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A differentiated approach to mission-oriented innovation policy: Contextualizing societal challenges in a problem-solution space

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ABSTRACT: We aim at contributing to a more differentiated understanding of societal mission-oriented innovation policy (MIP). Our starting point is an analytical decomposition of both societal problems and innovative solutions based on the degree of i) contestation, ii) complexity and iii) uncertainty. We argue that both societal problems and solutions can be diverging (i.e. contested, complex or uncertain) or converging (i.e. uncontested, well-defined and with sufficient knowledge on causes and consequences) and discuss four different problem-solution structures. We further argue that achieving converging socio-technical or socio-institutional innovations, embedded within a functioning innovation system, should be the central goal of MIP. Depending on the positioning in this problem-solution space, different policy strategies are required to transform 'wicked' structures into stable and broadly legitimized configurations. For policy makers, assessing the own location in the problem-solution space and designing targeted policy strategies accordingly can accelerate transformation and create consensus and legitimacy at the same time. We point to three stylized policy pathways to achieve widespread diffusion of innovative solutions in the context of societal missions.

1. Introduction

The meaning of mission-oriented innovation policy (MIP) has changed since the 1960s. MIP used to be defined by radically ambitious technical achievements with little regard to their economic or societal significance; with the archetypical example of placing a man on the moon (Nelson 2006; Mazzucato 2017). These missions were approached as "big science for big problems" (Weinberg, 1967, in: Ergas, 1987) and considered to be relatively tame, i.e. clear in terms of problem and solution definition (Nelson 1974).

Over the past two decades, however, policy makers at different levels of government have increasingly set research and innovation (R&I) missions to help tackle complex societal problems, or challenges, such as climate change, healthy aging and sustainable food production (Cagnin et al. 2012a). Compared to traditional technology-based missions, the societal challenge-led missions appear complex and unstructured, with targets that go clearly beyond technological feasibility or economic growth (Mazzucato 2017, 2018). It seems that the "wicked" nature of societal challenges may cause major obstacles for innovation policy makers. One of the key questions is how to identify, define and subsequently target a problem which is systemic rather than one dimensional, and for which the nature of the innovation, be it a technological or non-technological solution, can be hardly predefined.

The transition literature acknowledges that many complex societal problems may require transformation, instead of optimization of existing socio-technical systems (Alkemade et al. 2011; Borrás and Edler 2014; Fagerberg et al. 2015). Despite its problem-oriented focus (e.g. sustainability) and the strengths in understanding system transformation, this literature falls short of informing MIP in several respects. First, its analytical frameworks are unable to deal with the normativity involved in setting missions (Schlaile et al. 2017), both in terms of defining the societal problems at hand and in selecting the solutions needed to complete the mission. Second, the literature's focus on technological fixes overlooks the importance of solutions in the form of changes in behavior or practices (Shove and Walker 2010; Temenos et al. 2017). Hence, the literature runs the risk of providing a one-size-fits-all approach with high emphasis on the diffusion of (technological) solutions by overlooking the potential contestation involved in mission-setting. In other words, it runs the risk of limited social acceptance of the solutions developed to counteract urgent societal problems.

Recent innovation policy literature contributed to understanding the role of policy in supporting transformative system change and with that to address the needs of future society (Weber and Rohracher 2012; Rogge and Reichardt 2016; Schot and Steinmueller 2016; Boon and Edler 2017). The common argument is that traditional policies following market failure or structural system failure rationales are not far-reaching enough to induce system-wide change. As suggested by Weber and Rohracher (2012), challenge-led innovation policies need to focus more on transformational failures related to missing directionality, demand articulation, coordination or reflexivity regarding the direction of change. Moreover, the policy literature increasingly recognizes the role of policy in ensuring broad engagement and public acceptance (legitimacy) and cooperation among multiple actors to govern the wicked challenges of society (Borrás and Edler 2014; Schot and Steinmueller 2016; Kuhlmann and Rip 2018).

Until now, the literature on challenge-led, mission-oriented innovation policies has remained relatively silent on the fact that societal challenges may fundamentally differ in nature[1]. Consequently, it is less clear whether their differing nature affects the type of policy we need for addressing the challenge effectively. The policy planning literature shows that there is much more to say about the complexity and scope of societal challenges, instead of defining them generically in terms of wicked problems (Rittel and Webber 1973; Levin et al. 2012; Newman and Head 2017; Daviter 2017). Societal problems differ in many ways and that a simple tame-wicked dichotomy does not do justice to the heterogeneity of these problems and the missions that aim to (help) tackle them (Hoppe 2011; Alford and Head 2017). However, the understanding of learning, related to the creation of innovative solutions, new socio-institutional arrangements and its policy implications is limited in the policy planning literature.

In this paper we combine innovation and transition policy with the policy planning literature to develop a fully-fledged analytical elaboration. The aim is to provide analytical clarity about i) the types of societal problem and ii) the associated innovative solutions. It aims at clarifying where innovation and transition policy rationales hold and where they need to be complemented with concepts from other literatures. Our starting point is a multi-dimensional problem-solution space in which both societal problems and potential solutions can be either diverging (i.e. contested, ill-defined or perceived differently by stakeholders) or converging (i.e. uncontested with broad societal support, well-defined and with sufficient knowledge on causes and consequences). Based on this analytical decomposition of problem and solution structures, we regard MIP as policy that strives for achieving convergence of problem-solution configurations/constellations that can be transformative in nature but at the same time are sufficiently stable in socio-technological or socio-institutional terms to serve as frame of reference for actors. If converging problem-solution structures emerge, such a mission-oriented approach can be complemented by the more conventional market- or system-based innovation policies.

The remainder of this paper is structured as follows: In Section 2 we briefly discuss the development of MIP and its current implementation at the national and European level. Section 3 provides the analytical decomposition of diverging/converging societal problems and innovative solutions and introduces four different problem-solution structures with the associated governance strategies. In Section 4, we discuss 3 stylized policy pathways to achieve convergence around societal problems and solutions. Section 5 provides implications for policy and further research on MIP.

[1] This is a first conference draft. In future versions of this paper we include also a more thorough literature review of the scientific literature on mission-oriented innovation policy.

2 Missions-oriented policy approaches in Europe

Mission-orientation has been a strong feature of R&I policy for many decades, since its origins in agricultural and military science missions in the 1930s and 1940s. With the growing professionalization of technology policy in the 1960s, the 'classical' interpretation of missions (i.e. Apollo-type missions) became the prevailing form of mission-oriented policy, motivated not so much by economic considerations, but by political ambitions. It was only in the 1970s that technology-centric missions for purposes of economic competitiveness turned into a new and dominant variety of mission-orientation. However, with the apparent failure of government-led mission-oriented initiatives for economic ends, the entire mission-oriented approach became increasingly discredited. And since the change to the innovation systems paradigm in the 1990s, the past two decades of R&I policy were dominated by a belief in structural, often technology-neutral policies to improve innovation performance without mission-oriented ambitions.

In recent years, there has been a renewed interest in the concept of MIP in Europe and the US. Already in the preparation of the fourth European Framework Programme for Research and Technological Development, the Maastricht Memorandum (Soete and Arundel 1993) prepared by an EC expert group, emphasis was put on the importance of diffusion policy and thus on the better definition of the demand side of innovations. Based on a systems approach to innovation, the idea of a new type of mission-orientation in R&I policy was suggested for long-term goals, exemplified by the area of environmentally sustainable development, which needs to be well embedded into societal needs and requirements. The influence of this programmatic document on the shaping of FP 4 was limited, but it seems to have been more influential on the next framework programme (FP 5), which introduced key actions as element long-term ambitions cutting across established areas of research and technology development.

However, it was not before the middle of 2000s that basic idea of missions was taken up again, then under the headline of 'grand challenges', promoted both by the private sector and by major scientific associations. Whereas in the US the emphasis was put on scientific and technological challenges, the debate in Europe took a different direction and stressed the importance of societal issues giving rise to challenges for research and innovation. The Aho-Report (Aho et al. 2006) called for 'resurrecting of the demand side of innovation' as a means to guide search processes of discovery and innovation (Edler and Georghiou 2007), and the subsequent expert group on ERA rationales re-introduced the notion of 'societal challenges' to the debate about R&I policy in Europe (Georghiou et al. 2008). While this term was inspired by the 'Grand Challenges' debate in the US, it differed by stressing the societal nature of long-term future challenges rather than focusing on scientific-technological challenges. The Lund declaration of the European Council (2009) took up this idea and stressed the key role of the European Research Area for strengthening Europe's ability to tackle such challenges like global warming, tightening supplies of energy, water and food, ageing societies, public health, pandemics, security or an eco-efficient economy. With Horizon 2020, this approach was put into practice in programmatic terms, with the third pillar of Horizon 2020 and other multi-lateral initiatives in Europe (e.g. Joint Programming

Initiatives) being dedicated to societal challenges. It needs to be stressed, however, that societal challenges differ from missions in lacking a clearly defined target, and by being often focused on "wicked" problems.

In parallel to these developments at European level, several member states also embraced similar concepts for re-defining their research and innovation policies. The Netherlands had already started during the 2000s to integrate research and innovation policy initiatives into the wider context of transition policies, focused on specific areas like water management and energy supply. The specificity of the Dutch approach consists of combining R&I policy with organizational, regulatory and institutional changes in order to trigger a transition of the respective supply systems. In Germany, the High-Tech Strategy may have been motivated initially by the ambition to strengthen the competitiveness of German industry, but it combined this goal with other, for instance, environmental goals (Dachs et al. 2015). The German Energiewende is yet another example of an ambitious policy aiming to trigger a process of transformation by combining new impulses from research and innovation with changes in regulatory and institutional framework as well as with major infrastructure investments. The French Commission Innovation 2030 and the Swedish Challenge-Driven Innovation programme (VINNOVA 2016) may put more emphasis on the supply side of innovation than the Dutch transition approach or the German Energiewende, but they equally frame R&I policy in the context of ambitious sectoral policies.

The OECD has equally re-discovered the importance of a more comprehensive approach to innovation policy, by looking into experiences with what it calls system innovations, drawing among others on some of the aforementioned national experiences (OECD 2015).

In the meantime, however, it has become evident that the programmatic change in Horizon 2020 of giving high prominence to the notion of societal challenges is not enough to re-orient significant parts of research and innovation activities towards more ambitious and longer-term goals. As long as the modalities of FP implementation remain largely the same as they have been for the past thirty years, the gap between ambitious long-term and higher-order goals on the one hand and the prescription of specific topics as defined in work programmes on the other will continue to be too wide to lead to the ambitious and sometimes even transformative solutions needed to tackle grand societal challenges. Moreover, without a serious embedding of the R&I agendas into the wider political agendas in key policy areas such as health, environment, transport, energy, etc., the wider uptake of novel R&I-led solutions is going to be as uncertain as ever. Without improved coherence of policies and stakeholders' strategies, the grand challenges are likely to remain unanswered.

It is against this backdrop that the specification of 'missions' at an intermediate level of granularity has recently been suggested as focusing device to bridge the gap between grand challenges and specific R&I projects has been suggested more recently as a guiding element of the next and ninth framework programme (Lamy and et al. 2017). With the recently published programmatic paper on mission-orientation in European R&I policy (Mazzucato 2018), the rationales for a mission-oriented approach have been visibly spelled out as a trigger of further political debate and public consultation. It is backed up by other expert groups (ESIR 2017, RISE 2017), analytical studies (JIIP 2018a, 2018b) and foresight

activities (Weber et al. 2018). As regards the preparation of the next and ninth framework programme for research and innovation, the debate about the relative importance to be given to mission-orientation, not to speak of its specific approach, is not yet closed and still in need of further conceptual clarifications.

3 Conceptualizing societal challenges in a problem-solution space

We define societal challenges as more or less wicked societal problems requiring innovative solutions, which can be of technological or non-technological nature, to be created in order to address them systematically and on a large scale. Most of the mission-oriented or challenge-oriented policy concepts (Foray et al. 2012; Mazzucato 2017, 2018; Edler and Boon 2018) recently developed in the innovation and transition literature seem to under-conceptualize that societal challenges may differ greatly. For some societal challenges, technological innovations might indeed be the key (e.g. water safety, clean air, biotech, drugs against rare diseases), while for others social change should be more crucial (e.g. health (obesity, diabetes, mental health), education (analphabetism), or inequality). In some cases, it requires a broader transformation or combination of both (e.g. preventing climate change, resource scarcity, smart mobility). In any case, the suitability of a particular solution depends on the level, or broadness, at which a societal problem is defined.

We argue that a one-size-fits-all approach fails to recognize potential variations in both problem statements and associated solutions. To flesh out the conceptual differences between different societal problems and their solutions we derive basic characteristics of wickedness by building on topologies and distinctions of wicked and tame problems in the policy literature (Head 2008, Alford and Head, 2017, Daviter, 2017). We apply these characteristics of wickedness not only to the problem (Section 3.1), but also to the solution side (Solution 3.2) in order to position societal challenges in a broader problem-solution matrix and suggest different governance strategies for different problem-solution structures (Section 3.3).

3.1 Differentiating societal problems beyond the wicked vs tame dichotomy

The wicked-tame dichotomy is based on the major contributions of (Rittel 1972) and (Rittel and Webber 1973) in which the authors provide an analytical decomposition of wicked problems. Accordingly, wicked problems[2] are those societal problems that are complex, unpredictable, open ended, or intractable (Alford and Head, 2017). Inherently different to wicked problems are so-called tame problems resembling the problems of scientists or engineers. Once a tame problem is understood well enough, a solution can be found and its feasibility instantly assessed. Several authors draw on this key dichotomy to develop typologies based on which the degree of "wickedness" or "tameness" of policy problems can

[2] Wicked problems are also known as persistent problems (Rotmans and Loorbach 2009); unstructured or incorrigible problems (Hisschemoller and Hoppe 1995; Hoppe 2011); tangled problems (Dawes et al., 2009); complex problems (May et al, 2013), complex challenges (Hassan 2014) and grand challenges (Cagnin et al. 2012b; Kuhlmann and Rip 2014).

be determined (see Head 2008, Dawes et al. 2009, May et al. 2013, Weber and Khademian 2008, Hoppe 2011, Farrell and Hooker 2013, (Head and Alford 2015), Alford and Head 2017, Carley and Christie 2017). In these typologies, recurring dimensions which contribute to the level of problem wickedness are:

(i) *contestation* which refers to the degree of normativity in terms of the normative, often diverging claims, values and framings related to an issue, or the inherent conflicts of interest resulting from social pluralism and stakeholder divergence;

(ii) *complexity* in institutional or contextual terms relates to the multi-scalar nature of many societal problems and the difficulties in determining responsibilities of actions in systems of inter-organizational cooperation and multi-level governance;

(iii) knowledge or scientific *uncertainty* points to the lack or limited availability of knowledge on the risks or damages of action and non-action, the specific knowledge on the relations between causes, consequences and side-effects of a problem, or the fragmentation of knowledge across different stakeholders.

Based on these three basic characteristics of wickedness, we argue that the problem statements related to a particular societal challenge can be diverging in terms of how different stakeholders perceive the challenge or contest a specific narrative (e.g. climate change). Problem divergence increases if (scientifically) accepted knowledge on a problem is lacking, the division of responsibilities to address the problem not clear and institutional complexity high (see Table 1). Such problem statements converge if different stakeholders agree on a problem framing and the importance of tackling it (lowers contestation), responsibilities for addressing the problem – in institutional or geographical terms – are more clearly defined (lowers complexity), and if the main causes and effects of a problem are fairly understood (lowers uncertainty). With higher convergence, problems can be 'tamed'. However, fully tamed problems refer mainly to the engineering-type of problems and are hard to achieve in policy realities on societal problems (Alford and Head 2017).

Table 1: Converging vs. diverging societal problems

Contestation: Stakeholder divergence, normativity	High	Low
Complexity: institutional and situational	High	Low
Uncertainty Lack or fragmentation of knowledge	High	Low
Problem statement	**Divergence** ⟶	**Convergence**

Mission-oriented approaches that under-conceptualize the 'risk of contestation', or over-emphasize the lack of scientific or technological knowledge as the cause of a problem, run the risk of building their arguments on the assumption that problems are reasonably well understood (i.e. already tamed to a certain extent). For instance, if problem identifications are

based on specific epistemic knowledge of a certain group of experts, it may indeed allow to agree on a problem and take action faster. At the same time, however, it limits open debates and the possibilities for learning about the structure, the causes and effects of a problem. As emphasized by Daviter (2017), governing wicked problems comes with trade-offs. With a taming strategy, policy accepts the fact that competing problem perspectives are disregarded or a specific perspective prioritized, which may facilitate governability but comes at a high cost of problem reflexivity (Daviter 2017).

3.2 Differentiating innovative solutions

The policy and planning literature often draws no clear distinction between problem statement and solutions (e.g. Alford and Head 2017), and assumes that every problem statement is linked to a solution. This assumption is based on the contribution of Rittel and Weber (1973) emphasising that definitions of a wicked problem are suggestive as they automatically favour a particular solution over others (Rittel and Weber 1973). Without neglecting this normative character of problem statements, we see the inseparability of societal problems and solutions as problematic. Even if there is growing consensus on a problem statement (e.g. greenhouse gas emissions are too high), the views on how to best address the problem can still be diverging (e.g. whether to focus on radical transformation of our production and consumption patterns or to support generic or specific technological innovation).

The innovation and transitions literature emphasizes the systemic nature of solutions in a socio-technical sense and acknowledges the challenges in governing the complex network of different actors that are guided by conflicting institutions (Turnheim et al. 2018; EEA, 2017; Kuhlman and Rip 2018). Hence, the literature acknowledges that different stakeholder groups have different interests regarding the technically feasible solutions to a problem, resulting in contestation (Broecks et al., 2016; Wesseling et al., 2015). Given the need for broad actor support to enable systemic embedding and societal diffusion (e.g. the case of electric vehicles), solutions can, despite a relatively clear problem definition, be subject to different degrees of uncertainty or complexity.

Accordingly, as soon as we frame solutions in a socio-technical way, we can apply the same wickedness characteristics. Here, *contestation* on a solution can emerge if different stakeholder groups have strong and diverging views on the best way to tackle a problem (e.g. more scientific knowledge vs. more social innovation), or refuse a technically feasible solution due to particular norms and values (Broecks et al. 2016). *Complexity* is the need for combining multiple solutions and the fact that systemic approaches integrating technological, organizational, institutional and social innovations are missing or too fragmented. *Uncertainty* refers to lack of knowledge on the feasibility of a solution, or the fact that multiple solutions seem to be possible and promising (technological, organizational, institutional, social) without indication which works best for tackling the challenge in reasonable time. The higher the degree of contestation, complexity and uncertainty about a solution, the more diverging the views on innovative solution (see Table 2).

Table 2: Converging vs. diverging views on innovative solutions

Contestation: Different opinions on best solution, normativity	High	Low
Complexity: Need for systemic approaches	High	Low
Uncertainty Lack of knowledge on feasibility, reach and impact	High	Low
Solution	**Divergence** ⟶	**Convergence**

3.3 Differentiating problems and solutions: a two-dimensional space

To implement challenge-oriented policies it is essential to take the context and transformative character of the mission into account. As we argue, analytical clarity about the mission context can be improved by looking at the problem-solution structure, and how problem orientations and views on potential solutions diverge. In Table 3 we provide a two-dimensional problem-solution space based on which societal problems and solutions are contextualized as *diverging* or *converging.* According to the categorization in Section 3.1 and Section 3.2, four major types of problem-solution structures are conceivable[3]. Then, each problem-solution structures (i.e. cell in the matrix) can be related to a governance strategy which is characteristic for the specific stage of problem definition and solution development. Such governance strategies can be pursued by innovation policy or socially-led by other stakeholders with specific interest in an issue (e.g. NGOs, experts, everyday users, social entrepreneurs, or civil society organizations or associations of people affected). The actors shape the orientations, cognitive frames and expectations in designing and implementing the governance strategies. Four major types of problem-solution structures and associated governance strategies are distinguished:

I. Learning and framing is necessary if there is neither a consensus on the nature of the problem nor a clear idea about solutions that are realistic and practicable to address it. Examples include the range of broadly defined societal challenges included in European and national research and innovation policies regarding ageing population and public health or the challenges involved in ensuring food security and making agriculture more sustainable. The degree of wickedness of these problem statements are high as a commonly accepted framing of the challenge (and consequently the mission) did not emerge yet. Relevant knowledge spreads across various actors and stakeholders (experts and non-experts), participatory governance and research practices are necessary to collectively develop a better understanding of the challenges related to a certain problem, but different actor types might be due to conflicting interests and viewpoints often reluctant to cooperate.

[3] We are aware that problems or solution convergence (divergence) is neither a discrete nor a self-contained phenomenon; each of the illustrated problem-solution structures represents a more symbolic and simplified representation of a continuum.

As choices about challenge and mission framing may be inevitable to transform the situation, awareness and understanding the implications of framing choices is central to govern this situation. Knowledge co-creation, exploring and experimenting with different technical and socio-institutional arrangements is necessary to understand the complexity of the challenge, including collective learning and anticipating effects and consequences that may follow from taking action (Schot and Steinmueller 2016). Deliberative processes in this problem-solution structure can be characterised by processes of social learning (Ison et al. 2015), understood as negotiating about the purpose, success criteria and different knowledge on the issues at stake. Social learning increases awareness of different framings, to accommodate these differences and to build mutual expectations (convergence) (Ison et al. 2015), related to processes of collective visioning (Loorbach 2010). The more inclusive, open and engaging for those people affected by a societal problem (citizens, civil society organizations, etc.) the higher will be the input and procedural legitimacy of framing and shaping the problem (Boon and Edler 2018; Wesseling and Edquist 2018).

Table 3: Contextualizing mission orientation in a problem-solution space

	Diverging societal problem	**Converging societal problem**
Diverging views on solutions	**I. Learning and framing:** knowledge co-creation and learning about different values to develop a shared interest and vision	**II. Prioritizing and targeting**: translating vision, knowledge pooling and targeted transformation
Converging views on solutions	**III. Considerate selection and implementation:** solution-based selection. transfer and refinement	**IV. Systemic embedding:** upscaling and societal diffusion; stable transformation

II. Prioritizing and targeting should be the key strategy if a dominant definition of a societal problem has emerged and enjoys broad acceptance. Examples for such situations could be the search for solutions in order to deal with Dementia or cancer, or to harm damages and make polluting industries more sustainable. This field comes closest to what Mazzucato (2018) generally describes as mission-orientation. Once the actors have learned about a societal problem and associated challenges, their views on the problem are converging, and a clear vision is shared by multiple actors, the mission can be operationalized in terms of clear and measurable goals (output legitimacy). In this situation, multiple ways to approach the challenge are still conceivable (technological, institutional or social innovation) but more knowledge on their individual feasibility and interoperability is needed. Ideas on how to solve the challenge, or achieve transformation, are still vague, uncertain and often disputed (diverging views on solutions).

III. Considerate selection and implementation is necessary if a potential design for a promising solution has been developed with concrete expectations regarding future applications (e.g. new technologies, institutional innovations or social innovations resulting

in new business models). Yet, the societal problem is not well defined, normatively loaded, or faces public reluctance due to insufficient knowledge on risks, interlinkages and consequences of action. In such situations, vested interests of certain stakeholders (e.g. the providers of potential solutions) can be influential in defining and shaping the problem statement to their benefit. Targeted policies run the risk of limited legitimacy since broad awareness and acceptance of the societal challenge is missing (Borràs and Edler 2014). Promising solutions can face considerable social barriers (e.g. vegetarian diet as solution for more sustainable consumption, eHealth to improve patient treatment and medication), and missing demand to scale the solution and tackle the challenge on a broad basis (Boon and Edler 2018).

IV. Systemic embedding refers to the situation in which both societal problems are relatively well understood and supported, and in which views on promising solutions have converged. A clear example is the automotive industry, were the problems of climate change and the adverse health effects of local air pollution and the impact of fossil-fuel powered transport has been widely acknowledged and supported. Convergence on the most suitable solutions (i.e. plug-in hybrid electric vehicles, full-electric vehicles, hydrogen fuel cell vehicles, flex fuel vehicles, etc.) has been a continuous struggle (Bakker et al., 201X; Wesseling et al., 2015), but has played out increasingly in favour of electric vehicles as their diffusion accelerates and supportive infrastructure is rolled out. However, despite convergence around a solution for a clear, legitimate problem, the solutions are often still not able to compete on the mainstream market with incumbent products and services that have benefited of decades of incremental improvement (Geels 2004). Policy support for upscaling and broader societal embedding (e.g. supporting adaptation of user practices in favour of electric driving) is needed. Particularly when problems are urgent, strong leadership in policy support for systemic embedding of solutions is needed.

4 Dynamics in the product-solution space: the role of policy to create convergence

4.1 From directionality and missions to dynamic policy pathways

Finding solutions that are stable and broadly legitimized for a problem of high societal importance is a central goal of MIP. In terms of our problem-solution space, this goal reads as arriving at converging socio-technical problem framings and solution structures that are clear and agreed upon by many stakeholders. Such a situation is illustrated by the lower right corner of the matrix in Table 3. With the advent of converging structures, more conventional, systemic innovation policies (including demand-side or regulatory measures) can come into play to support the market creation and diffusion of a societally relevant innovation, or the broader societal embedding of particular ways of acting.

Mission-oriented policy is not only about providing direction at the outset but also about supporting the convergence of societal problem-solution configurations/constellations that are transformative in nature but at the same time sufficiently stable in socio-technological or socio-institutional terms to serve as frame of reference for actors. So far, the directionality rationale has been the predominantly discussed rationale for challenge- or goal-oriented policy approaches (Gassler et al. 2008; Weber and Rohracher 2012; Mazzucato 2017, 2018;

Edler and Boon 2018). For instance, Mazzucato (2018) recently made explicit that good societal missions should provide direction to a problem of wide societal relevance[4]. Missions that are goal-oriented, measurable and time-bound, she further argues, make vague societal challenges such as climate change or a healthy population more concrete (Mazzucato 2018). Framing a mission in a specific way allows narrowing down a big societal problem, to reduce the complexity and uncertainty, and to orchestrate innovation activities at multiple ends based on a consistent problem orientation. However, it may also run the risk that different actors across sectors, industries, or scientific disciplines do not share their views on what is a relevant mission, or which mission should be selected and pursued to address the bigger problem. Hence, diverging strategic intentions, expectations or opinions of actors may considerably impede legitimization and effectiveness of a specific mission but also the wide acceptance of innovative solutions (Borras and Edler 2014, Kuhlmann and Rip 2018).

Looking at MIP from the perspective of different problem-solution structures reveals the dynamics involved in the directionality principle. If the goal is to come from a broad societal challenge to credible, systemic and widely adopted innovations, providing direction also needs to incorporate governing mechanisms for different stages of the process to complete the mission. The aim is to tame a societal challenge to the extent that normativity, uncertainty and complexity of societal issues can be better understood, structured and managed (Roberts 2000; Daviter 2017)[5]. For such 'convergence processes', policy makers need to provide directionality along the way in accordance with the overall path as well as the current state they are in.

4.2 Three stylized policy pathways

We argued that different types of societal problems require different types of innovations, ranging from individual technological or institutional innovations, to more systemic or transformative socio-technical or socio-institutional changes. Consequently, there must be several ways for a mission-oriented policy to pursue the goal of creating solutions to a problem of high societal relevance, and a one-size-fits-all method seems not appropriate. Hence, policy makers following a mission-oriented approach should be critical about the societal problem type and the range of available and potential solutions, and consider social barriers and normativity of different stakeholders when framing a particular problem.

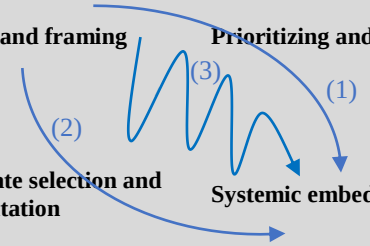
[4] In Mazzucato (2018) the following criteria for selecting societal missions are mentioned: A mission should 1) be bold, inspirational and of wide societal relevance; 2) provide clear direction, meaning it is measurable, targeted and time-bound; 3) be ambitious but realistic; 4) be cross-disciplinary, cross-sectoral and cross-actor to generate a broad range of solutions; 5) have multiple, bottom-up solutions.

[5] The idea of movement is somewhat contractionary to what is assumed in the policy planning literature (Alford and Head 2017, Hoppe 2011). This literature takes a static perspective and sees wickedness as an inherent quality of certain problem/solution situations that cannot be changed. On the contrary, the literature on social learning (e.g. Ison et al. 2015) suggests that wicked problems can be tamed through framing. In doing so, a problem is simplified but remains wicked in nature. We build on the latter assumption by emphasizing the need for technical and social learning about different solutions, expectations and problem perceptions (e.g. learning about causes and consequences, technological feasibility and expectations related to solutions, or the conflicts, strategic considerations or values systems attached to societal problem definitions)

In what follows, we describe the stylized pathways a mission-oriented policy can take in order to stimulate the movement towards converging problem-solution structures. Hereby, we zoom in on the mission-oriented area in Table 3 and describe three possible pathways to depart from the most 'wicked area' (i.e. area I). Table 4 illustrates the different pathways of so-called (1) problem-led missions, (2) solution-led missions and (3) hybrid missions. We characterise each path based on the underlying search processes and innovation strategies, point to corresponding policy approaches and barriers associated with a certain state or course.

Table 4 Different pathways for MIP in the problem-solution space

	Diverging societal problem	**Converging societal problem**
Diverging views on solutions	**Learning and framing**	**Prioritizing and targeting**
Converging views on solutions	**Considerate selection and implementation**	**Systemic embedding**



(1) Problem-led mission

A problem-oriented strategy starts from a big societal challenge that is, or needs to be, framed in a comprehensive way. To formulate a shared vision, social learning about alternative perspectives and expectations is combined with anticipatory instruments to explore alternative futures, their effects and side-effects. A problem-oriented mission is reflexive from the start, enables an analytical problem understanding based on open and participatory practices. It is followed by the formulation of clear goals or transformation strategies that are legitimate and backed by many actors. The mission is further developed in terms of one concrete and measurable target, or several complementary goals of smaller scale (operationalization). Based on a clearly defined problem, distributed efforts can be concerted and directed towards a targeted search for multiple solutions (social, technological, institutional, or a combination of all is possible).

A problem-oriented strategy combines the mission-oriented ideas brought forward by Mazzucato (2018) with reflexive governance approaches (Voss and Bornemann 2011), to better comprehend the multiple dimensions of a societal problem (and its perception), and to increase awareness on normative choices that are necessary when selecting, defining and pursuing missions. However, the challenge of this approach is how to deal with societal problems of great urgency, so-called super-wicked problems (Levin et al. 2012), requiring transformation under time pressure. Deliberation and balancing of interests together with social learning and experimenting, may take (too) long; success and outcomes are, at the same time, highly uncertain. On the one hand, a move to the right in the matrix may not take

place as no clear and uniform problem framing may emerge due to lack of knowledge about the problem and its causes or due to the diversity of values and conflicting interests. On the other hand, if the decision on a certain mission framing is taken too fast, without integrative and considerate selection, this can be a breeding ground for new contestations leading to reversion to a state of diverging interests and opinions on the basic framing of the problem (bounce-back effects). Moreover, it is possible that the initially high expectation to solve a problem cannot be met due to technological (e.g. no feasible large-scale solutions, no convergence of expectations about solutions) or economic barriers (e.g. high costs of the solution impedes the creation of markets or finance for innovations).

(2) Solution-led mission

A solution-driven mission constitutes a pathway from learning and experimenting with potential solutions to the selection of particular (technological- or non-technological) innovations. Initially, this path follows a bottom-up approach based on the development of multiple, often conflicting, solutions. Once a dominant solution with converging expectations has emerged, the focus can be on prioritizing (selecting) and scaling the innovation to create a market (for e.g. a certain technology) and ensure its systemic and societal embedding.

The approach of experimenting and subsequent scaling corresponds to policy strategies such as Strategic Niche Management (e.g. Caniëls and Romijn 2008; Schot and Geels 2008) or Technological Innovation Systems (Hekkert et al. 2007; Bergek et al. 2008). In the matrix, a solution-driven mission or pathway is illustrated by a first downwards move due to the initially open and bottom-up societal problem framing. Only if an innovation 'finds' an extended socio-technical framing based on converging expectations it will eventually lead to a shift to the right.

Along this pathway, focus is on the development of solutions. Attention to societal problem definitions is underrepresented though. Particularly solution providers, but also other stakeholders with strategic interests, might try to rule the societal framing of the problems to which the solution could contribute and how (e.g. safety, urban planning and environmental advantages of self-driving cars). This can impede the diffusion or broad embedding of solutions, either because the societal consequences of the solution are not fully clear, or it is not possible to overcome societal barriers. Such societal barriers setting back the convergence process can range from limited acceptance or awareness of a particular problem (related to societal needs in the future), uncertainty about the impact of a solution on that problem (e.g. are autonomous cars really more sustainable?), or limited willingness to collaborate across actor types to implement the solution on a large scale. New problems can appear with the large-scale diffusion of a solution (e.g. visual, audible and safety effects of wind turbines, negative effects on biodiversity and food supply related to biofuels).

(3) Hybrid mission

A hybrid approach may seem to be promising for wicked societal problems that are ill-defined and solutions not known. It is a co-evolutionary approach, involving experimenting in both directions and learning about the challenge in the course of finding solutions, pursued as a matter of urgency given the nature of the problem, high societal expectations or political

pressure to act. However, following this pathway by neither aiming at a promising solution that could benefit societal problems and that is supported by a broad range of actors, nor a thorough understanding of the causes and effects of the societal problem at hand, runs the risk of remaining stuck in an ill-structured mission approach without clearly-defined goals, expected solutions or clear solution paths. Problems of contestation, complexity and uncertainty may come from both sides: the inhibited specification of the "real" problem and selection of the "best" solution.

There is high likelihood that missions nevertheless specified in this situation can be too broad or misleading. Regarding the former, Mazzucato (2018) criticises the current EU grand challenges policy which calls for research and pilot projects on solutions directed at grand societal challenges that are too generic to provide sufficient directionality to succeed. However, these research and pilot projects do generate expectations and a better understanding of the nature of the problem at hand as well as the suitability of the solutions explored. If this knowledge was used to guide the specification of the mission and the selection of solutions, this could result in an iterative process of problem and solution convergence (pathway 3: marginally wiggly line/sinusoidal function).

Moreover, the mission can also be misleading if specific, measurable goals are set based on unfounded assumptions regarding solutions and problems. It may turn out that a) the problems specified turns out to be wrong or short-sighted (e.g. setting goals in terms of only one greenhouse gas, ignoring the others, for climate change), or b) the solution converged upon turns out to generate other unforeseen side effects (e.g. biofuels solve the problem of fossil fuel scarcity, but creates deforestation and food poverty problems). This can result in a redirected mission (pathway with high amplitude) or even discontinued mission (unfinished pathway).

5 Conclusions

The starting point of this paper was our observation that innovation policy is increasingly targeted towards societal challenges such as climate change, food security or ageing population. Mission-oriented innovation policies are currently put in place with the major aim of contributing to the big problems of our society by the means of research and innovation. The innovation studies and transition literature made great efforts to better understand these societal challenges and to formulate rationales for directed and transformative innovation policy approaches (Weber and Rohracher 2012, Kuhlmann and Rip 2014, Schot and Steinmueller 2016, Boon and Edler 2018). Typically, societal challenges are characterised as wicked, inherently systemic and complex given the multiple actors, sectors and levels they encompass, but with this broad definition they might be too vague to serve as clear reference for mission-oriented policies (Frenken 2017, Mazzucato 2018). Yet, surprisingly little attention has been paid to the fact that societal challenges vary considerably in i) the scale and scope of the underlying problem statements and ii) the solutions that are regarded feasible and legitimate to tackle the problem. Current 'one-size fits all' approaches therefore run the risk of providing less effective reference frames for both the actors engaged in

challenge-oriented research and innovation and the policy makers engaged in formulating such mission-oriented approaches.

The aim of this paper is to provide an analytical decomposition of different problem-solution structures to achieve conceptual clarity about different societal challenges, on the one hand, and to better inform mission-oriented innovation policy on providing directionality, on the other hand. To achieve this aim, we suggest the characteristics of *contestation*, *complexity*, and *uncertainty* to determine whether societal problem orientations and solutions to a societal problem are diverging or converging. On this basis, we introduce a two dimensional matrix involving four major problem-solution constellations of societal problem and solution framings. These constellations range from a situation in which both the societal problem itself and the associated solutions are still vague, not well understood or contested, to a situation in which the problem is well-structured and defined, first solutions available and broadly accepted but still too immature to address the problem at a large-scale. We discuss empirical examples and governance strategies that a characteristics for the different situations.

Against this background, we regard mission-oriented innovation policy as a policy that provides direction for innovation activities by being critical with respect to diverging societal problem framings, the range of solutions from technological to institutional or social innovation, and the barriers related to the different forms. At the same time, mission-oriented policies need to be process-oriented in order to support the movement from vague problem orientations to converging problem-solution structures. In this paper, we provide a first characterisation of three stylized policy pathways to 'tame' societal challenges to the extent that normativity, complexity and uncertainty of societal issues can be better understood, and system transitions supported by policy. At the same time, we emphasize the need for more research on the interplay of problem-solution constellations and governance mixes, and the implications for innovation system thinking to accelerate the creation and diffusion of innovative solution to the most urgent societal challenges.

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