW[s(\tau),\tau]}{d\tau} < 0 \quad \text{for all } \tau > \hat{\tau}.$$

Since $dW[s(\tau),\tau]/d\tau$ is continuous, positive at $\tau = 1$, and negative for $\tau > \hat{\tau} > 1$, there exists at least one $\tau^* \in (1, \hat{\tau}]$ such that $dW[s(\tau),\tau]/d\tau = 0$. As $W[s(\tau),\tau]$ is continuous and decreasing for sufficiently large τ, at least one such stationary point is a global maximum. Each such τ^* satisfies (12).

Finally, note that the left-hand side of the argument in (12) is uniformly bounded above (because $s(\tau) \geq 1$ and $m(\sigma,\tau) \leq 1$), while $C'(\tau) \to \infty$ as $\tau \to \infty$. Thus the equality cannot hold for arbitrarily large τ; hence $\hat{\tau}$ may be taken finite and every solution τ^* is finite and lies in the compact interval $(1, \hat{\tau}]$.

Verification that Assumptions 1–4 can simultaneously hold in equilibrium. For convenience we restate the four assumptions:

$$\tau^* < \frac{\phi}{[s(\tau^*)]^2} \quad \text{(Assumption 1)}$$

$$\sigma < \frac{1}{\phi} \quad \text{(Assumption 2)}$$

$$\frac{2\phi(\alpha-1)}{\alpha(\phi-1)} > 1 \quad \text{(Assumption 3)}$$

$$\delta < \frac{\alpha-1}{\alpha}. \quad \text{(Assumption 4)}$$

Assumption 1 can be rewritten as

$$\left\{\max\left[1, (1-\lambda)\frac{2\phi(\alpha-1)}{\alpha[\tau^*(\phi-1)+(\tau^*-1)\delta]}\right]\right\}^2 \tau^* < \phi. \tag{24}$$

It was shown above that τ^* is finite and lies in the compact set independent of ϕ. Thus, as $\phi \to \infty$, the left-hand side of (24) converges to a finite limit while the right-hand side ϕ diverges. Hence for sufficiently large ϕ condition (24) holds. Finally, we can choose σ sufficiently small so that Assumption 2 holds, and for any given $\phi > 1$ one can pick α large enough to satisfy Assumption 3 and then δ small enough to satisfy Assumption 4. Therefore all four assumptions can be satisfied simultaneously.

Proof of Proposition 1. Consider any interior optimum τ^* satisfying the strict second-order condition

$$\frac{d^2W[s(\tau^*),\tau^*]}{d(\tau^*)^2} < 0.$$

Totally differentiating the first-order condition with respect to τ^* and any parameter x gives

$$\frac{d^2W[s(\tau^*),\tau^*]}{d(\tau^*)^2}\frac{d\tau^*}{dx} + \frac{d^2W[s(\tau^*),\tau^*]}{d\tau^* dx} = 0,$$

and therefore

$$\frac{d\tau^*}{dx} = -\frac{\dfrac{d^2W[s(\tau^*),\tau^*]}{d\tau^* dx}}{\dfrac{d^2W[s(\tau^*),\tau^*]}{d(\tau^*)^2}}.$$

Since the denominator is negative by the strict second-order condition, the sign of $d\tau^*/dx$ is the same as the sign of the cross-partial derivative. Using equation (23), it is then easy to verify that

$$\frac{d\tau^*}{d\sigma} \geq 0,$$

with strict inequality if $\lambda < 1$ or $\delta > 0$. This establishes the first part of the proposition. It is similarly easy to verify that

$$\frac{d\tau^*}{d\xi} < 0.$$

By equation (11), it is then

$$\frac{dm(\sigma,\tau)}{d\xi} = \frac{dm(\sigma,\tau^*)}{d\tau^*}\frac{d\tau^*}{d\xi} \leq 0,$$

which establishes the second part of the proposition. $\square$

Derivation of per capita real tax revenues. The expression for per capita real revenues from the transaction tax used in the text, R_t (see equation 8), can be re-written as

$$\begin{aligned}
R_t &= \frac{t-1}{t}\left[\frac{(1-\lambda)\sigma\phi}{s^2} + \frac{1}{\phi} - \delta\frac{1}{\phi}\left(1-\sigma\frac{\phi}{s}\right)\right] \\
&= \frac{t-1}{t}\left[\frac{(1-\lambda)\sigma}{s}p^* + \frac{1}{\phi} - \frac{\sigma p^*}{\phi} + \frac{\sigma}{s} - \delta\left(\frac{1}{\phi} - \frac{\sigma p^*}{\phi}\right)\right] \\
&= \frac{t-1}{t}\left[\underbrace{\frac{(1-\lambda)\sigma}{s}p^*}_{\substack{\text{Consumption}\\ \text{from private}\\ \text{monetary transactions}}} + (1-\delta)\underbrace{\left(\frac{1}{\phi} - \frac{\sigma p^*}{\phi}\right)}_{\substack{\text{Consumption}\\ \text{from all}\\ \text{barter transactions}}} + \underbrace{\frac{\sigma}{s}}_{\substack{\text{Silver}\\ \text{from all}\\ \text{monetary transactions}}}\right]
\end{aligned}$$

These revenues do not include taxes on consumption arising from government monetary transactions, that is, the taxes levied on the consumption goods that the government obtains when selling its silver. Since such taxes may be collected on expenditures financed by government revenues, however, they may be included in observed tax revenues. Let $\tilde{R}_t$ denote gross transaction-tax revenues, that is, revenues including those effectively collected from government expenditure itself. We can write

$$\tilde{R}_t = R_t + \frac{t-1}{t}\left[\overbrace{\underbrace{\frac{s-1}{s}(1-\lambda)\sigma p^*}_{\substack{\text{from selling}\\ \text{taxed silver}}} + \underbrace{\lambda\sigma p^*}_{\substack{\text{from selling}\\ \text{own silver}}}}^{\substack{\text{Consumption}\\ \text{from government}\\ \text{monetary transactions}}}\right]$$

$$= \frac{t-1}{t}\left[\underbrace{\sigma p^*}_{\substack{\text{Consumption}\\ \text{from all}\\ \text{monetary transactions}}} + (1-\delta)\underbrace{\left(\frac{1}{\phi} - \frac{\sigma p^*}{\phi}\right)}_{\substack{\text{Consumption}\\ \text{from all}\\ \text{barter transactions}}} + \underbrace{\frac{\sigma}{s}}_{\substack{\text{Silver}\\ \text{from all}\\ \text{monetary transactions}}}\right]$$

$$= \frac{t-1}{t}\left[\sigma p^* + \frac{1}{\phi} - \delta\frac{1}{\phi}\left(1-\sigma p^*\right)\right].$$

Per capita real tax revenue are found by adding to $\tilde{R}_t$ per capita real revenues from seigniorage, and from government's own metals:

$$\text{pc real tax revenues} = \frac{t-1}{t}\left[\sigma p^* + \frac{1}{\phi} - \delta\frac{1}{\phi}\left(1-\sigma p^*\right)\right] + \frac{s(t)-1}{s(t)}\sigma\left[(1-\lambda)p^* + 1\right] + \lambda\sigma p^*$$

Replacing $t = \tau^*$ and $p^* = \phi/s(\tau^*)$, and adding labels, we obtain the detailed version of expression (13):

$$\text{pc real tax revenues} = \overbrace{\frac{\tau^*-1}{\tau^*}\left[\underbrace{\sigma\frac{\phi}{s(\tau^*)} + \frac{1}{\phi}}_{\text{real GDP per capita}} \underbrace{-\delta\frac{1}{\phi}\left(1-\sigma\frac{\phi}{s(\tau^*)}\right)}_{\substack{\text{inefficiency in the}\\ \text{taxation of barter}}}\right]}^{\text{Revenues from the transaction tax}} + \overbrace{\frac{s(\tau^*)-1}{s(\tau^*)}\sigma\left[(1-\lambda)\frac{\phi}{s(\tau^*)} + 1\right]}^{\text{Revenues from seigniorage}}$$

$$+ \underbrace{\lambda\sigma\frac{\phi}{s(\tau^*)}}_{\text{Revenues from government's own metals}} \tag{25}$$

B Robustness and Additional Figures

B.1 Additional empirical analysis

We show that our results are robust to the addition of controls, including variables that capture economic growth and political regimes. We also show that violations of the exclusion restriction do not typically change our results: for the results to be meaningfully different from our baseline, the violation of the exclusion restriction would have to be large relative to our main proposed mechanism.

Robustness to control variables

Table B.1 presents the estimation results for different sets of control variables. For each specification, the size of the impact and standard errors are reported for horizons $h = 10$ and $h = 20$. The full set of impulse responses are reported in Appendix B.2.

Column 1 is the baseline specification, presented earlier in Figure 4. Columns 2 and 3 report the results when the money stock is instrumented with the contemporaneous or the second lag of metals production instead of the first lag. Across both specifications, the estimated coefficients are very similar in size and statistical significance to the baseline results.

Column 4 modifies the baseline specification by dropping real per capita GDP from the set of control variables. The estimated coefficients increase across all time horizons for England, while they stay similar for France and Spain. Note that in the baseline specification, the estimated coefficient for monetisation captures only its direct positive impact on fiscal capacity. When real per capita GDP is omitted from the set of control variables, the estimated coefficient also captures any indirect positive impact that may be transmitted through a higher real per capita GDP, which is consistent with a higher estimate.

Column 5 controls for the impact of warfare. Bellicist theories of state formation argue that wars in early modern Europe set in motion innovations in military and fiscal administration that resulted in ever higher tax revenues and the birth of the modern state (North, 1981; Levi, 1988; Hoffman and Norberg, 2002; Karaman and Pamuk, 2013; O'Brien and Palma, 2023). To account for any bias that the impact of warfare might introduce to the estimation results, we include a proxy for it in the regression equations. To construct the war proxy, we first calculate the total number of wars each state participated in each year, based on Brecke (1999). We then calculate a 3-year moving average of this variable, since the impact of war built up over time, and use this moving average as a control variable. When the proxy for warfare is included in the regressions, the estimates remain close to those in the baseline specification.

Column 6 controls for the level of parliamentary activity. The contract theory of the state argues that parliaments increased tax revenues, by making it easier for the executive and economic elites to settle on a tax-for-public-services deal, solving associated collective action problems, and lending legitimacy to taxation (North, 1981; Levi, 1988; Hoffman and Norberg, 2002). To account for the potential impact of the parliaments, we include in the regressions an indicator variable for parliamentary meetings for each year and state, based on Henriques and Palma (2023) for England and Spain, and De Magalhaes and Giovannoni (2022) for France, which takes the value 1 in years where the parliaments meet, and zero otherwise. For England and France, the estimation results remain similar to the baseline, while for Spain the estimate doubles. This result is consistent with the argument that American silver generated an "institutional resource curse" in Spain (see the discussion in the previous section). If the production of precious metals in the Americas had two separate effects on fiscal capacity, that is a positive effect through higher monetisation[9] and a negative one through the collapse of parliaments, then controlling for the latter would only leave the former to be estimated and result in a higher coefficient. Consistent with this interpretation, Figures B.9 and B.10 find that, when parliamentary activity is accounted for, the effect of higher monetisation on fiscal capacity builds up more slowly, peaking only about 10 years after the increase in monetisation.

The last column of Table B.1 controls for the impacts of warfare and parliamentary activity simultaneously. The estimates remain very similar.

We also consider the validity of our results for longer time horizons of up to 30 years. Note that, the further we extend our horizon, the smaller the sample becomes, and thus the less reliable and precisely estimated the results are. Nevertheless, Figure B.2 clearly shows that the

[9]Recall that, in the model, even if silver is entirely owned by the government ($\lambda = 1$), an increase in monetisation still increases fiscal capacity through the efficiency channel, that is by making transactions easier to tax.

Table B.1: Robustness checks

	Baseline	No Lag Instrument	Second Lag Instrument	No GDP Control	War	Parliaments	War and Parliaments
England							
$h = 10$	0.586	0.562	0.676	1.325***	0.479	0.633	0.529
	(0.443)	(0.448)	(0.433)	(0.478)	(0.512)	(0.460)	(0.539)
$h = 20$	1.232**	1.140**	1.175**	1.842***	1.293**	1.303**	1.376**
	(0.499)	(0.520)	(0.460)	(0.500)	(0.607)	(0.506)	(0.623)
France							
$h = 10$	1.354***	1.282***	1.462***	1.160***	1.546***	1.359***	1.587***
	(0.421)	(0.393)	(0.463)	(0.271)	(0.594)	(0.418)	(0.611)
$h = 20$	1.456***	1.369***	1.572***	1.299***	1.782***	1.458***	1.810***
	(0.403)	(0.371)	(0.447)	(0.259)	(0.593)	(0.408)	(0.613)
Spain							
$h = 10$	0.606***	0.601***	0.622***	0.601***	0.692***	1.566***	1.728**
	(0.134)	(0.127)	(0.139)	(0.128)	(0.177)	(0.536)	(0.675)
$h = 20$	0.554***	0.541***	0.582***	0.595***	0.595***	1.333***	1.411**
	(0.116)	(0.114)	(0.123)	(0.122)	(0.153)	(0.468)	(0.570)

This table shows second-stage results for horizons $h = 10$ and $h = 20$ for alternative specifications, with Newey-West standard errors in parentheses. The first column shows the baseline specification. The second and third column show alternative specifications where the contemporaneous value or the second lag of the metals production variable are used in the first stage, respectively. The fourth column shows the baseline specification without any GDP controls. The fifth, sixth and seventh column show results when adding war controls, parliament controls, and both of these controls to the baseline, respectively.

estimated effects remain strong and significant even over these longer time horizons.

Robustness to violations of the exclusion restriction

Thus far we have shown that our results are robust to the addition of controls, including variables that capture economic growth and political regimes. Nevertheless, violations of the exclusion restriction may still arise if precious metals increase fiscal capacity through a mechanism other than increased monetisation, whenever such a mechanism is not captured through our control variables. To further address this issue, we adopt the approach of Jordà et al. (2020) to construct impulse responses which take into account violations of the exclusion. The approach proceeds by calculating impulse responses for a set of different plausible assumptions about the size of effects that violate the exclusion restriction.

To see how this approach works, suppose that the excluded instrument has a direct effect on fiscal capacity that does not operate through monetisation and other control variables. In that case, the true two-stage relationship for each country i changes to the following system of equations:

$$y_{i,t+h} = \alpha_{i,h} + \beta_{i,h} ln(\widehat{monetary}_{i,t}) + \delta_{i,h} ln(metals_{t-1}) + \boldsymbol{\psi_{i,h}} \mathbf{x_{i,t}} + u_{i,t+h} \tag{26}$$

$$ln(monetary_{i,t}) = \alpha_i + \gamma_i ln(metals_{t-1}) + \boldsymbol{\phi_i} \mathbf{x_{i,t}} + e_{i,t}, \tag{27}$$

where $y_{i,t+h} \equiv \ln(fiscal_{i,t+h}) - \ln(fiscal_{i,t-1})$. The only difference to equations 14-15 is that the term $ln(metals_{t-1})$ now enters the second-stage equation 26 directly, violating the exclusion restriction.

Jordà et al. (2020) offer a potential way to test the robustness of the results to such violations of the exclusion restriction. In particular, suppose that $\beta_{i,h} = \lambda_{i,h} * \delta_{i,h}$. In our setup, $\beta_{i,h}$ is the impact of monetisation on fiscal capacity, whereas $\delta_{i,h}$ is the impact of American precious metal production on fiscal capacity that does not go through an increase in monetisation. Hence, a higher $\lambda_{i,h}$ corresponds to a greater relative impact for monetisation.

With $\lambda_{i,h}$ in hand, one can adjust the left-hand-side variable such that the exclusion restriction is satisfied (Jordà et al., 2020, B). In particular, define $y^{adj}_{i,t+h}$ as:

$$y^{adj}_{i,t+h} = y_{i,t+h} - ln(metals_{t-1}) * \frac{\widehat{\delta}_{i,h} + \widehat{\gamma} \times \widehat{\beta}_{i,h}}{1 + \lambda_{i,h} \times \widehat{\gamma}} \tag{28}$$

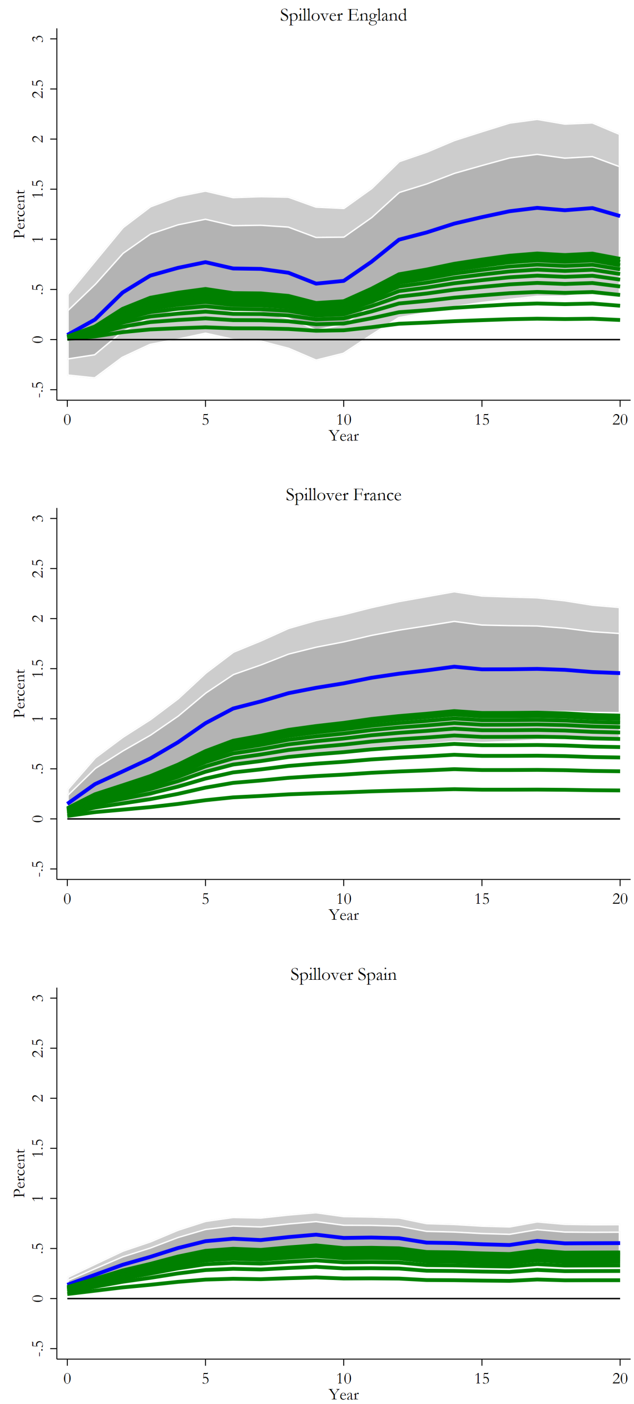
where the "$\widehat{\ }$"-symbol stands for OLS estimates from equations 26-27. After replacing the left-hand-side variable with the adjusted variable from equation 28, the LP-IV procedure will yield valid results.

The difficulty in implementing this procedure is that the true value of $\lambda_{i,h}$ is not known and cannot be determined from the data. Hence, Jordà et al. (2020) advocate performing the adjustments for various reasonable levels of $\lambda_{i,h}$. These levels can be viewed as the bounds on the true impulse responses that would have arisen if the exclusion restriction did not hold.

In our case, we estimate the model for $\lambda_{i,h}$ values between 1 and 10. Lower values of $\lambda_{i,h}$ are unlikely, as it would imply a large direct effect of precious metals on tax revenues which goes through channels other than changing monetisation. However, for Spain, the main beneficiary of American silver, the revenues from taxation of the domestic economy greatly outweighed the revenues associated with the colonies and silver (Coman and Yun-Casalilla, 2012); as for England and France, if American silver did have any impact on fiscal capacity other than by affecting monetisation, it must have been much less important than for Spain. A $\lambda_{i,h}$ value of greater than 10 is plausible, but as $\lambda_{i,h}$ increases, the estimation results converge to the baseline estimates, and so having very high values does not add additional insights to the robustness exercise.

Figure B.1 presents the estimation results for $\lambda_{i,h} = 1, 2, ...10$, alongside the original baseline impulse response and confidence interval. For each country in our analysis, the spillover-adjusted responses are similar in shape to the baseline results. At horizons $t = 10$ and $t = 20$, the results are robust for all $\lambda > 3$ for the case of England; $\lambda > 4$ for Spain; and $\lambda > 5$ for France. For the more realistic larger values of $\lambda_{i,h}$, the effect sizes are within the confidence bounds of the baseline results presented in Figure 4. Thus, violations of the exclusion restriction would have to be large in order to produce results that are statistically distinguishable from the baseline.

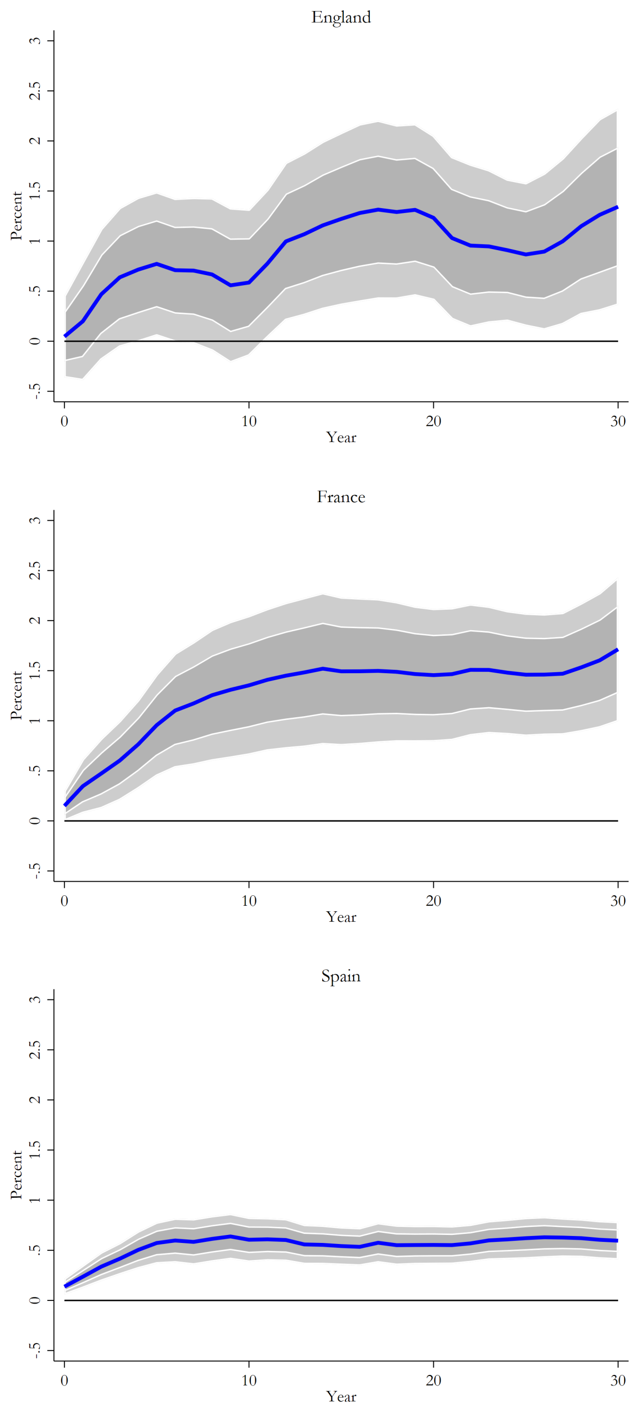
Figure B.1: Spillover-adjusted Impulse Responses



Note: This figure shows the baseline impulse responses (blue line and confidence interval) and spillover-adjusted impulse responses (green lines) (Jordà et al., 2020). Spillover terms are $\lambda_{i,h} = 1, 2, ...10$. Lower green lines correspond to lower values of $\lambda_{i,h}$. Specifications follow the baseline LP-IV approach. For data sources, see C.

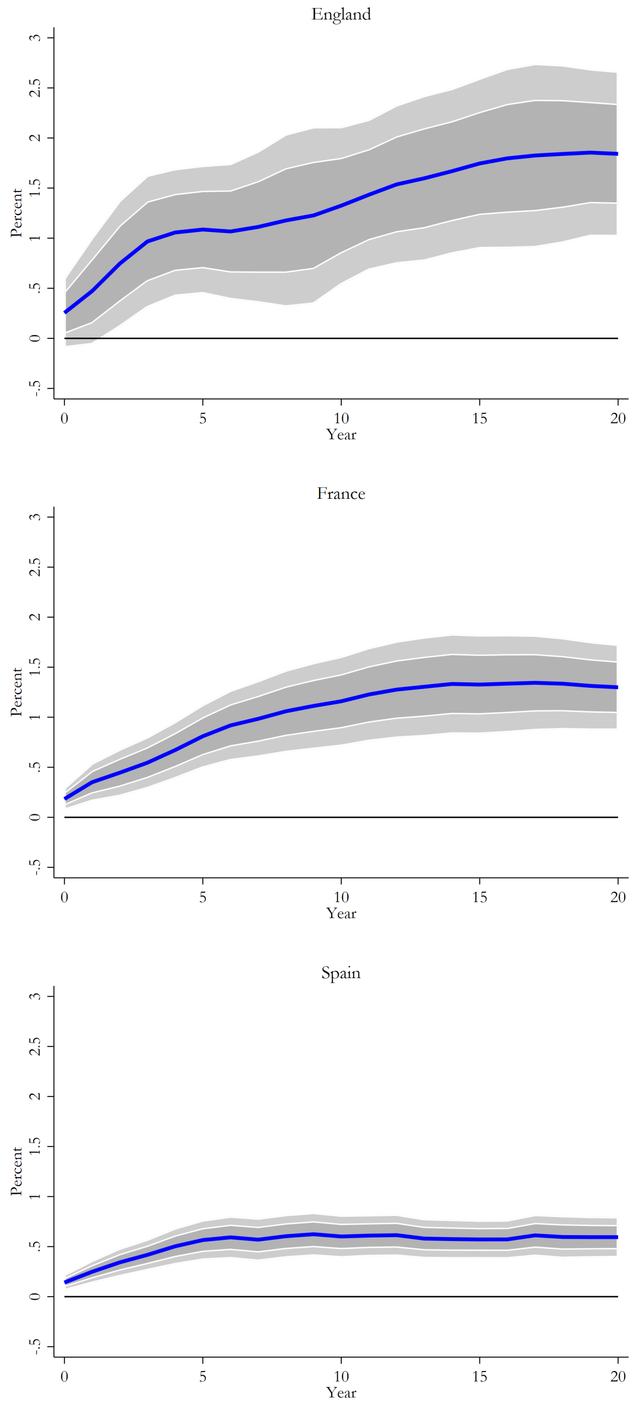
B.2 Additional Robustness Figures

Figure B.2: Robustness: horizon up to 30



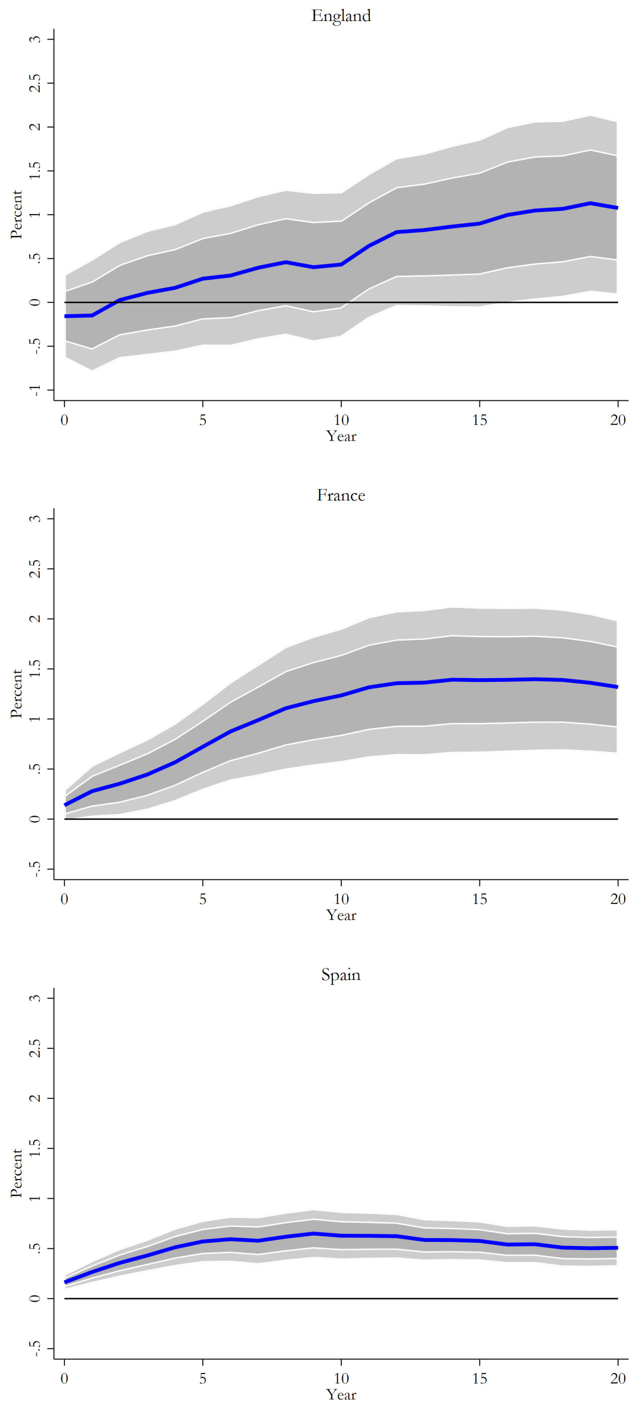
Note: Baseline LP-IV impulse responses, but with horizon up to $h = 30$.

Figure B.3: Robustness: no GDP control



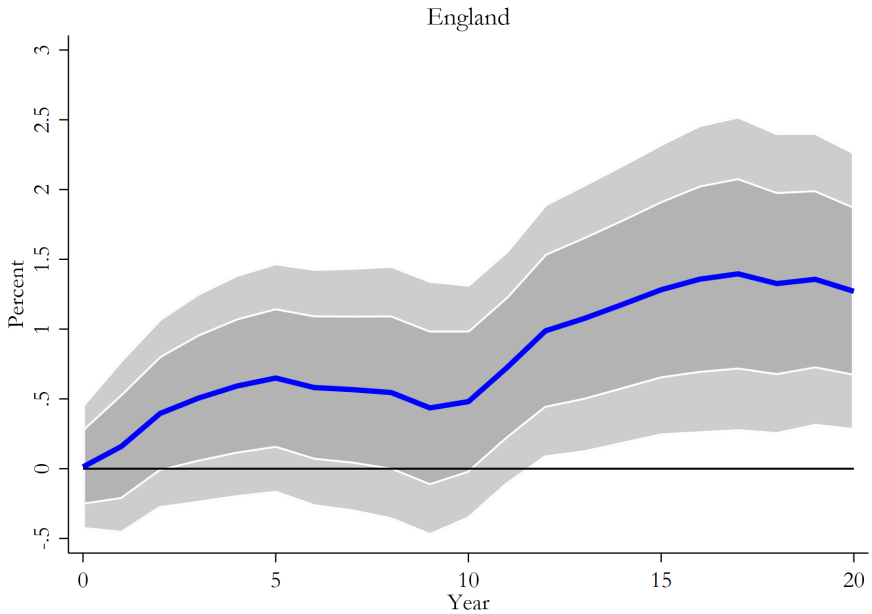
Note: LP-IV impulse responses, with no GDP control (Column 4 of table B.1).

Figure B.4: Leads of GDP



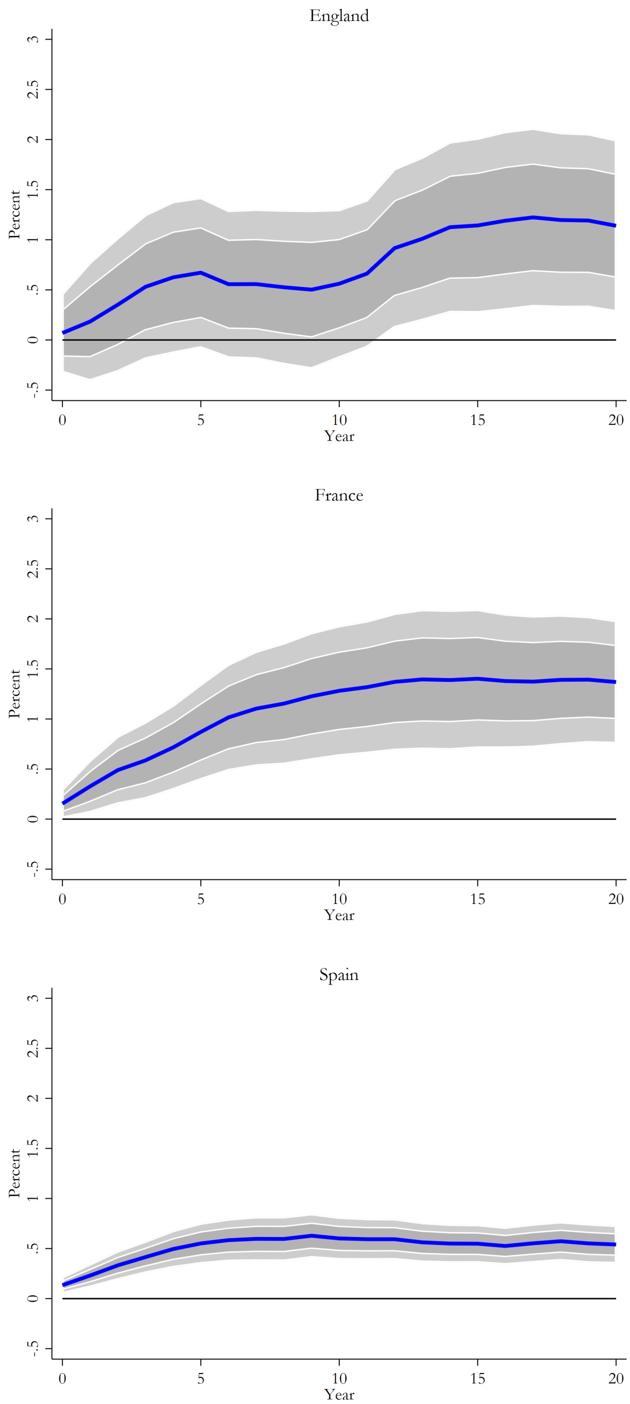
Note: LP-IV impulse responses, with leads of GDP as controls.

Figure B.5: Baseline Local Projections for England, excluding mint revenues



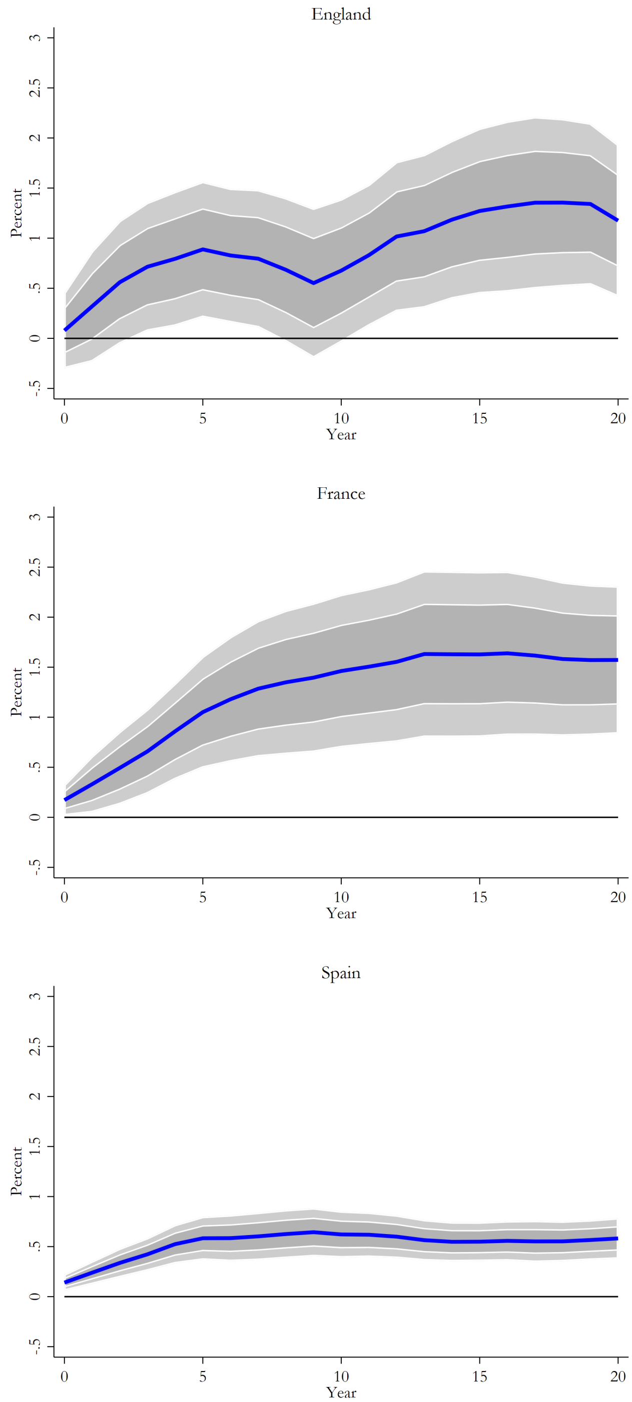
Note: LP-IV impulse responses for England, excluding mint revenues.

Figure B.6: Robustness: contemporaneous lag of metals production



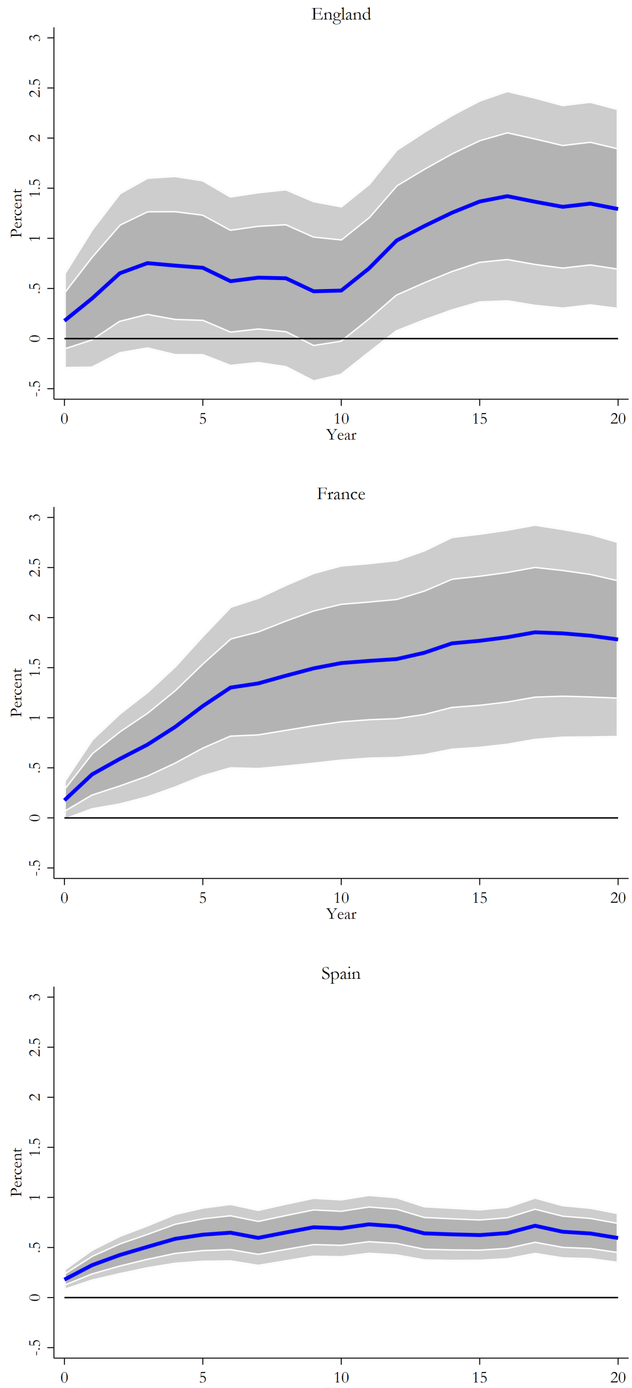
Note: LP-IV impulse responses, with contemporaneous metals production (Column 2 of table B.1).

Figure B.7: Robustness: second lag of metals production



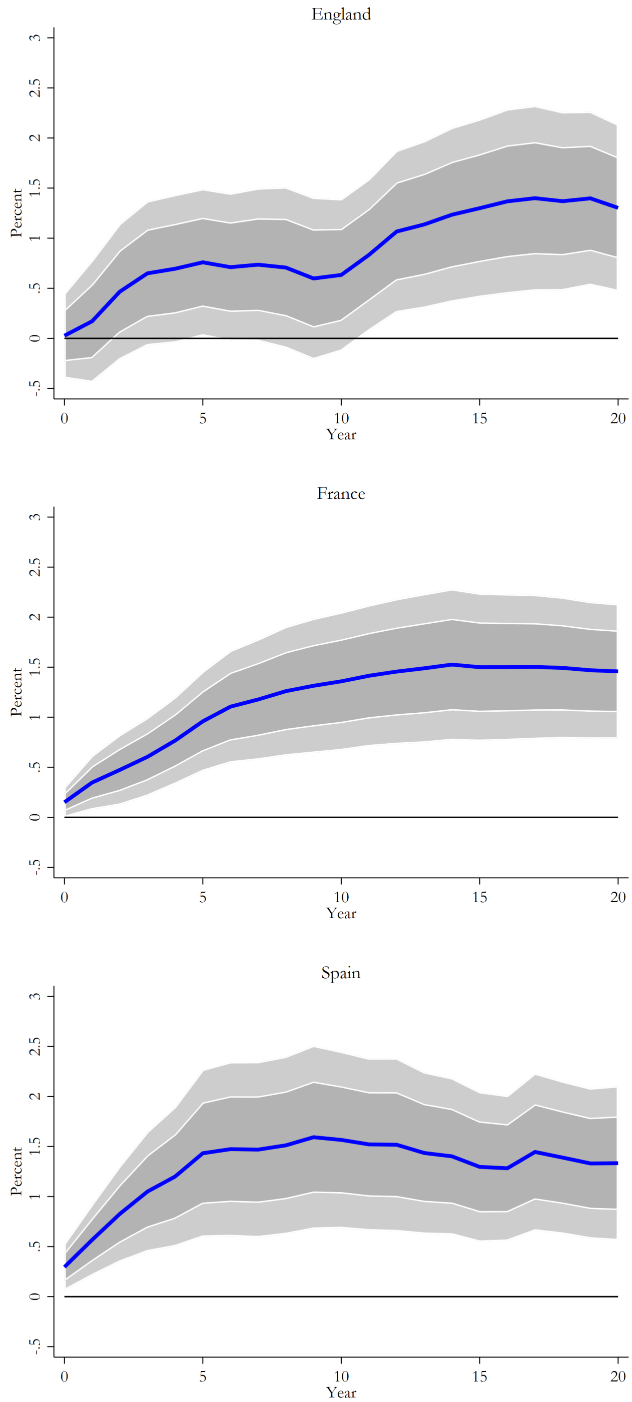
Note: LP-IV impulse responses, with second lag of metals production (Column 3 of table B.1).

Figure B.8: Robustness: war control



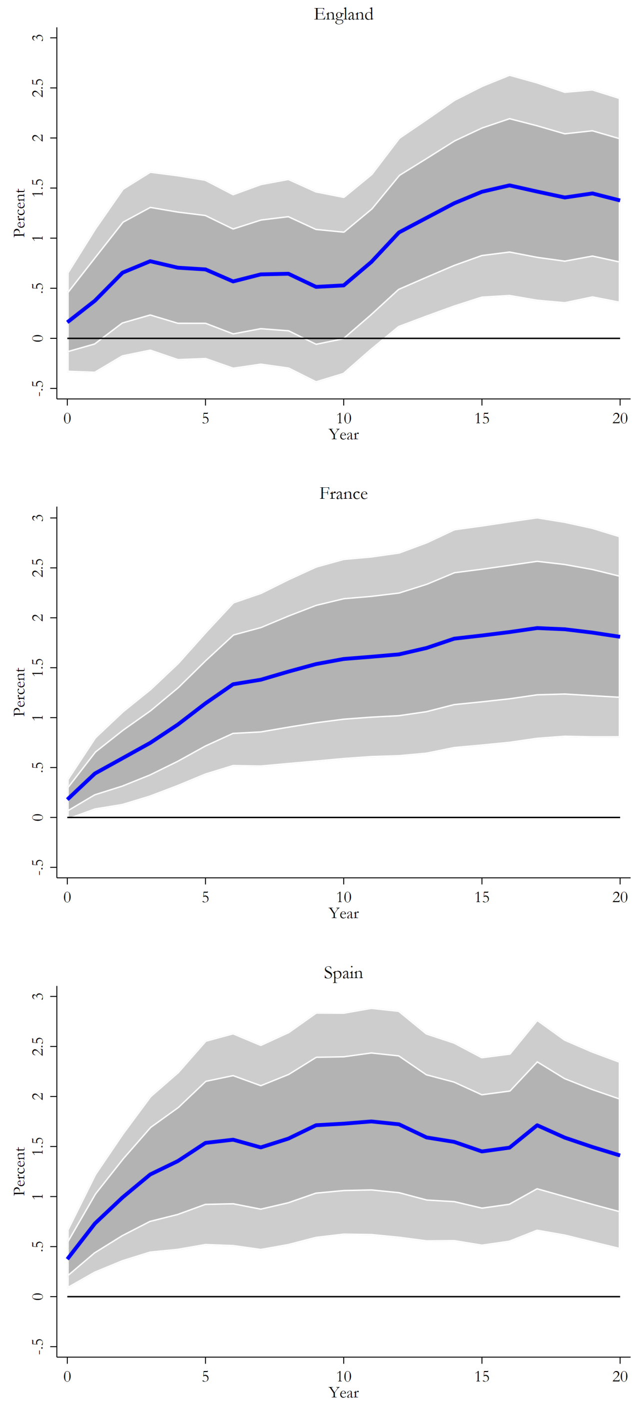
Note: LP-IV impulse responses, with additional war control (Column 5 of table B.1).

Figure B.9: Robustness: parliament control



Note: LP-IV impulse responses, with additional parliament control (Column 6 of table B.1).

Figure B.10: Robustness: war and parliament control



Note: LP-IV impulse responses, with additional war and parliament controls (Column 7 of table B.1).

C Data Sources

The money stock series for England is based on Allen (2001a) for 1158-1247, Mayhew (2013) for 1270-1470 and Palma (2018b) afterwards. The pre-1500 French money stock series is based on Spufford (1988). Annual estimates for 1493-1680 are based on Glassman and Redish (1985). Between 1680-1788, the series are interpolated based on the six benchmark estimates by Riley and McCusker (1983). The estimates include silver and gold commodity money, but not other types of fiat and paper monies, which were typically marginal until the 19th century. Spanish money stock estimates are based on Chen et al. (2021). For Dutch Republic, De Vries and Van der Woude (1997) and Weber (2000), for Portugal Sousa (2006), for Poland-Lithuania Wojtowicz et al. (2005) and for Russia Blanchard (1989) and Kahan and Hellie (1985) money stock series are used. For Europe the value of monetary units in terms of silver is based on Karaman et al. (2020) and the sources cited therein. For China, money stock for 1280 and 1350 is based on Guan et al. (2024) and for 1750 based on Liu (2015).

The tax revenue data is based on Costa et al. (2024) for Portugal and Karaman and Pamuk (2010), Karaman and Pamuk (2013) and the sources therein for other countries. English revenue data is available annually with few gaps. There are gaps for French revenue data in the 16th and Spanish revenue data in the 17th century, which are interpolated. These revenues are converted to silver, once again based on the rates in Karaman et al. (2020). For China, tax revenue estimates are based on von Glahn (2016a) for 1292 and 1329, and Brandt et al. (2014) for 1750.

Price level data is based on Allen (2001b).The price series tracks the daily cost of a standard consumption basket that includes food items totaling 1941 calories per day, fuel and clothing, and reflects the consumption patterns of an adult male for the early modern period. Population data is based on Broadberry et al. (2015), who in turn rely on Wrigley et al. (1997), for England, McEvedy and Jones (1978) for France, and Prados de la Escosura et al. (2022) for Spain. GDP per capita series is based on Broadberry et al. (2015) for England, Ridolfi and Nuvolari (2021) for France and Prados de la Escosura et al. (2022) for Spain. Chinese wage data for 1272 and 1342 is based on Li (2014) and for 1750 based on Liu (2024). European wage data is from Allen (2001b). The yearly precious metal production in the Americas is measured as the sum of silver and gold production in metric tons, with the latter translated to silver units. The production series is based on Palma (2022), which in turn largely relies on TePaske (2010). War data is based on Guan et al. (2024) for Medieval China and Brecke (1999) for other periods and countries. The parliamentary meeting data is based on Henriques and Palma (2023) and De Magalhaes and Giovannoni (2022).

D Historical Appendix

This appendix puts the theoretical model and empirical analysis in the text into a broader historical context by reviewing comparative evidence since antiquity. This evidence on the close relationship between monetary and fiscal capacity is available for a broader set of countries for which only sparse data are available, insufficient for econometric testing, but for which the patterns are nonetheless suggestive. All in all, the long-run historical evidence identifies large contemporaneous swings in monetary and fiscal capacity, which continued until the massive liquidity shock of American silver and gold. This shock transformed the European economy by increasing monetisation levels in Western Europe, and ultimately undermining the dependence on precious metals for the money supply itself. There is also overwhelming evidence that the shock triggered a virtuous cycle of monetary and fiscal capacity building, consistent with the theoretical and empirical analysis that we presented.

Monetisation and fiscal capacity in Antiquity: the case of Europe

Evidence for the close connection between monetary and fiscal capacity is available for antiquity, though data for that period is scarce. The first well-documented historical peak in monetisation and taxation was in the mid-5th century BC Athenian Empire. In this period, the estimated money stock per capita reached a level of around 200 grams of silver, and tax revenues per capita a level of around 10-15 grams. These levels were made possible, in part, by the Laurion silver mines located nearby the city of Athens, which had an estimated annual peak output of about 80 tons (Patterson, 1972; Ober, 2015).

After the decline of Athens, the second peak was reached during the Pax Romana. In the first two centuries AD, money stocks per capita rose to 50-100 grams of silver, and tax revenues per capita to 10-15 grams. Roman monetisation was supported by the Iberian mines, which had an estimated annual output of 200 tons of silver (Hopkins et al., 2009; Duncan-Jones, 1998; Goldsmith, 1987; Patterson, 1972). The Roman peak was in turn followed by a collapse in the third century AD. The precise line of causation is difficult to unravel. In terms of precious metal availability, the exhaustion of the Iberian mines and the resulting decline in annual silver output to about 30 tons arguably played a role (Patterson, 1972). Fiscally, the growing spending on war triggered depreciation of silver coinage and inflation, which in turn induced demonetisation of the economy (Bransbourg, 2015; Harris, 2008).[10]

Monetary and fiscal capacity from the Middle Ages to 1800: the case of Europe

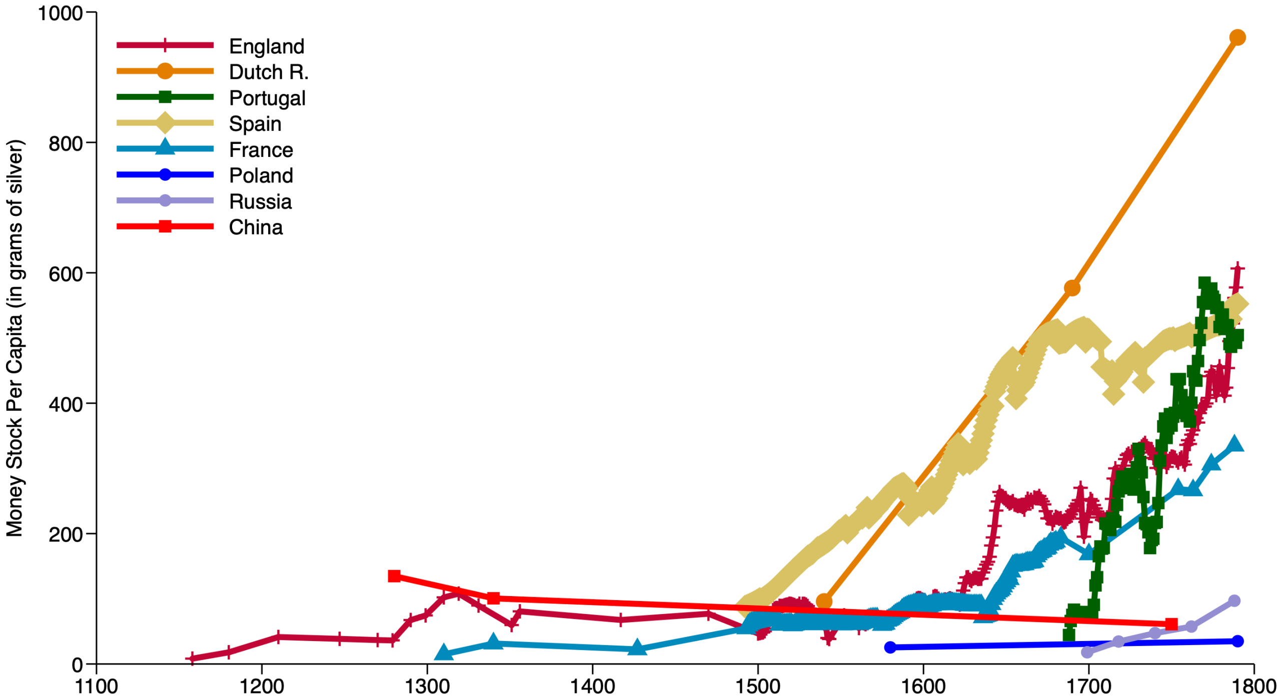
The early Middle Ages marked a nadir of both monetary and fiscal capacity. On the monetary front, annual silver output in Europe is estimated to have decreased to a few tens of tons, and money stocks per capita to about 15 grams of silver (Patterson, 1972). On the fiscal front, centralized taxation collapsed, leaving little historical record of treasury revenues. These two processes were inherently related. Demonetisation necessitated breaking up the armies into smaller units that could be supported by the local produce, and central governments ceded de facto control over the countryside (Kohn, 2001; Spufford, 1988). The collapse of central governments in turn undermined monetisation, as mining and minting required large-scale investments and centralized coordination.

Another cycle of expansion and contraction of silver output occurred from the 11th to the 15th centuries. With the discovery of new mines in northern and central Europe, annual silver output gradually increased to about 50 tons by around 1300. However, as soon as what could be extracted from these mines with the technology of the day was exhausted, the output began to decline, and collapsed back to around 15 tons by 1450s (Velde and Weber, 2000). Estimates

[10]During the Late Roman Empire, gold increasingly replaced silver, and perhaps constituted more than half of the money stock in value, but whether it was a perfect substitute for silver is debatable. Gold had a much slower velocity, and was only convenient for very large transactions (Goldsmith, 1987). Gold production itself declined after the fourth century and largely disappeared by the 8th century (Spufford, 1988, p. 18-21).

of the English money stock are available for this period, allowing us to track how its trajectory mimicked that of the medieval silver production cycle. Figure D.1 presents these estimates, expressed in grams of silver. The English per capita money stock increased from 10 grams to 150 grams from 1150 to 1300, but fell back to around 70 grams by 1450, in line with the silver production estimates.

Figure D.1: Money Stock Per Capita (in grams of silver)



Note: See Online Appendix C for data sources.

The 16th century marked a dramatic increase in the availability of precious metals, driven by massive silver and gold production in the Americas: annual production (in silver-equivalent units) varied between 200 and 800 metric tons over most of the early modern period (Palma, 2022, p.1599). The silver arrived in Europe in two waves, with Potosí silver peaking in the early 17th and Mexican silver in the late 18th century. Gold production, mainly located in Brazil, peaked around the mid-18th century (Barrett, 1990; Palma, 2020).

This drastic increase in precious metals availability marked the end of the cycles of monetisation and demonetisation and the beginning of a dramatic upsurge in money stocks in Western

Europe. Figure D.1 plots the available fragmentary evidence on the per capita money stocks of the Dutch Republic, Portugal, Poland-Lithuania and Russia, in addition to the more detailed estimates for England, Spain and France discussed earlier. It also includes data for China.

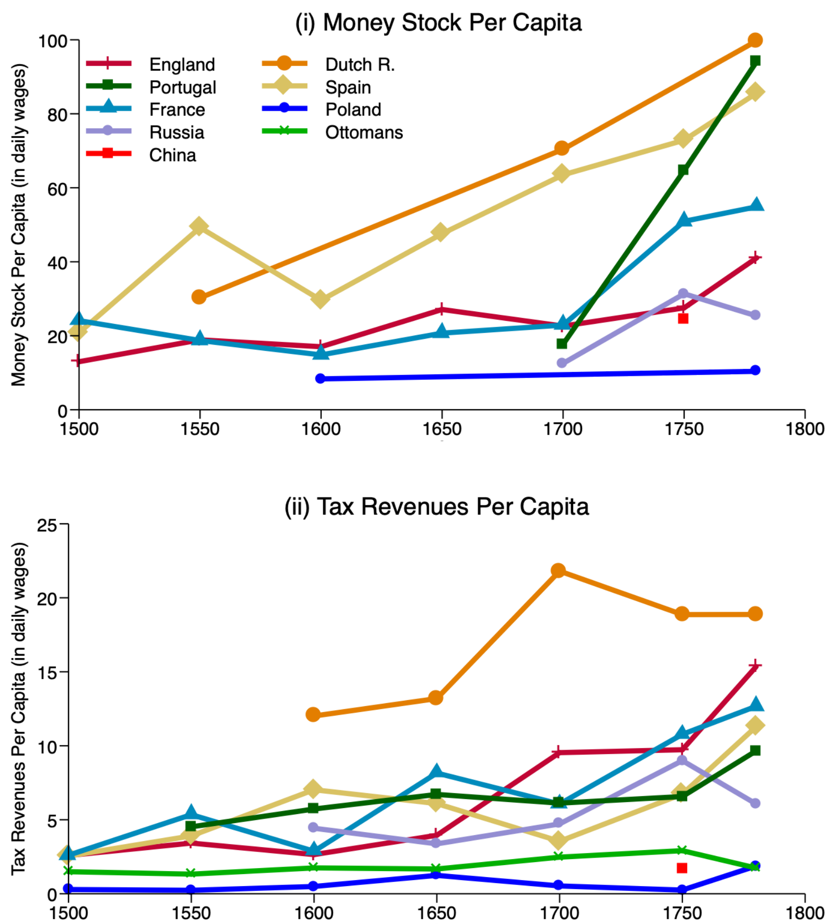
Three patterns stand out. First, the per capita money stocks of Western European countries surged following the inflow of precious metals from the Americas, from 50-100 grams in 1500 to 300-1000 grams in 1800. Second, the trajectory of money stocks once again mimicked that of precious metal production. For Spain, England and France, there were two local peaks, in the mid-17th and late 18th centuries, coinciding with the peaks in silver output. For Portugal and England, the main beneficiaries of the Brazilian gold, per capita money stocks increased rapidly over the 18th century. Finally, Figure D.1 also makes it clear that American precious metals had an asymmetric impact across Western and Eastern Europe. The precious metals first arrived in Western Europe. They then diffused to Eastern Europe through trade, but only to a limited extent, leading to a divergence in monetisation levels. As the figure illustrates, monetisation levels in Poland and Russia remained low.[11]

One limitation of the per capita monetary stock series presented in Figure D.1 is that they are in nominal terms, and are not measured relative to GDP. Establishing a real impact requires showing that the per capita money stocks increased in real terms, and also as a share of per capita GDP. The top panel of Figure D.2 addresses these issues by plotting, for the eight countries considered thus far plus the Ottoman empire, the ratio of per capita money stocks to the nominal wages of unskilled workers, a commonly used proxy for per capita GDP in historical studies. The results are consistent with a real impact. For Western European states, per capita money stocks increased from 15 to 20 days worth of unskilled workers' wages in 1500 to around 45 to 100 days by 1800, while in Eastern Europe they remained stagnant.

To explore the fiscal counterpart to this increase in monetisation, the bottom panel in Figure D.2 plots the ratio of per capita tax revenues to nominal wages, for the same countries. The figure confirms a corresponding real increase in fiscal capacity. In Western Europe, per capita tax revenues increased from about 3 days worth of unskilled workers' wages in 1500 to about

[11] Russia received limited American silver, and continued to rely on barter and furs in addition to foreign coins (LeDonne, 1991; Seljak; Bonney, 1995; Spasskii, 1970). monetisation levels only picked up in the 18th century, after opening of local silver mines (Kotilaine, 2005; Kahan and Hellie, 1985; Danila, 2006).

Figure D.2: Money Stock and Tax Revenues Per Capita (in daily wages)



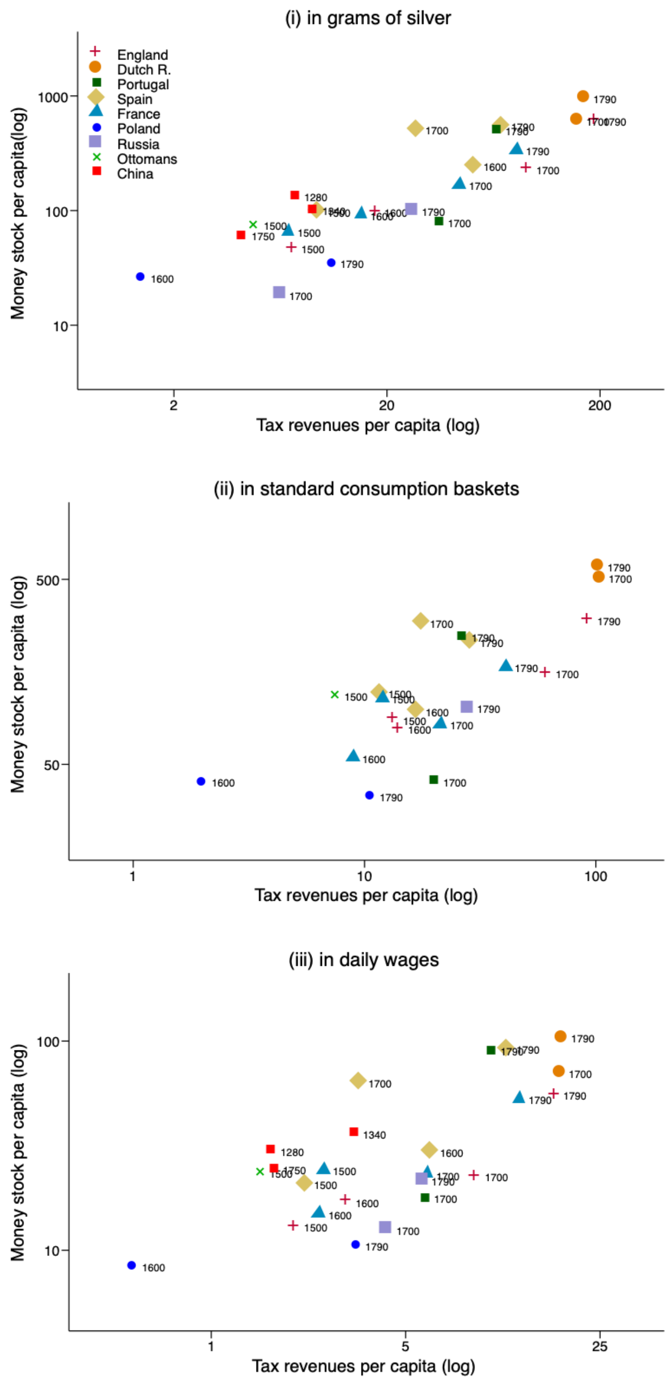
Note: See Online Appendix C for data sources.

10-15 days by 1800, while they lingered at lower levels in the East.

Additional evidence of the close relationship between monetary and fiscal capacity in early modern Europe is provided in Figure D.3. For all countries except for China, we plot per capita monetary stocks against per capita tax revenues at four points in time: 1500, 1600, 1700 and 1790. For China, we include all the available data (for 1280, 1340 and 1750) and further discuss this evidence below. The three panels present, respectively, nominal values, real values, and real values as a share of per capita GDP (as proxied by the wages of unskilled workers). All three panels find a clear, positive relationship between per capita money stocks and tax revenues.

The virtuous cycle of monetary and fiscal capacity building in early modern Western Europe

Figure D.3: Monetary and Fiscal capacity



Note: See Online Appendix C for data sources.

ultimately altered the nature of money, but not the close relationship between the two. The money stock series presented in this section keep track of the levels of commodity silver and gold money over time.

Increasingly, however, public banks began to experiment with paper money convertible to silver and gold. These experiments culminated in the successful paper note issue by the Bank of England in 1694—a model which later spread across Europe—following which banknotes gradually became an important means of exchange (Palma, 2018a,b). The growing adoption of convertible and later fiat paper money in turn weakened the historical dependence of the money supply on precious metals production. The value of paper money, however, still depended on the fiscal capacity of the state, perhaps even more so than commodity money. Hence, while the relationship between precious metals and monetisation weakened, the relationship between monetary and fiscal capacity persisted.

Paper money: the case of premodern China in Europe's mirror

The comparative evidence suggests that the link between monetary and fiscal capacity becomes even stronger when paper money replaces commodity money. It is informative to compare the European experience with that of China. In the Middle Ages, faced with the scarcity of precious metals which plagued China prior to direct contact with the Europeans from the sixteenth century (Palma and Silva, 2024), the Song dynasty (960–1279) was able to successfully introduce paper money in the Sichuan region. Paper money was used for both commerce and tax collection, the latter being a key motivation for the state's involvement with monetary affairs (von Glahn, 1996).

The Song's successors, the Yuan (1271–1368), inherited a favorable level of fiscal capacity and were then able to introduce paper money which circulated widely in all of China (von Glahn, 2024). Fiscal capacity was high by the standards of the time: according to Figure D.3, per capita tax revenues in 1340 stood at a higher level than those of many European countries as late as 1600. Monetisation was also comparatively high: despite China's scarcity of precious metals, its 1280 and 1340 per capita money stocks—as measured by Figure D.3, most likely an underestimate of the true value—were higher than most observations in 1500-1790 Europe.[12] There were in this period occasional episodes of high inflation due to war pressure, but they were only transitory.[13]

Paper money only collapsed for good during the early Ming dynasty (1368–1644), due to the fiscally weak nature of the state (von Glahn, 2020, 2024). Zhu Yuanzhang, a son of poor peasants who commanded the Red Turban Rebellions, eventually toppled the Yuan and became the first Ming emperor, Hongwu. The Hongwu Emperor rejected the market economy and steered China towards a new fiscal model, based on a collection of almost autarkic self-sufficient farming communities (von Glahn, 2016b, 2020). Due to scarcity of precious metals, paper money's existence had relied strongly on the credibility of the state. Given that fiscal foundations, in turn, matter for credibility and expectations formation, the Ming's destruction of the fiscal foundations of the state carried with it the seeds of destruction of paper money. The Ming (1368–1644) and Qing (1644–1911) dynasties remained anchored on low levels of taxation levied on land, commerce, industry, and consumption (von Glahn, 2020, p.22). By the late fifteenth century, paper money no longer circulated (von Glahn, 1996). As shown by Figure D.3, by 1750, China's per capita tax revenues were one of the lowest in the sample, and its per capita money stock was much lower than that of, for example, England, Dutch Republic, Portugal and Spain. China continued to have low state capacity until the second half of the twentieth century (Ma, 2013; Brandt et al., 2014).

The comparative experience of Europe and China is informative to understand why China eventually failed, while Europe succeeded. England's eighteenth century experience was the first successful, sustained experience with paper money since medieval China. Although the bank did suspend convertibility in 1797-1821, its holding of government debt as reserves during this period implied that the credibility of money (i.e. the likelihood of price stability) implicitly relied on the credibility of the government's fiscal position. The survival of paper money thus bears

[12] The data only includes paper money, however commodity-based money was also in circulation (Guan et al., 2024).

[13] For example, in the mid fourteenth century, the annual inflation rate was close to 13 per cent, and this was then followed by a brief period of hyperinflation (Guan et al., 2024, p.12). A contemporary scholar called Wang Yun wrote that unrestrained printing of paper money made it into nothing but empty script (von Glahn, 1996, pp.61-3)

testimony to the solidity of England's fiscal position. At the same time, the converse was also true: the Bank of England's success in circulating the notes contributed to war victories and the financial stability of the state, and made it easier for the government to collect taxes (Palma, 2018a; O'Brien and Palma, 2020, 2023). In the case of China, where the state issued money directly, it was even more evident that people could trust paper money to the same extent that they could trust public finance. Failure on the fiscal front was a key reason why China went permanently off paper money from the Ming dynasty until the twentieth century. But conversely, this monetary limitation bounded tax collection efforts.

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