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The subsidiarity principle in innovation policy for societal challenges

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ABSTRACT

While national governments are the main actors in innovation policy, we witness a proliferation of challenge-oriented innovation policies both at the subnational and the supranational level. This begs the question about subsidiarity: what innovation policies for societal challenges should be organized at subnational, national and supranational levels? We provide arguments that innovation policies aimed to solve societal challenges, such as climate change or aging, are best pursued at subnational levels given the contested nature of problem identification and the contextual nature of problem-solving. Regional innovation policy, then, should formulate concrete societal goals tailored to the local context, while the transnational context promotes inter-regional learning and provides the complementary policies in the realms of basic research, regulation and taxation. In addition, the supranational level can set overall goals that are made more concrete and operational at the subnational level.

1. Introduction

In recent times, innovation policies have seen a proliferation in terms of spatial scale. Innovation is nowadays a top priority on all policy agendas, from the urban and regional level, to the national and supranational level such as in the European Union (EU) and the OECD. At the same time, innovation policy experienced a turn from fixing market failures and system failures to solving societal challenges [1–5]. In particular, with the formulation of 'Grand Challenges' [6,7] or 'Global Challenges' [8], supranational bodies have taken an active stance in guiding research and innovation support towards explicit societal objectives. For a policy field organized in a multi-level setting [9], the questions of how to organize, coordinate and implement challenge-oriented innovation policies across different levels seem to be logical and urgent ones. Yet, these subsidiarity questions are rarely addressed.

At the supranational level, the weight of research and innovation policy increased steadily over the years both in terms of scope and financial substance. Taking the example of the EU, early initiatives were technology-oriented with a focus on establishing cross-border infrastructures in strategically important sectors (e.g. nuclear technology, information technology), but remained only of minor relevance in terms of size and scope compared to national policies [10,11]. With the implementation of the European Framework Programmes (FP) in 1984, European research policy experienced a gradual shift from the initial technology-led rationales towards a stronger focus on economic and industrial competitiveness. In the late 1990s, with the focus on more generic support measures such as science-industry collaborations, systemic innovation policies became the new paradigm. At that time, large-scale coordination initiatives started within the broader vision of a European Research Area (ERA) [12].

These examples are in line with the observations made by [13,14] that innovation policy priorities mostly reflect the dominant innovation paradigm of the respective period. The more recent

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developments in EU policy can also be understood in light of political practice, related to disappointments over the 'Lisbon Strategy' aiming for economic growth and the insufficient progress made towards achieving an integrated ERA [15]. The political discourse in the EU circulated around finding new rationales for a European research and innovation policy, and a practicable way was seen in linking ERA to a series of Grand Challenges.[1] Viewing "the grand challenges of our time" mainly in terms of societal and environmental goals was in further consequence proposed more explicitly in the Lund Declaration [16]. Societal challenges have been a key pillar of the EU Framework Programme Horizon 2020 [6], and will be even more central in its successor funding programme Horizon Europe for 2021–2027 [17].

A more general basis for challenge-oriented innovation policy at the supranational level rests on how societal challenges are typically viewed, namely as global societal problems that can only be dealt with by multi-lateral cooperation [8,18]. Challenges, associated with global warming, obesity, ageing, energy independence and food security, are framed as uncertain problems that require large-scale innovative efforts in order to come up with appropriate solutions. These solutions are usually considered as a public good. To the extent that new knowledge needs to be developed to provide these solutions and solve the challenges, the cost of duplicated research efforts provides another rationale for supranational policy. Therefore, it may be more efficient to address global societal problems at a supranational level.

Although the need to solve societal challenges as motivation for innovation policies is rather recent, it links back to Nelson's (1974, p. 376) famous question: "if we can land a man on the moon, why can't we solve the problems of the ghetto?" Nelson stressed that the challenge of putting a man on the moon was very different from that of solving problems in ghettos or, for that matter, most other societal challenges. What has often been overlooked is that moon-like problems are well defined in terms of their goals and type of solutions, while ghetto-like problems are wicked in that problems are ill-defined, contextual and often contested at local levels. Hence, a common understanding and globally applicable solutions may be hard to reach [3,19].

Given the wicked nature of societal challenges, we will in this paper address the question how innovation policy priorities can be implemented and coordinated among the subnational (municipalities, regions), national and the supranational level. In particular, we provide theoretical arguments supporting subnational policies that are challenge-oriented and contextual rather than generic and systemic. In light of the context dependence of innovation, including the importance of governing institutions and local users [20–22], we set out reasons for orienting subnational innovation policies towards societal challenges. At the supranational level, then, complementary policies can be conceived to set directions, develop generic regulations, or invest in supportive knowledge infrastructure.

As an empirical reference frame, we refer to the European level as the supranational level and to the regional level (including the metropolitan area) as the subnational level, but the theoretical arguments may apply to multi-level settings outside Europe as well. However, we do not touch upon the questions of legitimacy of regional or local institutions and the differences in competences and power of regional or local authorities across countries. Our main challenge lies in theoretically arguing for the highest (supranational) or lowest territorial level at which innovation policies can be implemented (national or subnational). Depending on the political realities, the arguments we put forward regarding subnational innovation policies may apply to cities or regions (particularly in federal states), but also to nation states in smaller countries with less pronounced regional policies.

As starting point in Section 2, we take the current debate in the academic literature for a new challenge-oriented innovation policy in order to revive the discussion on subsidiarity, that is, the legal-political principle underlying the division of policy responsibilities between territorial levels (regional, national, transnational) in the EU. In Section 3, we review alternative readings of the subsidiarity principle, before we argue for a regional innovation policy in Section 4. In Section 5 we provide recommendations for the multi-level governance of innovation policies for societal challenges to exploit policy complementarities. We also discuss the formulation of priorities at both the regional and supranational level.

2. From market and system failures to transformational failures and societal challenges

Justification for policy intervention in innovation goes back to neoclassical economic theory, legitimizing intervention only if an efficient functioning of markets is hampered. In this tradition, market failures occur in situations in which the market does not provide adequate incentives for private R&D, due to the uncertainties inherent in R&D or spillovers from knowledge creation to competitors [23]. As broadly agreed, such a view may be appropriate for the public provision of basic research, but it remains rather simplistic focusing mainly on firms and viewing the knowledge created in innovation processes as codified, thus easily spilling over to competing firms.

Contradicting the market failure rationale is the fact that governments have been proactive supporters throughout history by providing massive public investment contributing to the success of many technologies [24]. This observation applies to many countries like the US, UK, France and more recently China [4,25,26]. In the last decade, there have been repeated calls for national governments and the European Commission to extend this active role in steering science and innovation through the formulation of 'missions' and a mission-oriented innovation policy [7,11,27]. Following the distinction between moon and ghetto problems [28,29], a differentiation can then be made between old-style technological mission-oriented innovation policy ('moon projects') and more recent societal mission-oriented innovation policy ('ghetto projects'). Moon-type of missions have well-defined objectives and aim to develop technological solutions. Ghetto-type of missions are likely to be contested, rendering broad legitimization and huge public spending difficult compared to the narrowly defined moon-type missions [1,4].

What has been overlooked is that effective solutions to complex societal problems do not require technological innovation *per se*, but can equally be based on already existing technology, on new regulations, social innovations, behavioural change, or a combination of all these [3]. Only in some cases can societal challenges be easily mapped onto particular scientific or technological challenges. Such exceptions may include, for example, battery technology, specific drugs for rare diseases, or public infrastructures to protect citizens against flooding. More often, it is through a mix of technological, social and institutional innovations that complex

[1] As stated in the initial report, "[Grand] Challenges are rooted in economic, social or scientific goals but share a need to demonstrate their relevance at the European level" [76]; p. 5). Furthermore: "By giving ERA a content dimension, the Challenges must also inspire and motivate the research community itself." (p. 45). The initially envisioned challenges refer to a three-part set of economic challenges (combining supply-side with demand-side measures to create innovation-friendly markets), social and environmental challenges (such as climate, food and energy security, ageing society), and science and technology challenges (linked to frontier research).

societal problems are tackled.

Another policy question holds to what extent challenge-oriented innovation policy can be subsumed under systemic innovation policy. A departure from the market failure approach to innovation policy was accomplished with the introduction of the system failure framework [30]. The innovation system perspective places emphasis on the contextual and embedded nature of innovation by investigating the systemic conditions that promote, guide or curtail innovation activities. Main focal points are the actors (firms, universities, governments, users, intermediaries) involved in creating innovations, their interactions in networks and the institutional setting in which these interactions take place. Typical system policies indeed include governmental infrastructure provision, the support of innovation capabilities, or mobilizing different actor types and supportive institutions for innovation creation. Some suggest that an innovation system approach fits well with a challenge-oriented innovation policy given the multitude of actors, sectors, their relations and institutions that need to be mobilized in any serious effort to tackle complex societal problems [4,31]. However, from an innovation system perspectives the role of policy is mainly seen in supporting and optimizing the internal functioning of the system, inducing policy makers to focus primarily on the structural conditions of the system in delivering innovations.

As pointed out [2], structural innovation system policies are typically designed as generic policies but remain rather silent on the content of innovations. If anything, the implicit directionality is decided by powerful actors, for instance, large incumbent firms driven by a company strategy rather than a societal mission [32]. Furthermore, innovation system policies are often reduced to strengthening the relations within the triple helix of university, industry and government [33]. In the context of societal challenges, this science-orientation leads some to advocate “big science” for “big problems” [4]. This, however, pre-assumes that societal challenges need science-based or technological solutions, while some problems may be better tackled by regulation, social programs or behavioural change. What is more, triple helix policy models mostly neglect the role of users for innovation, assigning them a passive role as consumers in product markets. Disregarding users in innovation policy sharply contrasts with the burgeoning empirical literature on end-users as drivers of innovation in many sectors, including sustainable energy, information technology and 3D-printing [20,34–36].

Extending the notion of system failures based on a socio-technical system perspective, some [2] suggest that challenge-oriented innovation policy should be based on the so-called ‘transformational system failures’ rather than market failures or structural innovation system failures. These transformational system failures stem from established structures or processes that hinder a societal transformative change of the system (e.g., towards Sustainable Development Goals or any other societal objective). Weber and Rohracher [2] provide several rationales for a more active role of policy, which is not necessarily carried out by the state alone, but requires coordinated action and involvement of private and civic actors in new governance arrangements [37]. They identify four transformational failures: directionality failures (i.e. insufficiencies in setting priorities and guiding innovation towards societal problems), demand articulation failure (i.e. deficits in anticipating and learning about user needs), policy coordination failure (i.e. lack of coordination and coherence between supranational, national and regional policies, or between sectoral policies) and reflexivity failure (i.e. insufficient monitoring of activities and progress towards change) [2]. Table 1 summarizes the differences between policies addressing transformational failures and the more traditional market failure and structural innovation system failure policies.

While the transformational failure framework can be considered a valuable reference for challenge-oriented policies, the spatial perspective is still underrepresented in innovation policy discourses on societal challenges [38]. While supranational organisations such as the EU or OECD were active in pushing forward their ideas on the locus of societal challenge-oriented policies, regional authorities have for a long time remained comparatively silent about the possible roles of regions in challenge-oriented innovation policy. Especially in early reports, the implicit assumption was made that current societal challenges are inherently global and thus need to be addressed globally [8,18]. The main argument is that today’s ‘grand societal challenges’ affect everyone and therefore it would be in the common interest of all countries and regions to resolve them through common efforts. The global nature of most societal challenges renders it almost natural to consider the supranational level to be the most appropriate level to address them. In the following section, we attempt to challenge this view by unfolding the subsidiarity principle with respect to alternative readings.

3. The subsidiarity principle and the locus of innovation policy

This paper begs the question of whether and under what conditions a supranational innovation policy targeted at societal challenges is reasonable from a theoretical perspective.[2] In the EU, the subsidiarity principle is one of the guiding rules to determine the division of political responsibilities and the coordination of policies between regions, countries and the European level. Except for policy fields that are within the exclusive competence of the EU (such as monetary policy in the Euro area or competition policy related to the internal market) policy action is on the basis of the subsidiarity principle to be taken at the lowest level where it proves to be necessary.[3] The statutory law of the EU states the principle as follows: “*if the objective of the proposed action cannot be sufficiently achieved by the Member States either at central level or at regional and local level, but can rather, by reason of the scale or effects of the proposed action, be better achieved at Union level.*” (Art. 5(3) of the Treaty on European Union (TEU)). In addition, subsidiarity needs to be line with the EU’s democratic principles, ensuring that “*decisions are taken as closely as possible to the citizen*” (Art. 10(3) TEU). However, in political practice, the subsidiarity principle is often seen as “quite an abstract rule for practical policy decisions” [39]; p. 965), and EU actions in research and innovation are usually legitimized by the ‘European added value’ they are supposed to create.

If we approach the issue at a more theoretical level, we find multiple conceptions of subsidiarity which can lead to very different implications for policy-making, irrespective of the practical implementation. For instance, supranational action can be considered as necessary, and thus legitimate, in cases where countries (regions) have homogenous priorities but capacities and incentives for (sub)national actions to achieve the desired outcome are limited [40]. This line of reasoning is usually followed in

[2] We will mostly refer to the European institutional setting in our discussion, but the basic arguments we put forward can be adopted to other situations in a similar way.

[3] The EU has shared competences (Art. 4 TFEU) with EU countries in research and technological development, meaning that countries implement their own initiatives in cases where the EU does not exercise its competences (such as university policies, or different thematic country-specific policy priorities). In contrast, innovation policy agendas (SME and entrepreneurship, demand-side innovation, etc.) are assigned to industry policy in which EU competencies are restricted to coordinating and supplementing EU countries’ policies (Art. 6 TFEU).

Table 1
Comparing policies based on market, system and transformational failures (adapted from [2]; p. 1045).

Market failure	
Information asymmetries	Lack of collaboration and private funding for R&D due to uncertainty
Knowledge spillovers	Public good character of knowledge
Externalization of costs	Harmful effects of innovation
Over-exploitation of commons	Public resources are over-used
Structural system failure	
Infrastructural failure	Lack of physical and knowledge infrastructures
Institutional failures	Institutions create an unfavorable environment for innovation.
Interaction failure	Either too closely tied networks or too limited interaction within networks
Capabilities failure	Lack of appropriate competencies and resources at actor levels
Transformational system failure	
Directionality failure	Lack of shared vision regarding the direction of the transformation process
Demand articulation failure	Insufficient spaces for learning about user needs
Policy coordination failure	Lack of policy coordination across sectors, technologies and territorial levels
Reflexivity failure	Insufficient self-governance and lack of adaptive policy portfolios

challenge-oriented programs of the EU such as the societal challenge pillar in Horizon 2020 or the new research and innovation missions incorporated in Horizon Europe [7]. Along the same lines, we could argue though that the heterogeneity of priorities or preferences as well as diversity in (sub)national circumstances would consequently limit the scope of actions at higher levels in favour of more local activities.

The answer to the question of whether (sub)national entities should run innovation policies might look differently when we read the principles of subsidiarity through the lenses of economists, for whom efficiency is the guiding principle [40,41]. Here, subsidiarity is approached by investigating benefits pertaining from cross-border spillovers, economies of scale, or classic public good arguments. Economic criteria are indeed one of the dominant theoretical approaches to determine the scope of intervention in different fields [42], and with practical relevance as most supranational actions in research and innovation are based on economic justifications. For instance, the 'European added value' of Horizon 2020 was mainly seen in the efficiency gains resulting from community action, expected to be achieved by avoiding duplication, sharing risks and creating a critical mass among Member States [6].

Among the economic justifications, the *cross-border spillover* argument is probably the most compelling one in the context of societal challenge-oriented policies, either because of the international dimension of the addressed problems (related to e.g. climate change, food security), or the assumption that regions and countries invest too little compared to what would be necessary. Associated negative externalities arise, following economic theory, in case of adverse and destructive actions of others (e.g. regarding climate change), while positive externalities benefit others once a solution for a problem has been found. Such externality arguments principally favour global (centralized) action, although it is rather unclear whether efforts should be taken in a supranational setting or through more flexible multi-lateral agreements. *Economies of scale* would be another rationale for global large-scale actions that is valid in cases of high fix costs, or large investments necessary to build up research infrastructures.

From an economic point of view, there might indeed be a trade-off in determining the appropriate level of policies between the diversity of priorities favouring local policies, and the presence of cross-border externalities and economies of scale favouring global policies [41]. Regarding the latter, tackling a societal challenge in its international dimension, such as climate change or food security, is often linked to the need of creating a (global) *public good* [43]. Such public good arguments are, partly implicitly, based on the assumption that there is one large-scale solution to a grand challenge, that will, once discovered, create *per se* benefits in other regions or countries. For instance, gains from reduced emissions are expected to spread all over the world, so that other countries or regions cannot be excluded from benefiting from investments. As a result, (sub)national policy makers alone would invest too little in finding public good types of solutions. Instead, they are tempted to free ride on the efforts of others.

Turning to challenge-oriented innovation policy, the public good arguments may take on a double meaning. If one would assume that a global problem can be solved by a universal solution, supranational investments are warranted due to the public good nature of knowledge being non-rival and non-excludable. However, such a reasoning seems to be misleading as the knowledge required to tackle a societal problem is far from being fully codified. It is mostly tacit, distributed among many actors, and contextual vis-à-vis territorial institutions and practices [44,45]. Hence, certain innovations or solutions, especially those for societal problems, may be especially difficult to transfer across regions or countries. Apart from major scientific breakthroughs and supportive infrastructures, it is further questionable whether genuine public goods in form of global, ubiquitously applicable, solutions can even develop.

A shift towards societal challenges would suggest that societal or democratic motives require, apart from purely economic reasoning, more careful consideration in innovation policy making. Following the democratic principles underlying subsidiarity (decisions are to be taken "as closely as possible to the citizens"), this relates to possibilities for active political participation, accountability and legitimacy of action as criteria to determine responsibilities within and across levels [40]. It might also imply an opening of the policy process, involving a greater diversity of actors in collective decision-making, ranging from citizens, users and NGOs to experts, incumbents and entrepreneurs, with a stake in the issues. In more democratic governance arrangements, different actors can exert direct or indirect influence on agenda-setting, policy formulation and implementation. They have their individual cognitive filters according to which they perceive problems and solutions, and attempt to shape the definition and selection of policy priorities.

EU governance has indeed often been criticised for its insufficient transparency about who is involved in decision-making or the lack of democracy in how decision are taken [46]. Regarding the EU research agendas, many have claimed that decision-making needs to be more responsive to citizens' needs, and should focus more on the public value of science and innovation in selecting the challenges to be addressed in the future [47]. Closely related are the

Table 2
Challenge-oriented innovation policy following the principle of subsidiarity.

	Subnational	Supranational
Assumption	Challenges specific to local circumstances	Challenges affecting all regions in similar ways
Rationales	Finding ways to tackle contextual problems	Avoiding free-rider problem
	Improving democratic decision-making	Avoiding duplication
	Increasing variety	Sharing risks
	Achieving multi-actor coordination	Benefitting from scale economies
Scale	Small-scale and contextual solutions	Large-scale solutions requiring big investments
Legitimacy	Contested problem requiring responsiveness to citizens and multi-stakeholder participation in formulating needs and solutions	Uncontested problem with clear problem definition, often associated with need for scientific advancement, technology innovation and technology diffusion

calls for more open and deliberative considerations, more transparent selections of research priorities, or an increasing accountability when the laid down policy objectives are not met [48].

Global definitions of problems and priorities may run the risk of insufficiently reflecting the voice of the citizens. Disregarding the knowledge of those people most affected (e.g. by diseases, by pollution, by climate change) and the local values and conditions, more likely leads to one-sided problem definitions. It also undermines public consensus about the 'right' societal challenges and broad legitimization of the measures taken [37]. At a global (European) level, however, true collaborative governance beyond the representation of key interest groups in public consolidation processes is hard to achieve. By contrast, at the subnational scale, citizens and other societal stakeholders can be involved more directly in the processes of problem identification, formulation and framing. Also, citizens can be linked to innovation producers to be more actively involved in the innovation process to influence the direction and purpose of innovation, or to develop solutions on their own as user innovators [34].

Strengthening the relationship between science, innovation and society, in particular the legitimacy of science and innovation in society, is core to the recent discourse on responsible research and innovation (RRI) [49–51].[4] RRI envisions not only to increase the societal acceptance of science and innovation (i.e. the societal legitimacy of innovation) but also the inclusiveness, responsiveness and reflexivity of innovation policy in addressing societal needs and concerns (i.e. the democratic legitimacy of innovation). Both societal and democratic legitimacy have a clear geographical dimension, which need to be thought through jointly. A mismatch between the spatial impact of innovations and the spatial scale of the governance process in which societal problems are negotiated, framed and decided would contradict the democratic values as formulated in the subsidiarity principle [50].

Based on our discussion on subsidiarity, Table 2 summarizes the rationales, scale and legitimacy of a challenge-oriented innovation policy for the two extremes of the subnational level versus the supranational level. Clearly, policy realities are more complex and fluid. This complexity is a function of a policy-mix [52], with its multi-actor and multi-level interactions, the multiplicity of policy goals across levels and policy fields, and instruments that can be complementary or contradicting to the challenge-orientation of innovation policy. The aim of this paper is to initiate a discourse on the geography of a challenge-oriented innovation policy, and the implicit or explicit assumptions being made regarding scope and scale of challenges and solutions. In this sense, we discuss subsidiarity mainly as 'an abstract rule' [39] to govern different types of policies for societal challenges, rather than as a practical recipe for managing the melanges and specifics of ongoing policy programmes and actor constellations across scales and policy domains. Nevertheless, such a discussion may help us to achieve more clarity about the governance issues at stake in challenge-oriented innovation policy.

4. A case for regional challenge-oriented innovation policy

The classic subsidiarity principle rests on considerations of efficiency calling for more supranational policies, and democracy calling for more (sub)national policies. From our discussion, we concluded that the arguments for a supranational challenge-oriented innovation policy, given the alleged universal nature of the societal challenges, are ill-founded. Not only do supranational policies run the risk of creating democratic voids and lacking broad support, the economic arguments favouring supranational policies (spillovers, economies of scale, unnecessary duplication) also remain underdeveloped. In essence, efficiency arguments rest on the premise that societal challenges are best solved by a single best solution. If this were the case, arguments of spillovers, scale and duplication would indeed hold. Yet, given the complex nature of societal problems and the institutional diversity of local settings in which they are to be addressed day-by-day (schools, hospitals, NGOs, municipalities, etc.) it is rather unlikely that global problems require global solutions.

Societal challenges are often described as showing the features of 'wicked problems', a concept stemming from the planning and governance literature [53,54] and dating back to the work of Rittel and Weber [55]. They have also been linked to the notion of 'persistent problems' as discussed in the transition and system innovation literature [38,56]. The difficulty to clearly demarcate causes and consequences in societal processes makes most policy problems in our modern era surrounded by uncertainty. Here, uncertainty relates not only to the societal impacts and risks of action (or inaction), but also to the complex and erratic patterns of the problem itself. People usually experience a challenge or a problem differently, use their specific frames to analyse its dimensions or to weight existing knowledge about the issue [57]. Different actors create different beliefs about the urgency of a problem and the best ways to tackle it. Compared to systemic or generic innovation policy goals, societal challenges are indeed more unstructured and complex, often without a clearly delimited target area in the technological or economic sphere [19]. The multiple dimensions and trade-offs cutting across different often conflicting domains (science, economy, education, environment, health, etc.), render it hard for policy makers to identify and target a problem [2,58,59].

Contrasted with so-called 'tame problems' [55], the goals of a challenge-oriented innovation policy can be regarded as open-ended; there is neither an immediate or single cause for the problem nor a clear answer or simple solution for it. Accordingly

[4] RRI emerged as a policy concept developed by the European Commission rather than the scientific community, with the aim to increase the legitimacy and societal value of research and innovation policy (for a more detailed discussion see, for instance Ref. [50], or [51]. In this sense, it shows similarities with the European conceptualization of 'Grand Challenges' for innovation policy.

[54], the wickedness of most societal problems lies in the problem identification and definition. Often the choice of a problem formulation already suggests a potential solution, constraining the further search, exploration and experimentation with alternative approaches. If we consider, for instance, the lack of scientific knowledge about a new disease to be the root cause of a persistent problem, producing more scientific knowledge on the disease may be regarded as the obvious way to solve the problem. Most societal problems, however, pose multiple interrelated challenges related to work, health, environment, inclusion and psychological well-being. One-sided approaches appear often insufficient for tackling this complexity.

Next to being inherently complex, we can characterize societal challenges as diverse and evolving from the plurality of territorial or contextual conditions. Challenges do not present themselves as the same for every region or country, as underlying problems affect places in different ways and to different extents. Despite of labels of 'grand' and 'global', the challenges remain contextual. We observe very diverse forms of occurrence and harshness or disparities in risks and threats across regions resulting from the historical, geographical, economic or socio-ecological conditions.

A challenge-oriented regional innovation policy would at least to some extent imply a departure from the dominant regional innovation policies today, which tend to focus on the structural system failures. Policy measures typically aim to stimulate localized learning processes, technological transfer or triple-helix collaboration among universities, industries and government [33,60]. The rationale holds that overcoming structural system failures would render local firms more competitive in national or global markets, contributing to productivity increases, job creation and income growth. To the extent that collaborations focus on innovation related to societal challenges, such policies, implicitly or explicitly, privilege science-based and high-tech solutions for societal challenges over more integral solutions including organizational and institutional innovations [3].

To overcome insufficiencies of the structural system policies, we build our discussion on the transformative system failure rationales [2]. Here, a key point – differentiating societal challenges from generic economic policy goals – is that challenges need explicit normative *viz* political elaboration to translate a vaguely defined or abstract societal challenge into a clear policy objective. This links directly to the notion of demand articulation, which translates a societal need, that is the challenge, into a (public) demand [21,22]. By making a challenge operational, directionality is provided to heterogeneous actors that are part of the innovation network willing to take up the challenge. If this process is organized in some legitimate form of public consultation among a range of actors and fields of expertise, the process of demand articulation not only provides guidance but also legitimacy. The set of involved actors is undetermined both in the types (universities, industries, governments, users, NGOs, professionals, etc.) and spatial scale (regional or extra-regional). It depends on the willingness of actors to collaborate and the emergent policy process and prioritisation. Thus, it may, *or may not*, include local universities and corporations departing from the local triple helix model for regional innovation policy. Put differently, the relevant innovation system is not given *ex ante*, but emerging around a particular articulation of a broader challenge through collaboration and negotiation [3]. Having said this, the solutions resulting from this process need to be institutionalized in existing structures as to gain durability [61].

Since the articulation of demand and search for solutions is both normative and contextual the local level seems most appropriate to organize such innovation policies despite the fact that challenges are often global in an abstract sense. The key reason is that both preferences and institutions are rather specific to regions, meaning that demand articulation at national or supranational level will be both more difficult and less legitimate. Instead, temporary challenge-oriented initiatives based on a common understanding of a problem can be easier established locally, thus limiting coordination problems among established policy areas and sectoral policy fields [2]. Instead, local embedding helps to initiate a problem-based dialogue about needs and demand articulation among a diverse set of actors (including citizens, policy makers, local authorities, firms, universities, etc.). Local diverse networks with a strong shared interest in resolving a problem can thus overcome institutional and cognitive barriers that would otherwise hamper collaboration.

In this sense, challenge-oriented regional innovation policy can be made part of the current logic of 'Smart Specialization' in European regions, where opportunities and policies are generated bottom-up in a collaborative and contextualized manner, and where the adoption of solutions from outside the region is equally important as the generation of new solution within the region [62]. Depending on institutional context or economic conditions, regional support structures can be built around the challenge. The (public) provision of platforms for interaction, for example, enables appreciation and joint learning about the different dimensions of the challenge, while spaces for experimentation with potential solutions can stimulate creativity and risk-taking [63]. This does not preclude globally connected scientists, firms or NGOs from sharing within such platforms their knowledge coming from their global epistemic communities or communities of practice [64]. They bring in relevant knowledge or potential solutions from outside to evaluate, and if possible, adapt them with regard to the local context [65,66]. Once local actors with global links become involved, they can get into the position of regional gatekeepers for the regional initiatives providing access to the relevant global networks [67]. The interplay between the regional and the extra-regional level underscores that in challenge-oriented innovation policy the adoption and embedding of solutions from outside the region (i.e. diffusion policy) can be as important as the generation and deployment of new solutions from within the region (i.e. innovation policy).

Given that regions have their individual knowledge bases and capabilities, multiple and very diverse search paths potentially develop side-by-side. For challenge-oriented innovation policies this could imply more experimental governance arrangements [68]. In a multi-level framework broad societal goals can be set to give direction at a higher or transnational level, while local units receive autonomy to translate these goals into own policies, and to develop solutions bottom up in their own way. Such an approach would resonate with the idea of learning from diversity, as it allows to benefit from different combinations of transnational and regional factors in heterogeneous innovation settings. Solutions to local problems can be developed 'on the ground' and close to citizens, while coordination and monitoring takes place in form of transregional networks, to recognize what is possible, to compare alternative practices and to evaluate and learn about (non-)successful search paths. In this way, efforts to deal with directionality, coordination and reflexivity failures can be distributed across levels. However, as the experience with place-based approaches in EU Cohesion Policy shows,[5] key to its effectiveness is the quality of

[5] The Smart Specialization concept follows an experimentalist governance idea to regional industrial development and innovation [77]. However, surprisingly little work has been done on the ability of regions to formulate their societal needs or challenges, and the relationship between such societal challenge-driven approaches and smart specialization. The report by Ref. [78] is an exceptions in this regard.

political institutions to govern evidence-based monitoring and learning cycles at all levels [69,70].

Once particular solutions emerging from local innovation systems have been identified, follow-up policies can be developed to either codify the problem-solving activities in artefacts or templates, or translate them to other (similar) contexts. This task refers to the difficulty of scaling of local lessons, solutions and innovations. Scaling can occur along several dimensions including temporal, geographical and functional dimensions [71]. Follow-up policies can address the scaling difficulties by extending the time horizon or by locally embedding innovative projects (temporal), by supporting the multi-scale learning and diffusion of innovations (geographical), and by broadening the scope of projects to develop joint strategies within and across scales (functional). Solutions and successes at the local scale, although small, can be considered as 'small wins' [72], which can due to the functioning of certain propelling mechanisms[6] reinforce the accumulation, deepening and broadening of local achievements within and across regions [73]. Activating such small wins could be policy levers to increase the impact of small-scale local solutions. Hereby, intermediary organisations can be critical actors to couple the local solutions across scales and actors, to circulating ideas and to facilitate innovation diffusion within collaborative networks [74].

To conclude, while in some cases a challenge-oriented innovation policy is solely about solving a persistent societal problem, in other cases it can also be a basis for regional diversification as new export products or services. Indeed, the global nature of societal challenges implies that local solutions may diffuse, in commercial or non-commercial ways, to regions dealing with very similar challenges [75]. To circulate localized solutions to other regional contexts in the form of templates, artefacts or regulations, a challenge-oriented regional innovation policy can be supplemented by intermediaries and network policies – be it at the regional, national or supranational level – to promote the decontextualization and diffusion of local solutions.

5. Discussion

The current policy focus on grand societal challenges begs the question how innovation policy can direct innovation activities in a certain desirable direction. Instead of defining societal challenges exclusively at the supranational level, we argue that the broadly defined 'grand challenges' as agreed upon at a supranational level, are to be taken up and further articulated at the regional level. This would enhance the democratic legitimacy of innovation policy by tuning the problem, and its possible solutions, to the regional economic and institutional context. For regional innovation policy, taking up this active role in addressing societal challenges implies a supplement to the fixing of structural system failures which contributes to innovation more generally, but without directionality.

Our argument for a regional challenge-oriented innovation policy should not be understood as denying the relevance of supranational policies. On the contrary, regional policies should be supported by complementary supranational policies. Taking the example of environmental challenges, ambitious emission reduction targets, higher environmental taxes and stronger regulation at the European level would tilt the competitiveness of sustainable innovation vis-à-vis existing unsustainable technologies. Also, regarding science policies, a further extension of transnational policies would not be at odds with regional innovation policies as universities act as locally embedded hubs for international knowledge production and exchange. Furthermore, we do not advocate a phasing out of a challenge-oriented innovation policy at the supranational level. First, in cases where (technological) solutions to a societal challenge are widely supported and well-proven, the supranational level is most helpful in scaling up through standard-setting and diffusion policy. As examples, again in the realm of environmental challenges, one can think of supranational coordination in offshore wind or European super grids. Second, even in cases where both problem definitions and possible solutions are still uncertain and contested, supranational policies can play a role in fostering collaboration and deliberations across regions, but without specifying values, frames or solutions *ex ante* in too much detail.

Taken the subsidiarity principle seriously would require regional policy makers to rethink their supply-side bias in market and structural system failure innovation policies, and to reflect on their role in helping to solve societal challenges. Such a regional innovation policy would first and foremost focus on the local contextual manifestation of the broad challenges outlined at national or supranational levels as well as on forming multi-scalar institutions with which these challenges can be addressed. The involvement of a broad set of stakeholders including users and professionals on the ground seems to be crucial. At the same time, given the global nature of problems underlying societal challenges, local solutions may still find global export markets. Regional policies tackling societal challenges and promoting export-led growth may then, ideally, go hand in hand.

As our argumentation has been largely theoretical, key empirical questions remain regarding regional policy for societal challenges. First, following the subsidiarity principle, we argued that the regional level would be better able to pursue a challenge-oriented innovation policy that is democratic and sensitive to local contexts, contributing to policy effectiveness. However, in practice, subnational policy is not inherently more democratic and context-specific than national or supranational policy making. Indeed, as with any another policy, a regional innovation policy oriented towards societal challenges can be captured by regional vested interests as well as by extra-regional lobbies. Hence, the design of the policy process and institutional capacities to implement policies are crucial for subsidiarity-based reasoning to hold. Second, as challenge-oriented innovation policy has only been identified recently at a regional level, we currently lack empirical evidence that can inspire and inform regions in such an endeavour. Yet, many regions have been active in solving challenges ranging from ecological and social problems to industrial downturns and migration. Taking stock of successes and failures in such challenge-oriented innovation policies *avant-la-lettre* will help to avoid reinventing the wheel, and instead build on established experience and expertise, yet in a new narrative and policy context.

CRediT authorship contribution statement

Iris Wanzenböck: Conceptualization, Writing - review & editing. **Koen Frenken:** Conceptualization, Writing - review & editing.

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[6] According to Ref. [72]; propelling mechanisms are chains of events that reinforce themselves through feedback loops with an amplifying effect on an initial small change so that it becomes larger and stronger, or intensifies and escalates its consequences. The identified mechanisms refer to energizing, learning by doing, logic of attraction, bandwagon effect and coupling [72].

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