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Article

A framework for mission-oriented innovation policy: Alternative pathways through the problem–solution space

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Abstract

We aim for a better conceptualization of mission-oriented innovation policy (MIP). Our starting point is an analytical decomposition of societal problems and innovative solutions based on three dimensions of wickedness: (1) contestation; (2) complexity; and (3) uncertainty. We argue that both problems and solutions can be divergent (contested, complex, and uncertain) or convergent (uncontested, well-defined, and informed). Based on the resulting problem–solution typology, we suggest a process-oriented view on MIP and discuss three alternative pathways along which convergence between problems and solutions can be achieved to come from wicked problems to legitimate solutions. We illustrate these pathways using examples for different societal problems related to health (smoking bans), security (CCTV), and energy (wind turbines). For policy makers, locating a societal challenge in this problem–solution space, and implementing policy strategies to achieve problem and solution convergence, is expected to accelerate both the legitimacy of a mission and the resulting solutions.

Key words: mission-oriented policy; wicked problems; mission; societal challenges; innovation policy; transition

1. Introduction

In the wake of societal challenges facing countries around the world, innovation policy is undergoing major changes. No longer is economic growth the sole guiding rationale for stimulating technological development. Instead, there is an emerging consensus that innovation, and innovation policy, should focus on solving concrete and pressing problems in society at large.

The change in the key objective of innovation policy from economic growth towards societal challenges has prompted renewed interest into mission-oriented types of innovation policy (MIP) which were particularly prevalent in the 1960s and 1970s. However, the meaning of MIP in the past differs considerably from its meaning today. Past policies involved ambitious technical achievements with the man-on-the-moon project as the archetypical example of a technology-led mission (Nelson 1974). With a clear formulation of the problem and the solution, these missions addressed a relatively 'tame' problem, and paid scant regard to societal or economic impacts (Mowery et al. 2010). Many countries revived such a mission approach, such as the USA to support technological competitiveness and market creation in specific industries, or in Europe, where current mission approaches often target persistent societal problems, also labelled as 'grand societal challenges' such as climate change, ageing, and security (EC 2011; Cagnin et al. 2012; Mazzucato 2018a).[1]

Compared with traditional technology-led missions, societal challenge-led missions appear more complex and unstructured, going beyond technological advances alone. A societal challenge-led mission can be seen as a strategic goal that targets important societal problems and/or future societal needs, and requires the development, diffusion and embedding of technological and/or institutional solutions to accomplish it. It is the 'wicked' nature of societal problems (Rittel and Webber 1973) which poses new questions and obstacles for innovation policy makers. Pursuing a societal mission-oriented approach raises the issue of how to identify, define, and subsequently target a complex and unstructured problem, for which solutions—be they technological or non-technological—cannot be

predefined. MIP relates to policies supporting transformative system change (Weber and Rohracher 2012; Rogge and Reichardt 2016; Diercks et al. 2018; Schot and Steinmueller 2018). Societal challenges may need fundamental societal transformations, requiring not just technological, but also institutional and behavioural change, as recognized in the literature on socio-technical transitions (Geels 2004; Smith and Kern 2009; Alkemade et al. 2011). The persistent nature of societal problems may call for missions that go beyond the optimization of current socio-technical systems. In this context, Weber and Rohracher (2012) suggested that the rationales for societal challenge-led innovation policies follow from 'transformational' system failures, including a lack of directionality, a lack of demand articulation, limited reflexivity, and missing coordination across policy domains and levels. Accordingly, a major part of MIP lies in ensuring legitimacy, broad engagement, and cooperation among multiple actors to govern the wicked challenges of current societies (Borrás and Edler 2014; Kuhlmann and Rip 2018; Schot and Steinmueller 2018).

As yet, the literature on MIP has remained relatively silent on the fact that societal challenges may fundamentally differ in nature. Different societal problems may require different types of solutions, and consequently, different types of policies to address them effectively. Both academics and policy makers have focused primarily on the range of technological solutions conceivable to solve a societal problem (Diercks et al. 2018). In doing so, the framing and legitimacy of a societal challenge itself has been often taken for granted, just as the need for technological innovation. While some societal problems may indeed require research and innovation or fundamental transitions in the socio-technical regimes that society employs, other problems may be tackled by regulation and behavioural change (institutional innovations) without necessitating technological innovation *per se*. Hence, MIP goes beyond the spheres of science policy or innovation policy (Kuhlmann and Rip 2014), which implies that alternative policies, or policy mixes to tackle societal challenges should not be disregarded.

This article aims at providing a framework for a contextualization of the plurality of societal challenges to advance the understanding how MIP designs can help in meeting these challenges. We will argue that societal challenges, and the corresponding missions, may differ in many ways. Drawing on policy sciences, there is much more to say about the complexity and scope of societal challenges, beyond their generic definition as 'wicked' (Rittel and Webber 1973; Levin et al. 2012; Daviter 2017; Newman and Head 2017). The simple wicked-tame dichotomy often invoked in the MIP literature does not do justice to the heterogeneity of the underlying problem structures, nor to the specific design of missions needed to tackle them. Here, the policy sciences literature proves useful to take into account the value-based discourses in formulating a challenge or to capture the political dynamics in formulating missions or in framing the 'best' solutions for a particular problem (Hoppe 2011; Ison et al. 2015). By disregarding the 'degree of wickedness' involved in a particular challenge, the innovation policy literature runs the risk of providing a one-size-fits-all approach for MIP, with taken-for-granted problem definitions and a too strong emphasis on technological innovation, while marginalizing opposing voices or discarding complex trade-offs, for instance, between economic goals and societal goals, or when pre-defining problems or solutions in a narrow sense (top-down) versus leaving it open for identification based on plurality (bottom-up). As a consequence, MIP as currently conceived may turn out to be much less effective than many hope for.

Below, we combine insights from innovation studies and policy sciences to provide analytical clarity about the nature, scope, and scale of various societal challenges. We will distinguish between two analytical dimensions referring to the problem side (i.e. the type of underlying problem structures) and the solution side (i.e. the availability of potential technological and institutional innovations) of a societal challenge. From this, we derive a two-dimensional problem–solution space which allows one to locate different societal challenges depending on their divergence or convergence of both problems and solutions. We draw on different examples in the fields of food, energy, mobility, security, and health to demonstrate the usefulness of our framework for the broad array of current challenges and future needs of today's societies.

On this basis, we argue that a MIP should be viewed as a process-oriented policy that provides directionality and aims at supporting the process towards convergent problem–solution constellations. We introduce three policy pathways, i.e. a problem-led, a solution-led, and a hybrid pathway, to demonstrate different trajectories by which a mission-oriented approach can address the wickedness involved in a societal challenge at both the problem and solution side. In this way, MIP aims at advancing problem–solution constellations which become sufficiently stable to serve as common frame and direction, also by providing guidance to conventional market- or system-based innovation policies, to support the development, diffusion and embedding of technological, and/or institutional innovations.

The remainder of this article is structured as follows: In Section 2, we briefly review the MIP literature. Section 3 provides the analytical basis for decomposing societal challenges in a problem side (Section 3.1) and a solution side (Section 3.2), while Section 4 introduces four different problem-solution constellations resulting from a two-by-two matrix. In Section 5, we discuss three stylized policy pathways to achieve convergence around societal problems and solutions, and derive implications for a further theoretical conceptualization and practical implementation of MIP in Europe. Section 6 concludes with further research needs on MIP.

2. The re-emerging interest in MIPs

Mission-oriented policies originally emerged as a technology policy concept implemented to support governmental goals of national importance. Often recalled historical examples of technology-led missions are the Manhattan project undertaken by the allies to develop nuclear weapons or the Apollo project of putting a man on the moon (Hicks 2016; Mazzucato 2017; Kaldewey 2018). This classical mission-orientation was motivated primarily by political ambitions more than economic competitiveness. The technology missions in the 1970s and 1980s stand in contrast to the policy approaches adopted by countries such as Germany or Sweden at the time focusing predominantly on the diffusion of technological capabilities (Ergas 1987; Cantner and Pyka 2001).

It was only in the late 1970s that technology-led missions for economic purposes started to dominate as a response to the economic downturn. As a result, mission-oriented programmes increasingly pursued industrial policy ambitions. Among the best-known examples of a mission that was driven by both industrial and political ambitions was France's high-speed train TGV. However, with the limited success of government-led missions to deliver economic growth and employment, the mission-oriented approach became increasingly discredited. Instead, since the 1990s, innovation policy was dominated by a belief in generic technology neutral policies

fixing market failures and system failures as to improve a nation's competitiveness without the directionality provided by mission-oriented policies in the past (Boekholt 2010; Mazzucato 2017).

During the last decade, there is a renewed academic interest in mission-oriented approaches due to growing concerns about global warming. A belief that a 'strong, well-resourced government technology policy is part of the solution [for climate change]' (Mowery et al. 2010: 1012) has fuelled the academic discourse on innovation policy targets related to future needs of society rather than generic innovation objectives. Early contributions by Mowery et al. (2010) and Foray et al. (2012) emphasized four aspects in which societal challenge-oriented missions differ from traditional technology-oriented missions: Societal missions 1) show longer time frames and are of greater breadth, 2) make (technological) diffusion inevitable as neither the state nor any other actor will be the single user of the innovation, 3) require a diversity of funding and investment sources and coordination between numerous actors, and 4) often have to overcome established industrial structures dominated by incumbents with which new solutions have to compete (Foray et al. 2012: 1698). What is more, a stronger need for demand-side policies and policies targeted at behavioural change was identified (Mowery et al. 2010; Foray et al. 2012).

More recently, a wider literature stream emerged under the labels of 'innovation policy for grand challenges' (Ulnicane 2016; Frenken 2017; Edler and Boon 2018; Kuhlmann and Rip 2018), 'new mission-oriented policy' (Mazzucato 2017, 2018a) or 'transformative innovation policy' (Steward 2012; Diercks et al. 2018; Schot and Steinmueller 2018). Despite differences in emphasis and labelling, we can identify a set of defining characteristics broadly shared between these approaches.

First, new innovation policies are *directed towards complex, multi-dimensional, and systemic societal challenges*. Importantly, many challenges of current societies are wicked and open-ended in nature without the expectation that the underlying problems can be fully solved (Kuhlmann and Rip 2014). The complex and open-ended nature may impede the articulation of clear-cut missions and bears the risk of arriving at missions without a clear target. As a way to address the multi-dimensionality of societal challenges, Mazzucato (2018b) proposes to define of a set of clear research and innovation mission projects at the European level, all derived from a broader societal challenge. Her approach assumes that complex societal problems can be decomposed into more manageable building blocks with clearly defined targets. The transformational innovation policy approach of Schot and Steinmueller (2018) instead takes a different position in regarding the systemic nature as inherent to today's societal problems. They call for experimenting with fundamentally different policy models and the development of new institutions to foster socio-technical systems change.

Secondly, the *role of innovation policy* and *legitimization of policy intervention* are different for new innovation policies. While conventional innovation policies were mostly 'neutral' with regard to the innovation output, supporting 'directionality', 'coordination', 'reflexivity', and 'demand articulation' (Weber and Rohracher 2012) are now new references for innovation policy. Accordingly, the role of innovation policy is increasingly seen in shaping the direction of innovation activities (Mazzucato 2013, 2016), in formulating societal needs and their articulation into demand (Boon and Edler 2018), and in breaking-up the path dependencies in the existing system (Schot and Steinmueller 2018).

Thirdly, new innovation policies require *new and more decentralized governance modes*. With societal needs being a central innovation policy objective, there is an enlarged variety of stakeholders influencing and being influenced by policy agendas (Borrás and Edler 2014; Kuhlmann and Rip 2018). Governance arrangements may thus have to go beyond well-established innovation systems built around universities or incumbent firms, as to involve citizens, users, professionals, NGOs, and lower governments (Frenken 2017). A mission formulation is increasingly recognized as a political process involving a plurality of actors and governance structures that must be capable of dealing with conflicts emerging along the core values of societal actors (Steward 2012; Kuhlmann and Rip 2018). Broad societal acceptance and legitimacy of the defined challenge are considered essential to generate the demand needed for the diffusion of solutions to a societal problem (Edler and Boon 2018).

Against this background, we view MIP as a directional policy that starts from the perspective of a societal problem, and focuses on the formulation and implementation of a goal-oriented strategy by acknowledging the degree of wickedness of the underlying challenge, and the active role of policy in ensuring coordinated action and legitimacy of both problems and innovative solutions across multiple actors.

3. Contextualizing societal challenges: beyond a wicked problem framing

Despite progress in conceptualizing the new roles and governance modes necessary to deal with societal problems in the sense of a MIP, the innovation policy literature lacks approaches that can cope with the heterogeneity of societal challenges at hand. Challenges may be wicked in different ways and to different degrees. They vary considerably in the scale and scope of the underlying problem statements on the one hand, and the scale and scope of solutions that are regarded as feasible and legitimate to tackle the problem on the other hand. Conceptually disentangling societal challenges by their problem and solution structures may prove particularly useful if we assume that technological innovations may indeed be key but not necessarily sufficient in tackling current challenges.

3.1 The problem side: divergent or convergent problem statements

Wicked problems[2] are societal problems that are complex, unpredictable, and have poorly defined boundaries, while the so-called tame problems are inherently different by resembling more typical scientific and technical problems (Rittel and Webber 1973). As pointed out by Newman and Head (2017), fully tamed scientific or technical-type problems usually do not reflect the policy realities for societal issues. Most of the recent societal problems have highly wicked tendencies and are 'immune to linear, rational or scientific methods of problem-solving' (Newman and Head 2017: 414).

Several policy sciences scholars have attempted to determine the 'wickedness' of policy issues and problem structures (Roberts 2000; Head 2008; Hoppe 2011; May et al. 2013; Alford and Head 2017; Carley and Christie 2017). Accordingly, the degree of wickedness can be seen as a combination of different dimensions (Head 2008). Reoccurring aspects in the scientific discussion and typologies of wicked problems are:

i. *contestation*, referring to the degree of normativity related to a policy issue. Contestation is seen as the result of divergent claims, values and framings, or the inherent conflicts of interest

resulting from social pluralism and stakeholder divergence (Hoppe 2011; Alford and Head 2017);

ii. *complexity*, understood in institutional terms, is caused by the multi-scalar and multi-dimensional nature of societal problems to be addressed by policy (May et al. 2013; Carley and Christie 2017). Responsibilities for action or non-action are hard to determine, causing a 'problem of many hands' (Thompson 1980) especially if multiple actors, policy domains, and governance levels need to cooperate (Head 2008; Van de Poel et al. 2012);

iii. *uncertainty*, pointing to a lack of knowledge or limited availability of evidence to determine policies, for instance, related to the risks or damages of action and non-action, the specific relationship between causes and consequences of a problem, or the fragmentation of knowledge across different stakeholders about the (side-) effects of not tackling a problem (Van Bueren et al. 2003; Newman and Head 2017).

Consequently, the higher the contestation, complexity, and uncertainty of the problem underlying a particular challenge, the higher its wickedness and the more difficult it might be for (innovation) policy to derive legitimate, clear, and well-informed missions from it. The degree of convergence/divergence of the problem statement depends on how (severe) different stakeholders perceive a problem, or contest a specific narrative about the challenge. Examples can be found in the recent discourses around climate change, smoking, genetically modified food, or inequality (Oreskes and Conway 2010). Problem divergence increases if (scientifically) accepted knowledge on a problem is lacking, the division of responsibilities to address the problem is not clear, or institutional complexity is high (see Table 1). In contrast, problem statements are likely to converge when different stakeholders agree on a problem framing and the importance of tackling it (lowers contestation), political responsibilities for addressing the problem are clear (lowers complexity), and the main causes and effects of a problem are fairly well understood (lowers uncertainty).

Mission-oriented policy approaches that underestimate contestation and focus on scientific or technological uncertainties as the root of the problem run the risk of building their arguments on the assumption that the problem itself is well understood and widely shared ('tamed'). This is especially apparent in the motto of 'big science deployed to meet big problems' which did not only drive the policy logic in the 1960s, but is still referred to in some present-day proposals (Mazzucato 2017: 7). However, in discourses around social problems, 'hard facts' do not necessarily dominate 'soft values' (Funtowicz and Ravetz 1993) as the scientific evidence base on how to best address future societal needs may not be considered as strong enough by all stakeholders. Instead, particularly for societal issues, different beliefs, framings, and attitudes to evidence and data may co-exist and shape policy design and implementation (Turnpenny et al. 2009).

Table 1. The wickedness of societal problems.

Contestation: Stakeholder divergence, normativity	High	Low
Complexity: Institutional and situational	High	Low
Uncertainty: Lack or fragmentation of knowledge (cause and consequence of problem)	High	Low
Problem statement	*Divergence → Convergence*	

As emphasized by Daviter (2017), governing wicked problems comes with a trade-off. A 'taming strategy' that prioritizes one way of problem-solving and excludes competing perspectives may facilitate governability, but at the same time comes at high costs of problem reflexivity. If problem identification is based on specific epistemic knowledge of a certain group of experts, then it may allow faster agreement and action. On the other hand, the stifling of conflicts and competing perspectives in the policy process might not only reduce the quality but in the end also provoke resistance against the mission and its implementation.

3.2 The solution side: divergent or convergent views on innovative solutions

Contributions from policy sciences are valuable to determine the wickedness of problems, and to reveal the political dynamics in how societal problems become defined and shaped in the policy process (for an overview, see e.g. Sabatier 2007). However, these contributions have rarely drawn a distinction between the wickedness of societal problems and the wickedness of finding solutions for these problems (with the exception of Alford and Head 2017 who make a distinction between problems and solutions in their framework). Rather, for typical wicked problems such as poverty, drug traffic, and ghettos,[3] it is assumed that the definition of a problem emerges gradually, and based on specific idea about or definition of a solution. This inseparability of problems and solutions links back to the original contribution by Rittel and Webber (1973) who argued, from a governmental planning perspective, that social problems 'can't be defined until the solution has been found' (Rittel and Webber 1973: 161).

Insights from innovation and transition can help to shed a new light on how new solutions (i.e. innovations) emerge, why they diffuse or not diffuse, and how these processes can be supported by policy to solve a societal challenge. Even if there is growing consensus on a problem statement (e.g. greenhouse gas emissions are too high), the proposed solutions to be supported by policy to tackle a challenge are likely to diverge across different stakeholders (e.g. carbon tax, subsidies for renewable energy, subsidies for carbon capture and storage, and expand nuclear energy). It is therefore important to recognize that, despite a relatively clear problem definition, solutions can still be subject to different degrees of contestation, complexity, and uncertainty, resulting in a degree of wickedness of solutions that may well differ from the degrees of wickedness of the problem at hand. This can be explained as follows:

i. *contestation* can emerge around the feasibility of a solution, the opportunities and threats of innovations for businesses, for users, or for society as a whole. Actors usually build their opinions, for instance, around whether better technology, regulation, or new social practices are necessary to tackle a societal problem based on their institutional or cultural context (Wolsink 2000; Roeser 2011; Dignum et al. 2016). Such conflicting framings and interests restrict diffusion patterns, and can lead to the refusal of a technically feasible innovation or a proven regulatory solution, due to prevailing norms and values (Smink et al. 2015; Wesseling et al. 2015);

ii. *complexity* is related to the fact that novel technological or institutional solutions may require the restructuring of the broader socio-technical system, because they may co-depend on other technological solutions or require radical changes in social practices. The large-scale diffusion of renewable energy, for instance, calls for new technologies to balance supply and demand, but also for new governance institutions and behavioural

change (Elzen et al. 2004; Walker and Cass 2007). Even though changes in practices appear incremental and small at first, the accumulation of 'small wins' may in the end bring about systemic transformation (Termeer et al. 2017; Termeer and Dewulf 2018);

iii. *uncertainty* refers to limited knowledge about the availability or feasibility of potential solutions, or the fact that multiple technological and/or institutional solutions seem to be possible and promising without indication which works best for tackling the challenge in time. A lack of clarity about effects, and side-effects, of innovations can reduce the legitimacy and broad acceptance, and set back the development and diffusion of effective solutions (Sengers et al. 2010).

Consequently, we can say that the higher the degree of contestation, complexity and uncertainty about an innovation, the more divergent the views on its solution potential (see Table 2).

Table 2. The wickedness of innovative solutions.

Contestation: Opinions on best solution	High	Low
Complexity: Need for systemic approaches	High	Low
Uncertainty: Lack of knowledge (feasibility, reach and impact of solution)	High	Low
Solution statement	*Divergence → Convergence*	

4. A problem-solution space to differentiate types of societal challenges

We attempt to improve analytical clarity about the context of missions and MIPs by conceptualizing the underlying problem–solution structure. We focus on how problem statements and views on potential solutions may diverge or converge. Based on the categorization in Section 3, we can derive a two-dimensional problem–solution space in which we characterize four problem–solution constellations (Table 3).[4] This problem–solution space will further allow us to locate and characterize different forms of MIP based on the divergence/convergence of the societal problems and solutions.

Below we illustrate typical governance modes and arrangements[5] for each of the four problem–solution constellations, and discuss policy strategies to coordinate actions, to involve actors and to progress on the current state.[6]

4.1 Quadrant I: disorientation

The top-left quadrant characterizes a 'highly wicked' problem–solution constellation in which neither a consensus on the problem definition nor on a clear, realistic or practicable idea about solutions has developed. Such a situation of divergent problems and divergent solutions can be illustrated with the example of sustainable agriculture (see Box 1). Different stakeholders are highly influenced by their particular background and knowledge in understanding and assessing the situation, and driven by their individual interests, values, and opinions on what a desirable future state could be. Hence, a commonly accepted framing of the societal challenge in terms of

Table 3. A two-dimensional problem–solution space to contextualize missions.

	Divergent views on the problem	Convergent views on the problem
	I. *Disorientation*	II. *Problem in search of a solution*
	High wickedness of the problem due to i. broadly framed challenge ii. lacking problem legitimacy and responsibility (societal, geographical, and temporal) iii. limited knowledge on problem nature	Wickedness of the problem reduced due to i. legitimized problem or shared vision ii. clarity about political responsibilities to address problem iii. advanced problem understanding and social learning
Divergent views on solutions	High wickedness of the solution due to i. no (shared) vision on feasible solution, vague, and disputed ideas ii. fragmented approaches and low willingness to cooperate iii. limited knowledge on effects and side effects on innovations	High wickedness of the solution as in I.
	Example: sustainable agriculture	*Example: obesity*
	III. *Solution in search of a problem*	IV. *Alignment*
	High wickedness of the problem as in I.	Wickedness of the problem reduced as in II.
Convergent views on solutions	Wickedness of the solution reduced due to i. concrete expectations on technological or institutional innovations ii. new business models and integrated approaches iii. claims on feasibility and (positive/negative) societal impact of innovation	Wickedness of the solution reduced as in III; societal embedding limited
	Example: self-driving car	*Examples: smoking ban, CCTV, and wind energy*

Box 1. Sustainable agriculture—a divergent problem with divergent solutions.
To address the challenge of food security agricultural policy after World War 2 was first and foremost aiming to secure Europe's internal food production and market. Driven by technological innovations (Grin et al. 2004) and farm size increases, productivity has doubled (de Wit et al. 2011). European agriculture can be typified by what Duru and Therond (2015) define as a 'productivist' paradigm. This paradigm, however, has also led to a diverse set of large adverse social and ecological impacts (Henle et al. 2008; Stoate et al. 2009) like a strong decline of insects and birds (Sanderson et al. 2013), high nitrogen deposition levels (Bobbink et al. 2010), high impact on climate change, low animal welfare, and low or negative income for farmers (CBS statLine 2018). Different societal groups (firms, farmers, NGOs, and retailers) stress different problems and propose solutions for these problems. Apart from specific groups focusing on specific problems, also different and incompatible holistic visions for solutions dominate the debate. The two extremes are: (1) The belief in large-scale agriculture in which high tech knowledge is able to deliver high amounts and high-quality products within environmental constraints. Typical solutions are (A) high tech stables that filter air emissions of cattle, (B) high tech animal feed that reduces emissions of methane, (C) vertical farming (i.e. multi story indoor growth of vegetables through the use of LED lighting, and (D) precision farming (i.e. crops receive precise treatment with fertilizers and pesticides, using satellites and sensors for precise geo-monitoring of crop yield, pests and deceases). (2) The belief in small scale organic farming practices with low inputs of pesticides and fertilizer (Morgan and Murdoch 2000; Lamine 2011). Different strands are nature inclusive agriculture, organic farming, circular farming, perma culture, and agro-forestry. Different perceptions of the problem and different views on solutions that are highly contested make it very hard to develop a shared vision on a sustainable and sufficiently productive agricultural system.

the real problems and the best way(s) to solve them, with or without policy support, is missing.

In a highly wicked situation, scientific evidence regarding problem causes and consequences is crucial to learn about and better specify the problem. However, policymaking in the context of societal problems can rarely be based on objectivity and technical evidence alone, but involves trade-offs between competing social values (Parkhurst 2017). Processes of social learning (Ison et al. 2015), collective visioning (Loorbach 2010; Hajer and Pelzer 2018), and participatory governance and research practices (Weber 2006; Cagnin et al. 2012) allow different actors to cooperate despite their divergent viewpoints and interests. New institutional arrangements are needed to provide a platform for discussion, allow for conflict and negotiation, and enable the development of a collective understanding. It is about increasing awareness about different framings and explanations of a problem, accommodating these differences, and building mutual expectations (convergence). Recent studies suggest that the more open and inclusive these *processes of learning* are, not only for policy actors but also for societal actors (experts and non-experts such as citizens, firms, civil society and interest organizations), the higher will be the legitimacy of framing and shaping the problem (Boon and Edler 2018; Wesseling and Edquist 2018).

4.2 Quadrant II: problem in search of a solution

The top-right quadrant typifies a situation in which a dominant definition of a societal problem enjoying broad societal acceptance has emerged, for instance, due to convincing evidence or rising urgency. However, multiple solutions to approach the problem are still conceivable, and ideas on how to achieve transformation or solve the challenge are vague, uncertain, or disputed. The case of obesity provides an illustration (Box 2).

If a dominant definition of a societal problem has emerged and enjoys broad acceptance, then *setting priorities and targets* may be a means for policy to overcome coordination and directionality failures (Weber and Rohracher 2012), to pool knowledge, and to accelerate progress towards meeting the challenge. For situations in which a convergent problem understanding has developed, the formulation of clear and approachable research and innovation missions, as recently advocated in Mazzucato (2018b), could indeed be an effective instrument for a targeted transformation. In this way, a joint vision about the future can be translated and operationalized in the form of missions and projects with clear goals and target values that are realistic and in line with the envisioned future state. The question of how innovation can contribute to achieving the mission is still open and uncertain at this stage, and requires exploration and experimentation with different types of solutions before converging on a dominant set of solutions.

4.3 Quadrant III: solution in search of a problem

The bottom-left quadrant of Table 3 refers to a situation in which shared and optimistic expectations have emerged regarding the feasibility and importance of an innovation. Yet, the nexus between a societal problem and the innovation is ill-defined, normatively loaded, or faces public reluctance due to uncertainties regarding risks or trade-offs. As such, the solution appears to be in search of a concrete problem formulation to showcase its feasibility (see the example of self-driving cars in Box 3). Social barriers originating from the prevalent practices, limited legitimacy, and awareness of the need for change hamper the societal embedding of the innovation to provide a large-scale solution for a societal challenge.

A situation of convergent solutions but still divergent problem perceptions may require *high reflexivity* of policy (Weber and Rohracher 2012), meaning evaluating the validity of the innovation's expectations and future application potentials. Without sufficient reflexivity, the implementation of targeted policies focusing on one specific innovation runs the risk of low acceptance. Here, low societal acceptance can be due to high uncertainty about the effects, side effects and the real contribution a proposed solution can make to solve a societal challenge. Such a situation may give room for stakeholders (e.g. incumbent firms) to capture processes of problem framing according to their interests and own benefits (Frenken 2017).

Box 2. Obesity—a convergent problem with divergent solutions.
Obesity is under the top three global social burdens generated by human beings, after smoking and armed violence/war/terrorism (Dobbs et al. 2014). Specialized agencies have initially stressed the obesity epidemic as a societal problem (WHO 2000), followed by politicians who increasingly recognize childhood obesity as challenge for both public health and social inclusion (; Dobbs et al. 2014). The shift from seeing obesity as a personal matter to seeing obesity as a major policy issue can be explained not only by the rising obesity rates across Europe and the USA, but also by increasing scientific understanding about the risk of other chronic diseases (like Type 2 diabetes, heart diseases, and cancer) and the society-wide costs obesity causes due to treatment expenses or increasing health inequality. (Childhood) obesity is nowadays recognized as highly societally induced, namely as a systemic problem rooted more in lifestyle choices, dietary choices as well as socio-economic conditions than only in genetic predisposition (HM Government 2016). Despite increasing recognition that only individualized, science-based treatment based on drugs, therapy, or bariatric surgery will not be sufficient and effective enough, as of yet there are no comprehensive solutions or policy models of how to prevent or stop the rising obesity rates. It is argued that obesity requires coordinated and cross-sectional action beyond the health sector, including agriculture, manufacturing, and retailing (for changing product ingredients and availability, pricing, and portions), education, media, and culture (for building knowledge, skills, and awareness around food and physical activity), transportation and urban planning (for car-free and physical activity-based mobility), or economic policies (for subsidies or taxation of food) (Lang and Rayner 2007; Gortmaker et al. 2011). For instance, Dobbs et al. (2014) identified seventy-four types of interventions in eighteen areas worldwide, but solid evidence on how well these intervention work or on their societal impact is scarce.

Box 3. Automated vehicle technology—a convergent solution with divergent problem perceptions.
Several terms like autonomous vehicles, self-driving cars, driverless vehicles, and robotic cars are used to describe the technology for autonomous transport, where car technology takes over the control of the car from a human being. The technology can best be understood through levels of automated driving where on the low-end Level 1 refers to driver assistance and on the high-end Level 6 refers to fully automated driving (SAE 2014). Car manufacturers have been working on innovative solutions to create more comfort for the driver using several levels of automation. Cruise control was already developed in 1945. Since then, car manufacturers have developed a range of technologies like adaptive cruise control, lane departure warning, parking assist and break assist to increase comfort, and driving safety. Google changed the paradigm that automation technology should aid the driver by introducing a self-driving car that was designed to replace the driver completely. Over the years, the set of reasons that support the development of automated vehicle technology has been increasing. Where driving comfort and safety had been original arguments, later many more arguments were added like: (1) increased productivity as the car becomes an office space; (2) higher capacity of highways and, therefore, reduction of congestion; (3) solution for an aging society where disabled elderly can now enjoy car mobility; (4) reduction of employee costs for taxi companies; and (5) allowing for improved car-sharing schemes (Brummelen et al. 2018). The increasing set of societal benefits that are argued to be stemming from this solution for future mobility is a clear sign that solution convergence has taken place, but that the solution is still looking for societal problems to link to in order to increase its legitimacy.

4.4 Quadrant IV: alignment

The bottom-right quadrant of Table 3 characterizes a situation in which societal problems are relatively well understood and supported, and in which views on promising solutions have converged. Good examples of such a constellation of convergent problem perceptions and solutions can be found in the fields of energy (wind turbines), security (CCTV), and public health (smoking bans). These examples are selected because they cover a wide range of societal problems, very different technological (CCTV and wind turbines) and institutional (smoking bans) solutions, and, most importantly, they cover different problem–solution pathways. In Section 5, we illustrate the historical developments of our examples, from wicked problem-solution constellations (Quadrant I) into widely accepted and well-aligned problem–solution constellations (Quadrant IV).

Situations in which societal problems are relatively well understood and broadly supported, and in which views on solutions with high potential have converged, call for policies that focus on the *targeted development and diffusion* of innovations and the embedding (widening and deepening) of new social practices. Diffusion-oriented policies are essential if convergence around a solution for a clear, legitimate problem has been achieved, but innovations are not able to fully compete on the mainstream market (e.g. renewable energies), due to incumbent products that have benefited from decades of incremental improvement (Geels 2004), or missing demand to upscale and implement the innovation on a broad basis (Boon and Edler 2018). Similarly, institutional innovation like recycling requires policy support to help consumers adapt their routines. With the advent of convergent structures, systemic innovation policies can come into play to support the emergence and optimization of socio-

Box 4. The case of smoking bans to reduce SHS: a problem-driven pathway.

Smoking is responsible for about six million annual deaths worldwide. This societal problem has, however, remained *contested* and *unclear* for a long time. Since the 1970s, the scientific evidence in the USA on the consequences of SHS has been mounting with impactful Surgeon General report in 1971 (anticipating health risks; Surgeon General 1971), in 1972 (identified SHS as a health risk; Surgeon General 1972) and in 1986 (conclusive evidence on SHS causing cancer and health problems in children; Surgeon General 1986). Subsequently, a 1993 EPA report classified SHS as a Group A carcinogen and determined that SHS leads to various diseases (EPA 1993), which provided grounds for the EPA to regulate smoking. Over this entire period, the tobacco industry questioned scientific evidence of the adverse health effects of SHS (Widome et al. 2010), and even started smear campaigns against the EPA (*contestation*) (Oreskes and Conway 2010). They invested significantly in smoking advertisement that associated smoking with coolness, strength, and freedom (Oreskes and Conway 2010). Due to this well-organized lobby and framing, SHS was not accepted as a problem by all stakeholders, scientific evidence on SHS was disputed (creating *problem uncertainty*), and divergent norms were actively promoted (*contesting the problem*). In 2006, at least the scientific debate was settled with the 2006 Surgeon General report concluding that '"the debate is over" and "the science is clear" that SHS causes lung cancer and heart disease in nonsmokers, among many other conditions' (Surgeon General 2006; Hyland et al. 2012).

With growing evidence on the adverse health effects of SHS, the range of solutions had increased (*solution divergence*). In the 1970s, governments started to tax cigarettes and control advertisement (Oreskes and Conway 2010); after the 1986 Surgeon General report, many local initiatives started banning smoking because of SHS; and in 1995 the first state-wide smoking ban in restaurants was issued in California (Widome et al. 2010). Over this period, public *contestation slowly decreased* as the norm changed from 'smoking bans impinge on people's freedom to smoke', to 'smoking in public places harms the health of others' (Oreskes and Conway 2010). Smoking bans were issued at both the local and state level, with the result that by 2010 '41% of the US population live[d] in a community that require[d] all indoor workplaces (including restaurants and bars) to be completely smoke-free' (Widome et al. 2010).

This convergent trend around smoking bans, however, was preceded by strong industry *contestation to this solution*. Since the 1970s, the tobacco industry has strongly lobbied against any restrictions on smoking (Mandel and Glantz 2004; Oreskes and Conway 2010; Widome et al. 2010). Regulations were assailed with normative arguments related to infringement of freedom or with references to Communism and totalitarianism (Oreskes and Conway 2010). At the same time, the industry offered technological solutions aimed at reducing the negative externalities of smoking and that did not require behavioural changes of smokers (*solution divergence*). These innovations include better filters, cleaner tobacco, and cigarette paper, and subsequently e-cigarettes and inhalers (Oreskes and Conway 2010). Industry also lobbied for the technological fix of better-ventilated spaces (Mandel and Glantz 2004). To support the development of these technological innovations, the smoking lobby demanded public research funding for developing even saver cigarettes instead of bans and successfully pushed for laxer e-cigarette regulation (Oreskes and Conway 2010). This all mitigated convergence around the smoking ban solution. Other technological and behavioural solutions have been developed to wean people off smoking, including replacements, such as nicotine patches and gums, telephone quit lines or web-based services, non-nicotine pharmacotherapies, or reinforced antismoking education in school (Bertollini et al. 2016). To conclude, although a range of solutions that link directly to the cause of smoking is needed to overcome the problem of SHS, smoking bans have, despite aggressive industry opposition, over time become increasingly accepted as a central part of the solution-range—in and outside of the US (*solution convergence*) (Hyland et al. 2012; Bertollini et al. 2016).

technical systems around the new (sets of) solutions. Reflexivity, in terms of both periodic monitoring of the solutions' contributions to the societal problems and the formulation of the mission, will remain important over time.

5. A role for policy to move towards convergent problem–solution constellations: three stylized policy pathways

Following our framework, MIP can be understood as an attempt to accelerate progress in solving societal challenges, by shaping the direction and supporting the diffusion and embedding of innovations in society. So far, we have argued that given the variations in the 'wickedness' of societal challenges and their associated problem–solution constellations, a one-size-fits-all approach to design mission-oriented policies seems inappropriate. In what follows, we make an attempt to characterize how policy might stimulate movements away from a 'wicked' towards an aligned problem–solution constellation,[7] and to support the creation of a stable basis for society-wide uptake of innovations. Hereby, a policy pathway constitutes a movement in the matrix reflecting the processes of problem and solution convergence. Our arguments are supported by three empirical illustrations (Boxes 4–6), based on which we point to possible barriers and limitations associated with a certain pathway and potential approaches to govern contestation, complexity, and uncertainty for different stages. The linear representation of different pathways in Figure 1, despite being highly stylized, indicates different possible movements towards higher problem–solution convergence (i.e higher directionality). In practice, these pathways are likely to follow less stable, interrupted or even reverse patterns.

Box 5. The case of CCTV to reduce crime in public spaces: a solution-driven pathway.

CCTV refers to video surveillance cameras used in public places. Its purpose is 'mainly to deter and detect crime, disorder and antisocial behaviour', but later also 'to help reduce the "fear of crime"' (Webster 2009: 11). Though CCTV systems have a long history in private spaces, its diffusion in public spaces started only in the 1990s. The UK is commonly regarded as the frontrunner in the deployment of CCTV. The central government played a key role in the diffusion of CCTVs by advocating its use and financing most of the costs in the 'Fight Against Crime' (Webster 2009).

The case of CCTV exemplifies a policy pathway in which CCTV was framed as the key solution to reduce crime by the UK government (*solution convergence*). The government invested large sums in rolling out the technology without formal regulation. Instead, technical standardization was achieved through self-regulation by service providers. In the process, the wickedness of the problem of crime was not acknowledged as the alleged benefits of CCTV to public safety were not weighted against other public values, such as privacy or discrimination. Instead, the national government politically prioritized crime reduction and acted upon the belief, shared by large parts of the general public, that CCTV would be effective to deter and detect crime (Webster 2009). During the initial stages of diffusion, however, no evidence about the effects of CCTV was available, marking the policy *uncertainty* typical for wicked problems. The wicked nature of the CCTV solution is further exemplified by *institutional complexity* following from the involvement of different government agencies and service providers. In the absence of national legislation, CCTV systems developed common technical standards and operational procedures through voluntary self-regulation. According to Webster (2004), the involvement of the government in pushing CCTV technology explains why it allowed CCTV to be adopted by local agencies without much formal national regulation. CCTV also met *contestation* by particular advocacy groups (especially those concerned with privacy). Yet, as Webster (2004) indicates, policy networks marginalized critical views and alternative solutions, and the public discourse concentrated on the (alleged) benefits of the cameras. As a result, politicians and policy makers downplayed possible problems regarding privacy, admissible evidence in courts, discrimination, and crime displacement effects.

One can understand the initial CCTV policy by the UK's national government as the key pillar in reducing crime as an instance of solution convergence without a comprehensive problem assessment (i.e. problem uncertainty). Slowly, in the wake of a more general turn to evidence-based policy-making, and to prevent further *contestation*, CCTV's legitimacy was sought in empirical studies looking for crime-reduction effects of CCTV. Such evaluations can be understood as part of a process of *problem convergence* by reducing the *problem uncertainty*, as evaluation necessitates defining and measuring crime in the first place. A systematic overview by Welsh and Ferrington (2009) found only a modest decrease in crime, which can almost fully be explained by the effectiveness of CCTV in car parks. Webster (2009), reviewing the UK evidence, also concluded that the evidence base is weak regarding the impact of CCTV on crime reduction. CCTV seemed to be more effective to reduce antisocial and undesirable behaviour rather than to prevent or solve real crimes (Gill and Spriggs 2005). This finding went hand in hand with a 'policy shift' (Webster 2009) to view CCTV policy as most effective in reducing antisocial and undesirable behaviour, which led to the deployment of CCTV beyond city centres and into residential areas. Overall, this case shows that despite the early problem convergence and widespread diffusion of CCTV across the UK, there was a continuous search for the problems CCTV would solve, which eventually, would converge around preventing antisocial behaviour, much more than about deterring and detecting crime.

5.1 The problem-led pathway

A problem-led pathway (top arrow in Figure 1) aims at creating a broadly legitimized and well-defined societal problem framing (movement towards a convergent problem), based on which the search for and experiments with different solutions can build. The initial focus is on comprehending the multiple dimensions, causes and effects of a problem for different social groups, and to stimulate the development of a common vision about a desired future. Different perceptions, expectations, and claims for action or non-action to mitigate or tackle a problem will be brought on the table.

As the illustration related to societal health challenges caused by secondhand smoking (SHS) shows (Box 4), even though contestation can defer the creation of a shared vision of the problem significantly and for a long time, the collection of evidence contributed to an improved understanding of the damages to health and societal costs of SHS. Once the problem of SHS was scientifically established and became publicly accepted as a societal problem, efforts were directed more strongly towards developing different solutions. Initially, different solutions were proposed, ranging from technological solutions (such as better filters, cleaner tobacco and cigarette paper, e-cigarettes, and inhalers) to institutional solutions (such as taxing smoking, bans, educational programmes, or telephone quit lines). After a period of evaluation and strong contestation, solutions converged around the most dominant institutional solution of smoking bans.

A problem-led policy strategy would be to combine the mission orientation with reflexive governance (Voss and Bornemann 2011) and social learning (Ison et al. 2015) to comprehend the multiple dimensions of a societal problem, and to increase awareness about the normative choices policy has to make in defining, selecting and setting innovation missions, or solution-seeking strategies. Also, a clear and uniform problem framing may be difficult to achieve due to the lack of knowledge, conflicting interests, or the high stakes involved. Fast decisions requiring the acceptance of a certain problem framing can create a new breeding ground for refusal (bounce-back effects), especially if the initially high expectation for a solution cannot be met due to technological or economic barriers (e.g. no feasible large-scale solutions, or high costs that impede the market creation and finance for innovations).

Box 6. The case of wind energy to reduce greenhouse gas emissions: a hybrid pathway.

The development of wind energy in the Netherlands started in the 1970s. Reasons for developing renewable energy technologies at that time were related to a range of problems: the 1973 oil crisis and its impact on fuel prices and the economy; declining fossil fuel reserves; and foreign dependencies related to fuel security. Wind energy was considered as a technology with high potential but with significant *uncertainties* regarding feasibility. The first period was characterized by investments in technology development for onshore wind turbines. The Dutch followed the so-called break-through strategy as there was a strong focus on developing highly complex large wind turbines which are most efficient from an engineering perspective (Garud and Karnøe 2003). There was optimism that engineers from the existing airplane industry in The Netherlands would be able to develop well-functioning large-scale turbines. This trajectory failed. During the 2000s, the Danes who followed a totally different, bricolage strategy—focusing on slowly upscaling small turbines—outcompeted the Dutch initiatives and only one Dutch turbine manufacturer (Lagerwey) survived (Garud and Karnøe 2003).

In 1995, the Dutch government *converged upon the problem* by setting concrete targets for renewable electricity: 10 per cent in 2020 (Economic Affairs 1995). The main arguments for setting such targets were the exhaustion of fossil fuel reserves and the emergence of climate change as a major societal problem (Economic Affairs 1997). A related, economic argument was that by getting experience with renewable energy now, the Dutch could regain an export position by building up a renewable energy industry. The target reduced *institutional complexity* as it provided clear guidance of the search (Economic Affairs 1995: 51). However, during the years that followed the diffusion of onshore wind energy did not develop according to expectations. Reasons for this were *contestation* by local opposition and by specific NGO's complicated planning procedures, and struggles related to responsibilities between local, provincial, and state government (i.e. high *institutional complexity*).

To solve the above implementation problems for onshore wind, attention shifted slowly to offshore wind, which was not considered in the initial plans (Economic Affairs 1995). At the same time, climate change was increasingly perceived as a societal threat, spiked by Al Gore's 'An Inconvenient Truth' in 2006, resulting in the Renewable Energy Directive (European Parliament & European Council 2009) that set a mandatory 14 per cent renewable energy target as share of total final energy consumption for the Netherlands in 2020. This increased problem convergence meant that significant additional policy efforts were needed to reach the target. In this light, ambitious targets were initially set for offshore wind (*institutional guidance*), but offshore as a solution was strongly *contested* by liberal political parties due to the high electricity prices associated with this technology. Consequently, the policy attitude towards offshore wind in those days was still defined by *uncertainty* and could best be characterized as a hedging strategy: some investments to keep options open, but no intention to fully commit and invest massive resources (Wieczorek et al. 2013).

Only recently, this attitude changed. The Dutch government was under pressure since the Netherlands was falling short in realizing its promised contribution to the European renewable energy target of 20 per cent in 2020. Offshore wind was identified as the only available technology to quickly upscale the potential of renewables (reducing *uncertainty*) (SER 2013). The high-cost argument, therefore, was overruled, and later it turned out that offshore wind parks can be built at much lower costs than previously expected. This led to a surge of political and societal interest in the technology from 2016 onwards, and the current tender procedures are even prepared for subsidy-free offshore wind parks. This has led to strong solution *convergence* around offshore wind as a key technology in realizing renewable energy and carbon emission targets.

5.2 The solution-led pathway

The solution-led pathway (bottom arrow in Figure 1) constitutes, in contrast to a problem-led pathway, a solution-push approach centred around the development of single innovations or specific solutions. Initially, the innovation's contribution to meeting a societal problem is not clear, not made explicit, or not intended. This pathway is consistent with policies that legitimize funding for basic research with reference to science's broad potential to solve societal challenges (Dosi et al. 2006; Mazzucato 2017). It also fits with disruptive innovation strategies applied by technology companies such as Airbnb, Google, Juul, and Uber, who often justify their lack of regulatory compliance by their alleged contribution to solving health, social cohesion, and sustainability issues without providing any solid evidence (Schor 2016).

As evident in the case related to security (CCTV) in the UK (Box 5), once an innovation 'finds' a societal problem, the build-up of expectations can be a major driver for its societal embedding. In such cases, uptake of a (technological or institutional) solution could take place despite the initially open, diffuse or even contested problem definition, or without profound evidence about the effectiveness of the solution.

Along a solution-led pathway, focus is on the development of solutions, while the attention to societal problem definitions and trade-offs between societal values is underrepresented. Particularly solution providers from science or industry, and possibly from other stakeholders with strategic interests, might try to influence the societal framing of the problems to which the solution aims to contribute. If the effectiveness and societal consequences of the solution are not fully clear, then this pathway bears the risk of societal barriers emerging along the way, ranging from limited public awareness and problem legitimacy (Is safety at public places a problem that justifies large-scale surveillance?), uncertainty about the solution's impact (Is CCTV capable of increasing safety and reducing crime rates?), or limited willingness to implement the solution on a large scale (At which places and at what time should be surveilled?).

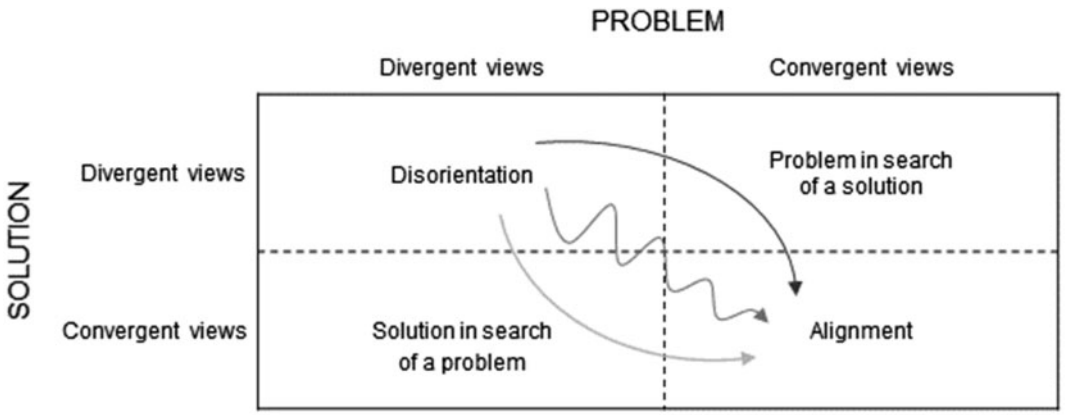

Figure 1. Different pathways for MIP in the problem–solution space.

5.3 The hybrid policy pathway

A hybrid policy pathway (middle arrow in Figure 1) follows a co-evolutionary logic, balancing problem, and solution wickedness at the same time by experimenting in both directions and learning about the problem(s) in the course of finding solution(s). It may seem to be a promising course for wicked societal problems that are ill-defined and have no known solutions, and might be pursued as a matter of urgency given the nature of the problem, high societal expectations, or political pressure to act. For instance, dealing with societal problems of great urgency, also referred to as 'super-wicked' problems (Levin et al. 2012), might be best addressed by a co-evolutionary approach. Negotiating, balancing interests, together with performing experiments at a small-scale allows learning about outcomes, possible impact, and potential for uptake.

However, as the Dutch case of wind energy shows (Box 6), it is possible that missions specified in such a situation can be misleading, for instance, if expectations associated with an innovation cannot be met or specific goals are set based on unfounded assumptions. For onshore wind, it turned out only later that the solution already converged upon, generated unforeseen side effects in the phase of large-scale diffusion (e.g. visual, audible, and safety effects of wind turbines). This hampered meeting the renewable energy targets and redirected the process of problem–solution convergence.

Following a hybrid pathway by aiming at a thorough understanding of the contestation, institutional complexity, or uncertainty related to a potential solution and the societal problem at the same time runs the risk of remaining stuck in an un-guided policy approach without realistic goals or a clear solution path. Set-backs are more likely to come from both sides; the inhibited specification of the 'real' problem or the unfounded selection of the 'best' solution, which might cause significant delays for a strategy initially built upon high expectations. However, if managed well, an iterative process of experimenting with new solutions, while better understanding the problem as well as the impacts of the new solution on the problem, offers a lot of learning potential.

6. Implications and conclusions

6.1 Implications for MIP

This article set out an analytical contribution to the recent debate on how MIP can help in meeting the challenges of current societies. Our aim was to provide an analytical framework for a better contextualization of the plurality of societal challenges, ranging from climate change to food security and to public health.

We argued that the policy discourse about directionality and mission-orientation insufficiently considered the contextuality of societal challenges related to different views on both the problem and the solution. Undoubtedly, remaining vague and defining societal challenges in broad terms can be the preferred political strategy, to circumvent conflicts or contestation along core values, and to support acceptance on a broad basis. Such a strategy, however, may come at a price. Disregarding the normative elements involved in prioritizing a certain problem framing or in prioritizing a certain innovation can impede the legitimacy of the mission, or the uptake of solutions across different structures of economy and society.

We therefore argue that the widening of the innovation policy agenda towards societal challenges has governance implications for MIP along two dimensions. At the problem side, a non-trivial part of MIP is to identify a societal challenge with the associated problem framings as well as to select and translate such framings into a clear problem formulation. At the solution side, societal challenges often require solutions that go beyond the traditional science- and technology-based strategies pursued by most research organizations, firms, and governments. Solutions result from various types of search processes, can be of technological or institutional nature, and require different actors in their development and diffusion. As such, not just problems but also solutions can be considered to have wicked elements. Hence, the derivation of a universal formula for effective societal mission-oriented policies might be both hard to achieve and ineffective in dealing with societal challenges.

By contextualizing societal challenges along both the problem and solution side, we depart from one-size-fits-all MIP approaches and suggest four different types of problem–solution constellations (I. Disorientation, II. Problem without a solution, III. Solution without a problem, and IV. Alignment). Assessing the location of a particular societal challenge in this problem–solution space seems necessary for the design of MIP, to consider the specific character of the challenge, and to pursue targeted policy strategies on the basis of broad institutional and public support for the goal at hand.

Moreover, by characterizing three stylized policy pathways, we suggested a *process-oriented view* on MIP, and revealed different routes a MIP approach may take—intentionally or non-intentionally—in dealing with the changing patterns of uncertainty, contestation, and complexity. Our elaboration makes clear that, if the aim of mission-oriented policies is to find effective solutions for ill-

defined societal challenges, more dynamic, and flexible approaches are needed. Setting the direction for innovation by defining targets at the outset might not be sufficient as it impedes actors to learn, in a reflexive manner, how to deal with the wickedness involved in addressing societal issues, and how to converge in both the problem dimensions and the solution dimensions. As our illustrative examples show, a process-oriented MIP would involve continuous learning and evaluating the dynamics of contestation, complexity, and uncertainty in defining problems, formulating objectives or targeting specific solutions. It would also involve more flexible and open governance arrangements, beyond traditional research and innovation actors and domains, to govern the movements in the problem–solution space.

6.2 Implications for the implementation of mission-oriented policies in Europe

Against the backdrop of these theoretical–conceptual implications, we can now take a look at current debates about mission-oriented policies in Europe, in order to exemplify the potential benefits of our approach for the governance of mission-oriented policies. With the launch of the still ongoing Horizon 2020 European Framework Programme for Research and Innovation, the orientation of research and innovation policy towards societal challenges has obtained a prominent place in the funding portfolio. A major part of Horizon 2020 has been earmarked for research and innovation activities on seven societal challenges.[8] However, it became evident in the aftermath of the interim evaluation that the prominence of societal challenges in the Horizon 2020 programme has proven insufficient to re-orient significant parts of research and innovation activities towards clear and ambitious societal goals (EC 2017; Lamy et al. 2017). As long as the modalities of research and innovation funding programmes remain by and large the same as they have been for the past 30 years, the gap between ambitious long-term and higher order goals associated with societal challenges, on the one hand, and the prescription of specific topics as defined in work programmes, on the other hand, will continue to be too wide and too difficult to reconcile to lead to the kind of transformative and solution-oriented innovations needed to tackle grand societal challenges. In recognizing these deficits, the specification of 'missions' at an intermediate level of granularity was suggested as focusing devices to bridge the gap between societal challenges and specific research and innovation projects. Such missions should ensure that the intended impact of research and innovation activities funded by the Framework Programme can indeed be achieved (Lamy et al. 2017). With the programmatic paper on mission-orientation in European research and innovation policy (Mazzucato 2018b), the rationales for a mission-oriented approach have been visibly spelled out as a trigger of further political debate and public consultation at the European level.

This approach has been largely followed in the proposal for Horizon Europe as presented in June 2018 (EC 2018). On this basis, the European Commission established five mission boards to help advance mission agendas in five fields of research, the so-called mission areas involving cancer, climate adaptation, healthy oceans and waters, climate neutral and smart cities, and soil health and food, for which first missions with clear targets and timelines need to be identified by mid-2020. The EU mission approach is a step forward because, first of all, it recognizes the wicked nature of the societal challenges that are in the focus of the Framework Programme. Secondly, aiming to translate broadly defined missions into inspirational plans with clear targets, it promises to make them manageable by an institution that relies on formal technocratic procedures. However, the current plans for a mission-oriented approach in Horizon Europe have been discussed also more critically, not least by studies and expert groups set up by the European Commission itself.[9] Four main points of criticism of the Commission approach can be identified to which the more differentiated perspective on missions presented in this article suggests some possible responses.

First, the understanding of missions in the Commission documents is too undifferentiated, which reflects a one-size-fits-all and technocratic interpretation of mission-oriented policies. It assumes the existence of convergent problem and/or solution specifications, which in the reality of most societal challenges do not exist. In this regard, the problems–solution framework suggested in this article can be put to use. Most of the societal challenges formulated by the European Union and its Member States are arguably best described as wicked. Little convergence so far has been achieved regarding concrete problem formulations in most aspects of climate change, cybersecurity, sustainable agriculture, and healthy ageing, and the innovation-led solutions are still unclear. Hence, for each of the challenges, one may ask how sufficient convergence can take place in terms of problem formulation, including specific and measurable targets, before embarking on ambitious innovation programmes (Frenken 2017). By taking into account differences across societal challenges in terms of their wickedness, and the convergence and divergence in the problem–solutions space, a more differentiated approach to mission-oriented policies can be developed.

A second important point of criticism refers to the governance of missions, and more specifically to the too narrow range of actors and stakeholders involved in the definition of problems and the ideation of solutions. Wicked and uncertain problems, however, require a wide spectrum of problem framings and potential solutions. Initially, the European Commission envisaged a wide consultation, involving also citizens, in the specification of missions, but this process is likely to be narrowed down to selected national events involving a rather limited number of stakeholders and citizens. The dimension of contestation, as suggested in our framework, captures this necessity to give enough room to divergent opinions and ideas to be harvested, before convergence around a shared understanding of the problem and of the solution(s) agenda can take place.

A third criticism refers to the mission implementation and stresses the necessity to fundamentally rethink the design of mission-oriented funding programmes. Past Framework Programmes, and also the societal challenges part of Horizon 2020, predefined their strategic and work programmes down to the level of specific research topics. If, however, the dimension of uncertainty as suggested in our framework is taken seriously, then a much more 'tentative' approach to programme design needs to be pursued (Kuhlmann et al. 2019). In practice, this suggests an open, multi-stage and experimentation-friendly process of moving from a large number of smaller exploratory projects to a limited number of large-scale research and innovation initiatives; a process that would emphasize learning about a wide range of possible ideas for solutions from the early stage of programme implementation onwards. Such an early learning approach would show which potential solutions might be promising for being carried forward in order to address a mission-type problem, while others can be discarded. The three types of pathways suggested in our framework indicate that there are different strategies to move towards convergence in terms of both problem and solution and that programme design should enable pursuing these different pathways. This kind of multi-stage

programme design has been tested in a number of national programmes already, which could serve as source of inspiration for the future design of mission-oriented initiatives in Horizon Europe.[10]

Finally, a fourth criticism of the Horizon Europe approach to missions points to the importance of strengthening policy coordination in several regards, if the ambitions of a mission-oriented programme are to be achieved. These ambitions go well beyond the delivery of new innovative solutions, and aim at contributing effectively to resolving societal challenges. In other words, much more attention needs to be paid to the ultimate impact of research and innovation, and how research and innovation outcomes are scaled, diffused, and generalized in order to achieve missions and trigger processes of transformative change. This implies that mission-oriented research and innovation activities cannot be seen in isolation, but need to be embedded in domain-specific policies of the areas in question. Effective coordination and alignment between research and innovation policy and sectoral/thematic policies, multi-level coordination between European-level research and local implementation, and the orchestration with private and third sector stakeholders pose serious challenges for the governance of missions (Wanzenböck and Frenken 2020). In terms of our conceptual framework, this points to the importance of the dimension of complexity and the need to strengthen the convergence and alignment of different policies and actor strategies. This poses high demands on the management of mission-oriented initiatives, which will need to be much more pro-actively monitored in order to facilitate the alignment between the different types of actors and stakeholders playing a role in the realization of a mission.

6.3 Implications for further research

Our analytical framework to contextualize MIP builds on academic literature in policy and innovation studies based on which we map a two-dimensional problem–solution space. With our brief empirical illustrations for different societal problems related to health (smoking bans), security (CCTV), and energy (wind turbines), we could draw tentative lessons on how different dimensions of problem and solution wickedness may interact and change over time, as well as on the different strategies a mission-oriented policy can take to govern this process. Our framework emphasizes the need for new governance modes involving new actors, such as users or other stakeholders; more reflexive strategies that facilitate adaptations in response to new knowledge on the problem, its causes and societal significance; and new developments with regard to the envisaged solution, its effectiveness, or side-effects (Loorbach 2010; Shove and Walker 2010; Bugge et al. 2018). However, more research of policy practices enriched with empirical data on the individual dynamics within mission pathways is needed to further develop the proposed process-oriented perspective on mission-oriented policies.

Necessary steps in this direction should include systematic empirical investigations regarding the drivers and barriers of policy pathways, in particular the difficulties in governing problem and solution wickedness in different institutional or geographical contexts (Coenen et al. 2012). Our illustrations of policy pathways serve only as first stylized examples, but cannot reveal factors that supported these movements. Future research should focus on developing solid operationalization of the different wickedness dimensions (contestation, complexity, and uncertainty) of problems and solutions, on the one hand, and on gaining better insights on how specific geographical and institutional conditions or multi-level arrangements can foster or hamper convergent problems and solutions, on the other hand. Especially, the latter calls for more attention to the legitimacy of public action, and the organizational capacity of public actors to implement societal challenge-oriented policies in different contexts. Developing such an approach on the wickedness of missions requires the systematic comparison of a rich selection of case studies, ranging from the global Sustainable Development Goals to specific missions at the regional level.

We further call for research on the interplay of problem–solution constellations and policy mixes along distinct pathways. Given that most societal problems cannot be tackled with a single solution, a set of solutions is typically necessary, and this requires the implementation of a mix of policy measures and instruments along the mission's lines. Recent literature on policy mixes for innovation and sustainable transitions (see e.g. Borrás and Edquist 2013; Rogge and Reichardt 2016; Kern et al. 2017) can serve as valuable reference here. How policy mixes can support spill-over effects between different missions, but also between societal and economic goals, is another fruitful venue for further research (see e.g. the cases of Mazzucato and Penna 2015; Robinson and Mazzucato 2019).

Finally, future research efforts can focus on the study of MIP in the context of socio-technical innovation systems. System thinking could provide a framework for understanding how system components (i.e. actors, institutions, network, and materiality) interact with different policy designs (Hoppmann et al. 2014), how they influence the formulation of missions and the search for solutions. So far, innovation systems have been defined around nations, sectors, and technologies, and have focused mostly on the supply of innovation. More attention should be paid also to the demand for innovation by defining innovation systems around societal problems or specific missions as suggested by the notion of Mission-Oriented Innovation Systems introduced by Hekkert et al. (2020).

Conflict of interest statement

None declared.

Notes

1. See also Robinson and Mazzucato (2019) for a comparison of the mission-oriented approaches of a USA and a European agency.
2. Wicked problems are also known as persistent problems in the transition literature (Rotmans and Loorbach 2009; Schuitmaker 2012). Other terms such as unstructured or incorrigible problems (Hoppe 2011), complex problems (May et al. 2013), or grand challenges (Cagnin et al. 2012; Kuhlmann and Rip 2014) are related.
3. Nelson (1974) mentioned the 'ghetto' problem as a counter-example to the 'moon' problem. While moon problems have relatively clear goals and technological solutions, ghetto problems are rather wicked. He argues that ghetto problems—a metaphor for more general societal problems—would require a fundamentally different type of knowledge, but both existing know—how and evidence on solutions is insufficient to effectively solve them (see also Nelson 2011).
4. 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.

5. We build on Borrás and Edler (2014) seeing governance as '*... a way in which societal and state actors intentionally interact [...], by regulating issues of societal concern, defining the processes and direction of how technological artefacts and innovations are produced, and shaping how these are introduced, absorbed, diffused and used within society and economy*' (Borrás and Edler 2014: 14). This definition is useful because of its comprehensibility from setting direction to the societal diffusion of innovations, on the one hand, and its emphasis on a range of actors and their intentionality in dealing with issues of social concern, on the other hand.
6. Importantly, our aim is not to conceptualize the role of actors for different problem–solution constellations. We do not address questions regarding the best actor arrangement for a specific problem–solution structure but see in policy, irrespective of governance levels, a central role for taking collective decisions and mobilising societal resources for societal ends . At the same time, we acknowledge that socially led stakeholders with a specific interest in the issue (e.g. NGOs, companies, innovators, experts, researchers, everyday users, social entrepreneurs, and civil society associations of people affected) may dominate, support, or accelerate political dynamics.
7. The idea of movement contradicts with the assumptions made in the policy sciences literature (e.g. Hoppe 2011; Alford and Head 2017). 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 to arrive at convergent and stable constellations.
8. These seven areas are: Health, demographic change, and well-being; Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy; Secure, clean, and efficient energy; Smart, green, and integrated transport; Climate action, environment, resource efficiency, and raw materials; Europe in a changing world—inclusive, innovative, and reflective societies; Secure societies—protecting freedom and security of Europe and its citizens.
9. See, for instance, the reports by two high-level groups (ESIR 2017; RISE 2018), analytical studies (JIIP 2018a, 2018b), and the foresight activity in preparation of Horizon Europe (Weber et al. 2018).
10. See, for instance, the Swedish programme 'Challenge-Driven Innovation' or the French initiative 'Commission Innovation 2030', which both followed a multi-stage model.

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