Demand, challenges, and innovation. Making sense of new trends in innovation policy

Wouter Boon[1] and Jakob Edler[2,*]

[1]Innovation Studies Group, Copernicus Institute Sustainable Development, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands and [2]Manchester Institute of Innovation Research, University of Manchester, Alliance Manchester Business School, Harold Hankins Building, Manchester, UK M13 9PL, UK

*Corresponding author. Email: jakob.edler@manchester.ac.uk

Abstract

In recent years, the traditional rationale for innovation policy has been expanded to more explicitly contribute to tackling societal challenges. There is broad agreement that demand should be at the core of challenge-oriented innovation policy. Nevertheless, demand and demand conditions are poorly understood and not yet in the focus of challenge-oriented innovation policy. This article conceptualises demand-oriented innovation policies and their links to societal challenges. We differentiate demand and need, and highlight different forms of demand articulation. Then, we characterise three ideal-typical policies that relate to demand: traditional innovation policy, sector-specific policy, and challenge-oriented policy. These three ideal-types are discussed focussing on output legitimacy, input legitimacy, and operational requirements. This discussion highlights the specific challenges and opportunities of demand-oriented innovation policies and allows to derive a set of recommendations to increase the effectiveness of such policies.

Key words: innovation policy; demand; societal challenges.

1. Introduction

The role of the state in innovation policy is changing. Rather than being limited to supporting the capability and connectivity of and within systems to innovate, the state is increasingly seen—again—as a major actor in shaping the directionality of innovation (Mazzucato 2011; Weber and Rohracher 2012). This shift is most clearly being expressed in 'challenge'-oriented and 'mission'-oriented policies such as the European Union (EU) grand societal challenges and the Sustainable Development Goals. The policies seek to define specific areas of societal concern and tackle societal challenges such as food security and ageing societies. In Europe, a first explicit manifestation of this was a strategic EU report in 2006 (Aho et al. 2006).

In our observation, however, *policies that are designed to support those missions and challenges* often ignore the demand conditions and activities. This is a curious shortcoming, given their explicit mentioning of the importance of demand conditions in the original 'Aho report' and subsequent policy documents (COM 2010), considering the conceptual claims of transition theory about the importance of demand (Schot and Geels 2008) as well as the attention paid to market formation in the literature on technology-related innovation systems (Bergek et al. 2015). We explicitly take a broad understanding of demand, not limited to an economic perspective (i.e. quantity of a product that someone wants to buy at a

certain price) but also considering the cognitive/substantive process of determining the nature of the demand. Including the substantive dimension of demand in the context of challenges is important because challenges can be perceived as accumulations of user needs and are often legitimised as such (Latour and Woolgar 1979; Peine and Herrmann 2012). Nevertheless, there is little insight into how demand can be articulated into challenges and transformative innovation policy activities (van Lente and van Til 2008). Moreover, challenge policies often focus on orchestrating and directing research, development, and innovation efforts towards desired outcomes, on linking capabilities of different, traditionally-separated areas. If challenges are to be met, if system transitions are to be made and fostered, then surely the readiness and willingness of consumers, firms, and public bodies to change practice and to adopt and use innovation is a basic requirement for change to materialise.

Even though we see a relative negligence of demand considerations in challenge-oriented policies, *traditional innovation—and increasingly industrial—policy* itself has opened up and started to target demand conditions and capabilities, recognising these basic requirements for innovations to be generated and diffused. Research and innovation strategies of countries increasingly contain a section on demand and a combination of the various demand-side instruments, such as monetary or price-based incentives (demand subsidies or tax allowances) that should stimulate consumers to buy an innovative product, public procurement of innovation, as well as soft

measures to increase awareness and information (e.g. labels, demonstration projects) and training of users (Aiginger 2014; Commission 2007; OECD 2011). Demand-side policy has, thus, come into the remit of innovation as well as of industrial policy in many countries and as well as at the EU level. The idea here is that demand conditions are important for the generation and diffusion of innovation and, thus, for the innovation and economic performance of countries, and that demand side instruments can be used to improve those demand conditions (Edler 2010; Falck and Wiederhold 2013). Stimulation of demand can potentially create lead markets (European Commission 2007) that support economic activities in a country, which happened, for example, in the case of mobile phones in Sweden and Finland (Beise 2004). However, this shift is still largely conceptual and, though increasingly prominent in strategic policy papers (Izsak and Edler 2011), it has not been rolled out broadly.[1]

There is another line of policy which has long been established and which sits right in the middle of cross-cutting challenges and demand side innovation policy, for example, *sectoral—or domain—policies* prominent in fields such as energy, transport, and health. Here, we find a long tradition of policies that target the demand conditions in a certain area for what is often a well-defined technology to support the goals of the policy domain. For example, energy-transition-management policies have long tried to create and foster markets for cutting-edge energy-efficient technologies (Alkemade et al. 2011), such as solar panels, LED lighting systems, or electric vehicles.[2] The main legitimation of those policies is foremost to advance the diffusion of products that contribute to the policy aim of sustainability in energy use and provision. Here, demand measures are not geared to the generation and support of innovation for the sake of economic competitiveness per se, especially as many programmes are not restricted to national suppliers. Those policies use the entire array of demand-side measures to create an environment that reduces the uncertainty for buyers and for innovators, and allows for rapid economies of scale and scope. Furthermore, those policies, whereas being problem-orientated, rarely tackle problems stretching across policy domains and, thus, fall short of aiming at systems transition (Edler 2016).

In this article, we want to conceptualise this—highly stylised—triad of policies to better understand the opportunities and challenges that are associated with the role of demand at the crossroads of challenge-oriented, economics-enhancing, and sector-specific policymaking. The three policy pillars, as introduced above, all miss out on some aspects of demand and challenge orientation. We focus on what all three of those policy pillars have—or should have—in common, but what we find is strangely underdeveloped: the requirement to focus on demand and, in doing so, to have societal needs as the starting and end points of policy intervention. In doing so, we contribute to overcome what Coenen et al see as a strong bias in the literature against demand-side policies (Coenen et al. 2015: 491) and, thus, an insufficient consideration of policies directed towards change (directionality failure, Weber and Rohracher 2012). In focusing on demand and articulation, we also contribute to a broader literature on system functions, which highlights market formation as one core function, but despite acknowledging that poor demand is a major blocking mechanism, it is not well equipped to discuss the role(s) of policy in such market formation process (Bergek et al. 2007; Hekkert and Negro 2009).

Our starting assumption is that the normative shift towards solving societal challenges—inter alia—by mobilising and diffusing innovation is hampered by a number of policy misconceptions and governance challenges. We argue that this is due to simplistic conceptualisation and institutional and cognitive rigidities related to the demand side of innovation systems. We base this argument on a conceptual framework which accommodates the normative underpinning (input and output legitimacies) and the core operational intelligence requirements of the three policy ideal types. This allows us to critically discuss their rationales, potential benefits, and shortcomings in relation to tackling challenges and mobilising demand. The idea of looking at demand in the context of innovation and challenges is not to advocate a super state or some optimal etatist top–down approach, but to argue for structures and processes allowing learning and interaction in the design and implementation of policy, and the mobilisation of complementary competencies—both statist and societal—to define directions that are based on societal needs articulated as demand. This shall help us to identify ways forward in which directionality of innovation policy, problem-solving, and system transition can be at the centre of policy by taking need, demand, demand conditions, and, finally, market formation, seriously.

The article is structured as follows. We start with a short discussion on the nature of demand and the policy requirements arising from taking demands as the starting point of policy (Section 2). We then introduce our conceptual framework with the three dimensions—output legitimacy, input legitimacy, and operational intelligence requirements—which we see as the three crucial dimension of policymaking and acceptance (Section 3). This then serves to critically discuss our three policy pillars (Section 4). On the basis of this critical discussion, we then develop ideas for a better governance of policies that have demand at their core and seek to mobilise innovation and innovation diffusion, and we end the article by outlining a number of requests for further research to better underpin the conceptual claims we are making.

2. Needs, demands, articulation, and policy

A response to societal challenges generally requires system transition with long-term visions and anticipation as regards, for example, emerging technologies and their socio-institutional acceptance and embedding. In such fluid and malleable contexts—and, often, in spite of an explicit definition of societal challenges—the concrete demand for innovation remains often rather elusive and undefined. Nevertheless, for challenges to be tackled, innovations need to be generated, bought, and applied. The question, therefore, is how to identify and mobilise demand and reconcile and align it with emerging innovative solutions in the context of societal challenges.

Demand featured large in the 'market pull versus technology push' debate in innovation studies, poling the likes of Schmookler (1966) who stressed the importance of market demand stimulating innovation, against Rosenberg (1976), who claimed the prevalence of complex and ever-changing supply conditions. Whereas both perspectives had been attributed some value, they were also seen as emphasising the linear model of innovation. The outcome of the debate was that both demand and supply of knowledge and technology play a role, and innovation processes are regarded as iterative (Mowery and Rosenberg 1979) with some de-emphasis of the role of demand. The demand-side seemed only to return later, in more systemic models of innovations alongside other system elements (Godin and Lane 2013).

All consideration about the importance of demand for innovation requires highlighting the difference between demands and

needs. Needs are associated with everything human beings require to function well. As such they are different from wants, which are things people would like to have. There are discussions about the extent to which you can discern needs from wants, and marketing science scholars have, over the years, discerned different categories of needs, including basic needs, non-basic needs (Doyal and Gough 1991; Soper 2007), must have's, one-dimensionals and de-lighters (Blackwell et al. 2001). Mowery and Rosenberg (1979) criticised the use of 'the rather shapeless and elusive notion of "needs"'. They distinguished between needs and wants on the one hand and demands on the other hand—whereby demand expresses a willingness to pay a certain price for the satisfaction of a need or want. For decisions on innovation directionality and policies to support it, differentiating between needs and demands now is regarded as necessary: needs are vague and potentially unlimited, whereas demands are linked to economic markets and, thus, made specific. The specificity of market demands could serve as a proper starting point for an innovation or R&D agendas (Edler & and Nowotny 2015), leading to—and interacting with—demand policy rationales and deployment of instruments, and, ultimately, to policy output and outcome. Figure 1 captures this train of steps towards demand-based policies, albeit in a simplified and stylised way.

The differentiation between demands and needs draws attention to the importance of the substantive/cognitive process of needs articulated into demands (Boon et al. 2011; Edler 2010; Teubal 1979). In strategic marketing, two potential forms of demand articulation have been distinguished (Slater and Narver 1998). The first concerns firms identifying and *reacting to* what they perceive to be the needs and wants of potential customers and developing products that satisfy those needs perceived for a non-prohibitive price. Demand articulation—or proposed in a less active form, demand orientation—here, concerns an iterative approach to make users' requirements about an innovation increasingly concrete and explicit, against a backdrop of other evolving dimensions of the innovation, such as the technological make-up and infrastructural embedding. Such a customer-led focus leads to successful innovation in the short run, geared to optimising customer satisfaction (Christensen 1997). However, this focus involves the risk of becoming myopic as customers often express middle-of-the-road needs, as the story of Kodak's inability to respond to digital photography conveys. Consumers are unable to foresee future needs and to express their 'latent needs' (Hamel and Prahalad 1991). This is especially problematic when considering emerging technologies and dealing with emerging challenges. The second direction of demand articulation is, thus, the identification of *latent* needs or the opening up of *new* needs or wants through providing new functionalities or designs. Demand articulation here can be a supplier-oriented enterprise, with firms or technology developers applying ideas about what a user would like and how user practices look—that is, adopting user representations. This type of demand articulation is often inspired by technological and scientific possibilities and do not necessarily relate to societal goals. One of the most cited examples would be the iPhone, which according to former Apple CEO Steve Jobs would not have been designed if Apple had only listened to what customers thought they needed and wanted.

To develop the role of needs and demand in the context of innovation policy and demand articulation calls for linking needs and demand to larger-scale, societal problems, such as climate change and ageing communities. Through this broadening, *societal* needs and their articulation into demand come more into focus (Edler and Nowotny 2015; Godin and Lane 2013). Demand articulation is a
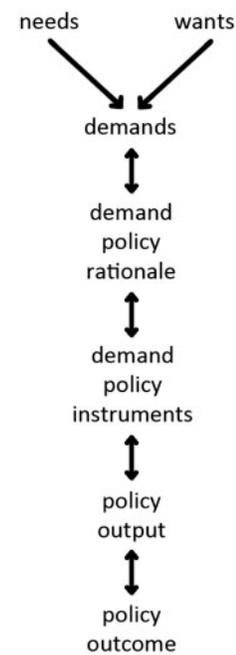

Figure 1. Prevailing simplistic model of demand-based policy.

political process, when 'societal demands' are defined or when demand for certain products or services is supported through state action. The political process of demand articulation can be discussed along the lines of the two firm-oriented strategies introduced above—that is, reacting to demand versus mobilising latent needs. What is defined as societal demand can be a reaction to—or an aggregation and re-orientation of—what citizen's need or want (what we could call *user- or citizen-led*). Here, the role of policy is mainly about supporting the articulation of existing needs and wants into demand in the face of market or system failures. Secondly, demand articulation in policy can be a result of a political process, whereby demand is defined and supported through policy that is seen as supporting political, such as grand societal goals—what we could call *policy-led*. The role of policy here is to support the process of defining the political goal, in the first place, and, subsequently, to design policy measures that steer citizen's demand into a direction that is in line with policy goals.

The involvement of citizens and users is important in both cases, but takes slightly different forms. With *user- or citizen-led articulation*, the definition of demand is a process of aggregation—of clarifying and articulating what it is that societies want and need, while leaving space for variation and dissent. State activity thus reacts to a market and system failures between demand and supply, such as inappropriate signalling of demand to the market, high entry costs, high externalities, and so on. An example would be constructive technology assessment that explores what citizens expect an emerging technology to deliver, and what development they would like to avoid. In the *policy-led* demand articulation, the process is more complex as ideas for innovations may originate with single actors (governments, lead users, etc.) who encounter certain problems. Translating these ideas into priorities and actions calls for an interplay of all kinds of societal stakeholders in the definition of longer term political goals, with the state taking a moderating role for the final political articulation and being responsible. The involvement of stakeholders in a co-creation process increases the effectiveness of

Table 1. Role of the state in articulating demand and supporting market creation.

	Innovation existing	Innovation to be developed/emerging
Existing need or want (user- or citizen-led), poor articulation	• demand articulation and demand instruments to support uptake of innovation, standardisation, regulation, training • Example: ride sharing services	• as left, plus • user (citizen)–producer interaction • complementary supply measures, infrastructure, demonstration • Example: electric vehicles
Challenge to be defined and need to be mobilised to support this challenge (policy-led)	• as above, plus • discourse organisation to define challenge and link emerging markets for innovation to challenge • Example: antiretroviral products against AIDS in Africa	• as above plus • articulation broad to involve all actors relevant for challenge in order to define challenge and identify technologies needed, support complementary technologies, infrastructure • Example: solutions for ageing populations

design and implement measures to achieve those goals (Kuhlmann and Rip 2014), as well as the legitimacy of these measures: because those who benefit from innovations are not always the ones who pay for them. An example of a policy-led demand articulation process is the WHO Priority Medicines initiative that defined an agenda of unmet medical needs, which inspired governments and NGOs such as the Gates Foundation.

In sum, as concerns demand articulation in public policy, we distinguish between any form of support for the (user- or citizen-led) articulation of *existing* needs and wants into demand on the one hand, and the process by which political goals are set and expressed as 'societal challenges' and subsequently supported through measures that mobilise demand in the direction of this challenge (policy-led) on the other hand. In both situations, the solutions required to satisfy the demand may already exist, but lack diffusion, or they may still have to be produced. The requirements for the state in articulating demand and supporting market creations will differ accordingly. Table 1 gives an overview of the role of the state in the various demand–innovation constellations.

The discussion in this section served to clarify the concepts of need and demand, the process of needs articulated into demands, the direction of demand policy as citizen-led versus policy-led, and the consequences for demand articulation. We can now move on to develop our conceptual framework in order to identify the specific requirements for the various—stylised —policy approaches that take needs and demands as focal point.

3. A conceptual framework to understand policies and instrumentation for demand-based policies

To characterise the challenges of policies that are—or should be—oriented towards needs and demands, we suggest a framework consisting of three dimensions (see Table 2 below). We argue that any policy will be designed and assessed against those three dimensions. The first two dimensions are directly related to social acceptance or the legitimacy of the policy. These dimensions are the *legitimacy of the output* and the *legitimacy of the input* or process, which are basic requirements for the decision for and direction of policy. The last dimension has to do with *operational intelligence requirements* for the policy to be designed and for policymakers and stakeholders to learn. Using the three dimensions has an analytical purpose, as it helps develop a more nuanced understanding of the nature of different policy ideal-types and, in particular, the ways in which demand-

and challenge-based policy are governed. For the first time, the three pillars are discussed using three traditional dimensions to characterise policies with what they mean for demand. This also has a normative purpose, as it can underpin a framework to work towards more legitimate and informed need- and challenge-based policy.

3.1 Output and input legitimacy as the linchpin of policy making

Our starting point is the basic, most general requirement for any public policy—that is, its legitimacy. We use a broad concept of legitimacy that has been well established in the literature (Boedeltje and Cornips 2004; Borrás and Edler 2014b; Scharpf 2003). A general definition of legitimacy is social acceptance and popular support of state decisions, or, as Dahl put it, legitimacy has to do with a 'general confidence among the public that a government's power to make binding decisions for the polity are justified and appropriate' (Dahl 1988).[3] Policy legitimacy has two dimensions: output legitimacy and input legitimacy (Borras and Edler 2014a). First, the legitimacy of public policy is based on the output of policy, which means that the intentions and effects of policy are generally accepted as being societally desirable and the intervention used is seen as contributing to that outcome. Second, legitimacy can also be based on the input or process of policy—that is, the way policy goals were defined and the way policy and its instruments were designed and implemented is seen as adequate. The latter has to do with concepts and perceptions of participation, openness, transparency, and the rules of law in the process.

Of course, 'societally accepted' does not imply consensus on goals or processes—far from it. In open societies, most outcomes will remain materially and normatively contested, just as perceptions that differ as to how democratic, participatory, responsible, and responsible a process has been. The higher the heterogeneity in societies and the difference in perceptions of policy goals, the more important is the input legitimacy (Mayntz 2010: 11). The more the process through which a policy goal and instrument is defined is seen as being participatory, deliberative, evidence-based, and transparent, the more likely it is accepted even by those who may differ with the normative orientation of the policy (ibid).

3.1.1 Output legitimacy
Policy interventions, in principle, are associated with a problem or opportunity that justifies that the state intervenes (Borrás and Edquist 2013). The justification will normally be twofold. At the basic, *normative* level, the question is what is to be changed and

Table 2. Conceptualisation of three policies concerned with needs and demands.

	Demand-side innovation policy	Sectoral policies and demand-side measures	Mission- and challenge-oriented policy
Output legitimacy	Market and systemic failures on demand side; creation of markets; societal goals as add-on and further justification	Innovation and economic growth not central; innovation subordinated to sector-specific goals	Beyond economic arguments; goals are inherently political and normative
Input legitimacy	Discourse to determine direction is political and normative; hardly inclusive	Stable, well-established networks determine policy; risk of exclusion and conservatism	Challenge to articulation challenges and coordinate a wide range of actors
Operational intelligence	Lack of methods to assess demand policy *ex ante* (and *ex post*), challenge to understand supply side effects	Stable and settled but there are questions about the scope, timing, and size of policy support	Concrete intervention rationale and instrumentation as well as the input, output, and outcome variables are difficult to determine

achieved in the economy or society (outcome). In our context of need and demand orientation, the basic, underpinning question thus is: are the choices of the societal need as well as the user- or policy-led articulation into demand as a basis for policy widely accepted?

The second level of justification is *conceptual*—that is, the question as to how the policy goal is supposed to be achieved as an outcome of policymaking. This raises the question of the intervention logic—that is, the conceptual rationale for the chosen intervention, the target groups, and the selection and application of instruments in order to achieve the change efficiently and effectively. The question in the context of demand-oriented measures is: are actors convinced that intervention on the demand side with the suggested instrumentation makes a significant contribution to satisfying the demand (and tackling the challenge)? Is directionality induced in ways that are comprehensible to stakeholders?

3.1.2 Input legitimacy

As developed earlier, the input legitimacy of public policy is defined as the social acceptance of the process by which goals and instruments are defined. This is heavily dependent on institutions. Different political systems have different arrangements in place to define goals of policy, and societies differ in their claim for participation and transparency in policymaking (Abromeit and Stoiber 2007). Further, within systems, the arrangements are often very distinct at different levels of policy, where we normally see more direct involvement at the local level as opposed to a more mediated or representative decision making at the national level. Moreover, it is an operational question, as domains and issues are characterised by different levels of material complexity and heterogeneity of the actor landscape that is affected by the instrument or by the intended outcome of the policy. Different policies and instruments will thus differ considerable as to the societal expectation for deliberation and societal discourse and interaction.

In our context of demand-oriented policies, the process of defining policy goals (e.g. problems, challenges, certain kinds of demands, certain kinds of innovations, etc.) as well as policy mechanisms is of paramount importance. What is at stake is the co-definition of the policy goals in conjunction with the co-articulation of needs into concrete demands and the joint understanding of what the bottlenecks are on the demand side against which the intervention can be designed. The buy-in to a policy intervention is critical exactly because of the importance of recognition of the target groups. If improved satisfaction of demand is the goal, the *discourse arrangements* leading up to the intervention are of the essence.

Examples include the German BMBF Foresight Process and the Dutch national research agenda in which citizens play an important role. Interestingly, the emergence and shaping of demands that are turned into policy can create legitimacy later on in the process. Though contested for about a decade by some car manufacturers, the zero-emission vehicle mandate in California can be regarded as an example of public policy that directs and legitimises future innovation (Collantes and Sperling 2008; Wesseling et al. 2014).

3.2 Operational intelligence requirements

Designing, implementing, adjusting, and adapting a policy necessitates all kinds of strategic intelligence to inform policy decision making (Kuhlmann et al. 1999). We specifically focus on operational intelligence—meaning the data and analysis needed to support the design and implementation of policy—to inform the intervention logic and to translate it into concrete choices and instruments. The need for and provision of operational intelligence depends on a number of factors, ranging from the *type of interventions*, the *actor landscape*, the *complexity of the policy problem*, the *decision making* and *implementation structures*, the *location and distribution of expertise*, and so on. To make decisions on demand-side interventions, this would, for example, mean to deploy analytical and discursive methods to understand the needs of potential buyers, the barriers that hinder a better communication between suppliers and buyers, the bottlenecks that hold potential buyers back from purchasing (learning costs, high price, infrastructure gaps, etc.), the potential societal and economic effects of increased diffusion of an innovation, and the current and future capacities of the supply side. This would allow deciding whether demand-side intervention would be justified in the first place, to choose and design interventions that could tackle the identified obstacle, and to identify scale, scope, and duration of the intervention.

4. Towards a better understanding of demand- and challenge-oriented policy

Having developed our understanding of the nature of needs, demand, and demand articulation, and having introduced a three-dimensional concept (output legitimacy, input legitimacy, and operational intelligence requirements) to characterise policy—in particular, demand-oriented policy—we can now critically discuss the three pillars of policies. We start with demand-side innovation policy served as our point of entry and is about traditional *innovation* policy targeting demand for the sake of stimulating innovation

as an economic activity (Section 4.1). Then, we focus on demand-side policy on the level of specific policy sectors (e.g. energy, health, transportation), which is more geared towards particular, sector-specific goals and has a tradition of mobilising demand-side instruments (Section 4.2). Finally, we extend our discussion to challenge-oriented policy that is the 'new kid in town', trying to achieve broad societal goals by making linkages, innovation across sectors, but being somewhat unclear about the role of demand and demand-side policy (Section 4.3). Discussing the three pillars using the three dimensions of Section 3 highlights the specific challenges those policies face and lays the ground for drawing lessons that may help to overcome those challenges.

4.1 Demand-side innovation policy

Edler and Georghiou (2007) defined demand-side innovation policies as 'all public measures to induce innovations and/or speed up diffusion of innovations through increasing the demand for innovations, defining new functional requirement for products and services or better articulating demand'. This policy ideal type sees innovation as the result of an interplay of supply and demand, and asserts that there are a number of reasons on the demand side or between the demand and the supply side that hamper the interaction between demand and supply when it comes to the generation, acceptance, and diffusion of innovation. Though the rhetoric for those policies is often linked to societal challenges—as, for example, when demand-side policies were strongly advocated in the EU (Aho et al. 2006)—the main lever of this policy is to support the capabilities, linkages, and learning that is needed to (co-)generate, absorb, and use innovation. Demand-side innovation policy has become, in some countries, an integral part of governmental science, technology, and innovation (STI) strategies (Izsak and Edler 2011; OECD 2011). Responsibility for this kind of policy is shared between ministries of the economy or innovation and their associated agencies, and the instrumentation of demand-side innovation policy ranges from public procurement of innovation to price-based measures (e.g. subsidies and tax incentives) and a set of measures to support learning, awareness, and articulation (Edler 2016).

4.1.1 Output legitimacy
Demand-side policy as innovation policy draws its main justification from the fact that it tackles market and system failures at the demand side and, thus, supports the build-up and formation of markets (Falck and Wiederhold 2013). Organised by innovation and economy ministries, the expected outcome is an increased uptake of innovation and innovation-driven competition. Those market and system failures include information asymmetries and inefficient interactions between potential buyers and producers, both in the short and especially in the long run. Demand-side innovation policy is citizen-led in terms of supporting the articulation of existing needs for the sake of generating more innovation demand and uptake. For example, Dutch farmers collectively defining agricultural R&D through a farmer-levy funding scheme (Klerkx and Leeuwis 2008). Though there are technological and business uncertainties on the supply side, there are deficiencies in how societies define and articulate their longer term, often latent, needs on the demand side, creating a gap between what society would want to get out of innovation and the direction innovations may take (Boon et al. 2011; Edler 2016). This has to do with the fact that the articulation of needs—or wants—into demands in the market is insufficient. Further, users are often reluctant to pay a high entry price for an innovation and to

create adoption externalities—meaning that the first users of an innovation generate learning benefits that spill over in the system and benefit subsequent users in terms of increased reliability, lowered price, better interfaces, etc. (Arthur 1983).

A second rationale, often driving demand-side innovation policy, is economic. Markets that are at the forefront of asking for and using innovation are attractive for innovative investors as test and lead markets (Jänicke and Jacob 2004; Meyer-Krahmer 2004). Not only will the system benefit from the use of innovation, it will also be a location for innovation generation, with strong interaction to lead users and a high potential for learning both between buyers and producers and between end producer and supply chain. Prime examples include solar photovoltaic systems in Germany (Lehr et al. 2008) and information communication technologies (ICT) innovations in the USA.

Thirdly, and this is the most obvious link to the other two pillars of demand-side policies: demand-side policies are justified through the benefit generated by the use of the innovation—be it in terms of productivity in the private or public sector (process technologies, ICT solutions, etc.) or in terms of societal benefits that products or services offer. However, as an innovation policy, this demand dimension is often under-conceptualised and poorly underpinned by expertise and follow-up. This is the main difference to demand-side measures in sectoral policies (see below), and a major drawback with regard to the input legitimacy of demand-side policies.

4.1.2 Input legitimacy
Traditional supply-oriented innovation policy is understood as being based on an innovation and economic rationale, focusing on uplifting the system to improve innovation performance rather than giving innovation a direction and with limited inclusion of societal groups in the definition of innovation policy. Thus, it is defined mainly between representatives of business sectors and public policy actors. It targets firms, often in conjunction with intermediaries and knowledge providers, and the innovation policy discourse is thus largely an economic one. An example is the Dutch Topsector approach that is defined by the Ministry of Economic Affairs, together with employers' organisations and is demand-driven (Gerritsen and Høj 2013). However, the target group and the benefit claim of demand-side innovation policy have broadened to include public buyers as well as firms and end consumers as private buyers. The broadening poses a challenge for those institutions that traditionally deliver innovation policy. Economic ministries and innovation agencies are generally isolated from those policy actors and stakeholders that are knowledgeable about the issues in specific domains (e.g. health, transportation, energy) and are not embedded in the social networks required to establish the discourse on need articulation, directionality, and learning. Thus, the established, traditional models of innovation hamper the need articulation and discourse necessary to deal with some of the very failures demand-side innovation policy are set out to tackle.

4.1.3 Operational intelligence
Demand-side innovation policy poses a number of operational challenges for all actors involved. One set of challenges refers to the design of policies. Notwithstanding the abovementioned societal discourse on directionality, there are issues about the readiness of the supply side to deliver the innovative solutions, having to do with the maturity of the underlying technology, bottlenecks in the delivery models, and so on (see also Bergek et al. 2007: 416). The

operational intelligence, thus, requires an understanding of the supply side, its future capacities, and how it relates to the demand side. Furthermore, the selection and concrete design of instruments *ex ante* is an issue, as the right level and timing of support on the demand side has been shown to be a real challenge, often leading to deadweight loss and limited effects of public investment, as has been shown for subsidies for thermal insulation technologies for buildings in a comprehensive evaluation of programmes of the 1990s (Kemp 2000) Those issues have to do with a lack of understanding of the specific demand conditions in any given context, the relative importance of the purchasing price as a constraining factor, and limited interaction of societal actors in the design of those innovation policy instruments (Bergek et al. 2007; Edler 2016).

4.1.4 Conclusion

Our discussion has shown that demand-side innovation policy is severely challenged both in terms of input and output legitimacies. This has mainly to do with the established structures to design and deliver *innovation* policy. As for output legitimacy, there are challenges of defining the mode, level, and area of intervention area. This puts more pressure on input legitimacy—that is, the need to demonstrate a level of interaction with stakeholders for the definition of needs and the design and implementation of policies, which are perceived as sufficient by stakeholders. Finally, the operational intelligence requirements go beyond those for supply-side innovation policy, and are harder to fulfil by the traditional innovation policy actors.

4.2 Sectoral policies and demand-side measures

Whereas, in traditional innovation policy demand-side measures are seen as new instruments or as having a revival, they have always been popular in a number of sectoral policies for which the diffusion of new technological solutions is perceived as a major means to meet sector goals. A recent evaluation and synthesis on demand-side innovation policies found that, by far, the greatest majority of demand-side measures are to be found in the energy sector (Edler 2016). For example, energy demand-side management programmes advocated and partly moderated by the international energy agency have a long tradition, using the full range of demand-side instruments from public procurement to awareness measures and labels.[4] Impressive examples of energy transformation programmes mobilising a range of complementary demand-side measures have been documented, for example, in market transformation programmes (Eto et al. 1998). Examples in other sectors include food labels for healthy or environmentally-friendly produce that are quite common, or from the pharmaceutical industry in which safety, product quality, and efficacy criteria are tightly regulated by responsible agencies, as such directing innovation to certain directions (Hill and Rang 2015).

4.2.1 Output legitimacy

Demand-side measures in sectoral policies support market transformation and acceleration geared towards sectoral goals. The generation of innovation or the speed up of innovation cycles, or even the economic benefits in terms of benefits on the supply side, are not the explicit rationale of sectoral policies. Sectoral demand-side policies are thus predominantly state-led—they start with a sectoral goal to push for certain solutions articulated through state policy, which may or may not align with what citizens regard as their needs. Moreover and consequentially, there can be conflicting rationales—at least in the short and medium terms—between the push for

innovation, and the secure, timely, and cost-efficient delivery of a policy or a public service on the one hand and the long-term economic effects of the diffusion policy on the other (Edler 2016; Peters et al. 2012). For example, diffusion programmes for solar cells in Europe have led to increased purchases from China, as such disfavouring European solar innovators but helping to reach sectoral goals such as meeting energy-efficiency targets.

4.2.2 Input legitimacy

In domain-based policies, the articulation of demand and the definition of intervention take place in often well-established sociopolitical actor-networks that are organised around prevalent sectoral policy goals and have been developing over decades. The leading ministries and agencies responsible for the policies serve as focal points, often as initiator and always as addressees of lobby groups of diverse stakeholder interests. Those networks or advocacy coalitions are, thus, very often stable actor constellations around certain issues and solutions, with ample room for contestation about goals, technological alternatives, and policy interventions. The wind turbine industry is an example, with a wide array of promotors—and resisters—engaged in policymaking (Friebe et al. 2014; Jacobsson and Karltorp 2013). The actors are used to articulate their interest in the process of defining policy goals, of deciding on solutions, and of designing instruments. Another example is the Swedish Vision Zero, which is an innovative road safety programme involving a broad coalition of public and private actors that starts from the objective to create a traffic system without any loss of life (Belin et al. 2012).

The input legitimacy depends on the perception of actors about the openness and fairness of the process of problem definition, (technological) solutions, and interventions, the fairness and relevance of the deliberation and negotiation process, and the soundness of the evidence underpinning decisions. The established actor networks and discursive routines allow a targeted interaction of many interested and affected stakeholders. However, input legitimacy can be under pressure due to the abovementioned, well-established institutions and networks. Strong lobbying activities from incumbent players may drown out marginal voices. These peripheral actors include those with less power, actors who are not recognised as a credible counterpart, or actors who are non-users of an innovation due to resistance, rejection, exclusion, or expulsion (Wyatt 2005). Exclusion or marginalisation is especially important if potential contributions to policy goals are situated outside, often adjacent to the established sociotechnical systems and networks. For example, in the political competition for different solutions to energy-efficiency gains for transportation, advocates for innovative videoconferencing are newcomers with entry barriers in the competition with traditional actors, for example, advocates of more effective traditional busses or electrical buses. Outsiders can also pose a serious threat to sectoral networks, which is the case with ride-hailing services like Uber attempting to disrupt taxi companies through suggesting changes in regulation and even sector boundaries.

4.2.3 Operational intelligence

Demand-side challenges in defining policy goals and directionality for solutions within a sectoral policy domain emerge from the definition of bottlenecks for the uptake, diffusion, and use of an innovation that is seen as preferential for society. This has been described above as market and system failures on the demand side (Edler 2010; Falck and Wiederhold 2013). At the same time, as pointed out above, it is important to understand the capability of the supply

side in a specific domain to deliver a reasonable solution and to be able to compare the value of different solutions. Further, as has been shown in numerous evaluations of demand-side policies, especially in energy-efficient technologies, the design for policies to support the diffusion of technologies is very challenging in terms of the right level and timing of incentives (Edler 2016; Kemp and Pontoglio 2011). For example, creating a protective space for electric vehicles using subsidies that induce market demand poses questions about when the electric vehicle industry has matured enough to be able to compete with dominant, conventional cars (Boon and Bakker 2015).

Established domain policies are, in principle, well equipped to tackle those operational challenges, as they are usually characterised by widespread specialised expertise. The ministries or agencies have specialised staff and support through mission-oriented research institutes and specialised public and private research institutes that provide forefront research and support in the definition of problems and interventions. In addition, there is a range of specialised intermediaries, such as regulatory or labelling committees with long histories of expertise. Similarly, businesses and NGOs concerned with the policy have their own intelligence sources for issues in their specific domain. These well-established institutions provide the basis for solid and heterogeneous evidence production. However, it does not guarantee that policy is based on objective and unambiguous evidence, especially as evidence is used in the established, interest- and value-driven political negotiations and as evidence mobilisation is unequally spread. This becomes, for instance, clear in the case of interactions between pharmaceutical companies and regulatory agencies about the safety and efficacy of medicinal products (Carpenter 2004).

4.2.4 Conclusion

Demand-side policy is prominent in specific domains such as energy, food, and healthcare. At the same time, domain-specific policy is not primarily geared to support innovation as such, but—first and foremost—addresses sector-specific targets. Therefore, output legitimacy is linked to the sectoral goal—not to the innovation and economic effect—leading to potential tensions with economic policy goals or a failure to realise the economic and innovation potentials of domain-based policies. Demand-side policy measures are created and managed in the context of a wide range of actors who have a well-established role in the sector and are regarded as legitimate players in the policymaking process. Those policy actor networks, however, can have conservative effects, as they pose a challenge of high-discourse entry barriers for (innovative) newcomers. Finally, operational intelligence requirements are challenged with issues of policy design around form, scope, timing, and size of policy support.

4.3 Mission- and challenge-oriented policy

In dealing with grand societal challenges, policymakers often seem to regard large-scale, centralised R&D projects as archetypes of instruments (Foray et al. 2012). At the same time, Nelson (1977, 2011) in his 'The moon and ghetto' makes the point that, precisely, these solutions are geared to challenges that have well-defined problems and directions for solutions. The mission to get to the moon had a clear end goal, and even the ways to get to the moon were restricted to certain technological trajectories. Societal challenges—such as eradicating poverty or mitigating climate change—are multi-faceted or 'wicked' problems involving a wide array of stakeholders, interests, and institutional levels (Martin 2015; Nelson 2011; Rittel and Webber 1973).

In the last decade, challenge-oriented STI policy increasingly starts from the premise that there are a number of societal problems that are playing at a larger (geographical/institutional/sectoral) and complex scale and are in need of tackling (Ulnicane 2016). Maybe the first explicit example of the term 'societal challenge' in conjunction with strategic innovation policy has been the abovementioned Aho report for the EU, which not only coined the term, but also defined rather broad areas of societal challenges that have hitherto served as orientation for many EU countries, such as health, demographic change, and wellbeing; secure, clean, and efficient energy; and secure societies. Our point here is that the solutions—or even the solution directions—are not clear from the start and that there is an implicit impression that needs and wants, and the demand side in general, should play a role in developing these directions.

4.3.1 Output legitimacy

The basic rationale for challenge-oriented innovation-based policy is the societal benefit of solving an important problem. Thus, there is a need for intervention and extending innovation policy beyond economic growth and employment aims (Aho et al. 2006; Kallerud 2013; Kuhlmann and Rip 2014). Economic literature offers a number of objections to this rationale. First, there is a basic concern of (primarily neo-classical) economists about supporting specific innovation initiatives as these might jeopardise the 'level playing field' and discriminate against non-local practices, and which lead to inefficient allocation of resources (Evenett and Hoekman 2005). Second and related, a more heterodox view argues that, often, the claim to tackle a certain challenge is combined with considerations to prioritise local or national industries. Thus, an implicit normative orientation—to support local suppliers—then distorts the playing field and may be in conflict with the best way of tackling the challenge (similar to Lember et al. 2014). Third, critics claim that even if societies define a certain challenge as important to tackle, to define the right set of policies in order to steer the market efficiently is beyond the operational intelligence of policymaking.

Challenge-based thinking counters the neo-classical view by emphasising that an innovative Europe, addressing issues such as ageing societies and climate change, requires a paradigm shift that extends beyond the narrow domain of R&D. This paradigm shift includes combining supply-side R&D investments with creating markets and demands. Challenge orientation increasingly also extends to the industrial policy discussion, with the notion of 'beyond GDP' industrial policy (Aiginger 2014). It postulates that: (1) the market alone would fail to identify and address a certain challenge; (2) markets on their own even contribute to making a problem bigger; or (3) that societal challenges are too urgent and too complex to leave them exclusively to the coordination of the market. Though we recognise the importance of market forces as coordination and incentive mechanisms, the idea of policy for societal challenges presupposes a positive interplay between market forces and policy intervention, whereby targeted interventions in research, innovation, and use of innovation cannot only create relevant knowledge and technologies, but also alter incentives in the market to form in directions that are likely to help tackle the challenges.

In line with this, systems transition and innovation policy literature also advocate ways to address societal challenges. Taking advantage of scholarly work in transition theory, there is a growing realisation that challenges are no isolated phenomena: they must be seen as embedded in systems. Tackling challenges thus requires system innovation, which implies support for the transition of systems

rather than providing distinct innovations (OECD 2015). As elaborated in the various strands of transition or niche management literature, public policy would not only focus on intervention in the incentive structures of dominant and prevalent markets, but help to create new markets as part of experiments or on a larger regime-level scale (Kemp et al. 2007; Loorbach 2007).

4.3.2 Input legitimacy

The main requirement of challenge-oriented (innovation) policy is to define and select societal challenges to be tackled. To decide which challenge to prioritise —and, thus, to define directionality of innovation activities supporting the challenge—is inherently normative and political. Therefore, in those challenge-oriented approaches, the legitimacy derives from the legitimacy of the established democratic processes and from broad participation of diverse types of actors leading to an inclusive agenda-setting process about missions and challenges. This is not only about deciding on defined alternatives, but also on the very process of defining the challenge—of articulating the challenges themselves.

One issue about defining challenges concerns the level on which challenges should be addressed. Challenges are often defined quite broadly (e.g. sustainability, ageing societies) to allow for many subtopics to benefit from their legitimacy (Latour and Woolgar 1979). However, policies for these challenges need to be broken down to levels in such a way that they are manageable for individual scientists, companies, and governmental agencies (Bos et al. 2013). Such a definition of challenges calls for a broad demand articulation exercise in which problems, solutions, as well as demand bottlenecks are addressed. This might imply fundamental choices to be made.[5] For example, in the context of climate change, strategic goals vary from becoming less dependent on fossil fuels to curb global warming. In general, the way a problem is defined predetermines the kinds of solutions that are put forward and, the less concrete a problem is defined, the more neutral it is towards the solution in terms of technologies and knowledge areas involved (Boon and Bakker 2015).

Defining problems and solutions in the context of broad challenges is inherently associated with engagement of a heterogeneity of interests and values, actors, and directions for solutions. Whereas challenge policies—as sectoral demand policies—are inherently state-led, that is, the starting point is a politically defined challenge, and the process of challenge definition is more complex and contested than in sectoral policies. Governing innovation activities for the benefit of these societal challenges means pursuing a networked solution, for example, in the form of co-creation of innovative ideas and solutions (Funtowicz and Ravetz 1992). This also implies the involvement of a wide array of actors in every stage of the innovation process, ranging from agenda-setting through to doing R&D and implementation of innovations. An example is Vinnova's Challenge-driven Innovation programme in Sweden that involves 'problem owners' in demand articulation during all stages of innovation projects (Palmberg and Schwaag Serger 2017). Coordinating parties need to deal with contestation, non-linearity, and bifurcations in developments in relation with challenge definition (Kuhlmann and Rip, 2018). Mazzucato (2011) has reminded us that governments have been involved in directed coordination as a so-called 'entrepreneurial state' in fields such as renewable energy, defence, and pharmaceuticals for rare diseases. At the same time, new types of institutions may arise that act as coordinators. Examples of such institutional entrepreneurs are public–private partnerships and NGOs, such as product-development partnerships that create novel therapeutics for neglected diseases (Trouiller et al. 2002).

4.3.3 Operational intelligence

Defining and dealing with societal challenges meets a number of operational challenges that, by far, exceed the intelligence challenge of traditional innovation policy. As outlined above, tackling societal challenges—rather than providing a certain technological solution or creating a certain kind of knowledge—means to provide capabilities, to create awareness, to change routines and practices, to build trust, to provide new infrastructures, to change regulation, to create standards and to shift technological trajectories, and so on, in a rather holistic way. To actively manage this transition thus poses a range of operational challenges in order to allow systems and their actors to shift, and public policy action has its inherent limits (Meadowcroft 2009; Voß et al. 2009). To decide on policy interventions—on both the supply and demand side—requires some understanding of the demand and supply conditions and their development over time.

Defining challenges on the right level with a right balance of interests may be facilitated through inclusion of stakeholders and co-creation (Kuhlmann et al. 2016; Nielsen 2014). There have been ample instruments at hand to assist in such process, including challenge-oriented foresight processes (Boden et al. 2012; Cagnin et al. 2012; Georghiou and Cassingena Harper 2011) and constructive technology assessment exercises (Rip and Te Kulve 2008), or the participatory definition of technological roadmaps (e.g. van Doren 2015). Another way to gain legitimacy and mobilise broad societal support is to have prime movers construct a narrative on which policy efforts can be based (Law and Callon 1992; Smith and Raven 2012). At first, the discourse may be rather ad hoc, driven by a first idea of the mission. Potentially, new actors and related discourses feed into the challenge—as such, broadening the support for the challenge and rendering a credible boundary around a policy effort. During the innovation policy process, actors actively maintain the actor network and narrative, and there is a reflexive relationship between the discourse organisation and the mission definition (Boon et al. 2014; Law and Callon 1992). The result is a vision that translates into an experiment that is small-scale in actors involved and has concrete targets. Many grassroots communities working on local energy provision work like this (De Vries et al. 2016). All in all, the operational intelligence to make binding policy decisions to tackle systemic challenges is a result of the very process of articulation of a challenge and the articulation of potential solutions.

4.3.4 Conclusion

Challenge-oriented innovation policy is driven by political and normative goals, which have a broad scope. Policymaking in the context of challenges leads to solution directions that cover a wide variety of actors, fields, sectors, and technologies. Such broad scope brings about the need to manage the divergence, which involves two complexities. First, the content of the challenge needs to be articulated to serve as a concrete vision to direct efforts and predetermines the solution space, but which is associated with normative and causal contestations. Second, the broad endeavour calls for extensive mobilisation and coordination—often taking in diverse actors with very different degrees of involvement and buy-in. These complexities point towards the immense normative, discursive, and operational difficulties of challenge-oriented policies.

5. Conclusion: making sense of needs, demand, and innovation policy

The starting point of this article was our observation of a turn towards directionality in innovation policy, where innovation is not a

goal in itself, but a means to a societal end. We argued that, for innovations to make a difference in society, to tackle a challenge, there must be a demand for them—or at least a conceptualisation of potential demand. We further argued that the demand conditions are often neglected, even when polices claim to tackle challenges. We, thus, set out to build a conceptualisation for policies that focus on directionality of innovations towards societal needs, with a particular role for demand and demand-side policy instruments. This does not preclude the importance of supply-side instruments or the interplay between demand and supply measures. However, given the increasing role innovation policy designates to the demand side without a sound conceptual underpinning, we focus our discussion on policies for the demand side and their association with directionality in innovation policy.

In the conceptualisation of demand-related, innovation-inducing policies, we first proposed the distinction between need and demand as a way to emphasise that the needs need to become articulated into demands. We then introduced the concept of citizen-led (existing needs) versus state-led (largely politically defined needs) demand articulation. We then identified and discussed three ideal-typical pillars: 1, demand-side innovation policies, increasingly popular and implemented in the realm of innovation and economic ministries; 2, sectoral policies that rely on demand-side measures for selected technologies or solutions to deliver policy goals; and 3, challenge policies that seek to develop interventions, which help to contribute to solving societal problems. We summarise the basic features of those three pillars based on the three dimensions we developed to characterise policies. The overview in Table 1 highlights the claims and challenges associated with those policies for *state actors*.

The table shows the various ways in which societal goals return in all three types of policies as a normative underpinning. It displays the fact that economic targets are mainly limited to demand-based innovation policy. This highlights the potential tension between demand-side policies as innovation and, thus, economic policies and challenge- or goal-oriented policies (Alkemade et al. 2011). Furthermore, the central role for needs, wants, and demands as well as different processes of articulation becomes apparent, but a shift towards societal goals, demands, and needs is challenging in all three policies in terms of articulation, policy design, and understanding of policy effects.

We further argue that for challenge oriented- and needs-based policies, there are additional challenges for operational intelligence requirements. First, the scope and scale of the demand failure or problem need to be established, in order to design and implement interventions that have an appropriate intervention lever. This is not an exact science, but rather an articulation exercise in understanding preferences and behaviours of actors. Second, demand-oriented intervention needs to be aware of other conditions that are necessary for innovations to be used and diffused, such as infrastructure, complementary services or networks, and the like. Finally, designing demand measures needs to have an understanding of the existing and developing capabilities of the supply side to react to a change of signals from the market—both in terms of technological capabilities to deliver and in terms of market entry, pricing strategies, and cooperation with users. Demand intervention can be counterproductive if the capabilities and reactions of the supply side are not taken into account and increased demand triggers markets for immature technologies or reduces the incentives to invest in innovation.

Based on these conclusions, we can draw a number of key lessons. The *main lesson* is that challenge orientation in innovation policy—more precisely, output and input legitimacies of policies

that are focused on needs and demands for and directionality of innovation—can be improved through a better understanding *and linkage* of our three ideal-typical policy pillars, thereby overcoming the institutional and cognitive rigidities in each of the pillars. This lesson has repercussions for all three pillars.

First, for *demand-side innovation policies* to work in terms of desired directionality and orientation towards the relevant target groups is needed, allowing for collective learning opportunities and reducing the risk of interventions that run counter to the preferences of targeted users, or failing to influence them appropriately. This is at the heart of the normative claim underlying the demand-side innovation policy pillar, which is to reduce asymmetries between supply and demand and bring innovation generation in line with societal expectation to increase the fit between innovation production and use. Policies that are based on needs and demands must take the definition and articulation of demand at centre stage, as the articulation process itself and its governance determine the output (effectiveness) and input legitimacies of demand policies. The necessary discursive process to articulate needs and to turn them into preferences supported by policy intervention is a politicised process, with multiple layers of contestation not only about maximising economic benefits—prevalent in much of the traditional supply side innovation policy—but also about the normative direction of policy. We further argue that any analysis of the role of policy for directionality of innovation must not only *target* the demand side, but include an analysis of the underlying demand conditions, latent societal needs, changing consumer practices, and their articulation into demands (Coenen et al. 2015; Weber and Rohracher 2012). This also includes awareness of industry contexts and dynamics and technological possibilities in order to produce meaningful innovation policy instruments. Further, it includes an analysis of the underlying contestation, politics, and power games, of who is involved and has voice and who is absent or shut out. For all these reasons, and in order to align different expressions of output and input legitimacy and to meet operational requirements, policy design and implementation need to be supported by those actors close to problems and demand, in order to mobilise knowledge about potential problems, needs, and ways to proceed in a complex actor field. Therefore, a strong link with relevant sectoral policymakers is essential. In fact, if directionality is the goal, all consideration in terms of output and input legitimacies and operational intelligence requirements point towards shifting the responsibility to sectoral administrations, with innovation expertise supporting, rather than the other way round. This could potentially reduce the possible tension between the orientation for transition (the societal goal) and the economic orientation of innovation policy (see for this discussion in Alkemade et al. (2011)).

Second, there is a need for sectoral policymaking to open up. *Sectoral demand policies* are often narrow in ambition, targeting specific technologies in support of their sectoral missions rather than comprehensive system innovations. The specialised expertise of sectoral administrations and their actor networks are functional for specific or isolated problems, but are of limited value or counterproductive when it comes to system-wide challenges or radical alternative solutions. Sectoral demand policies would surely benefit from linking up with broader challenge discourses and policies, to understand the relative contribution of specific technologies and practices in broader systems and in relation to defined challenges. This may also avoid the capture of articulation discourses in sectoral demand policies by established actor coalitions, as it opens up the competitions for and linking with radically different innovations. Moreover,

innovation policy expertise may support sectoral policies in helping to understand systemic bottlenecks and the spillover to economic effects.

Finally, we argue for an enlightened and enhanced *challenge policy* approach, mobilising the strengths of demand-side innovation policy and sectoral demand policy while avoiding their shortcomings. Challenge policies can be conceived of as holistic attempts to transform systems, to bundle different policies and practices across a variety of technologies and sociotechnical systems to tackle challenges that are collectively defined through societal and, often, political processes. The rationale for those policies is compelling; and needs and demands are part and parcel of challenges, though often in an implicit and distributed way. The multi-sided nature of grand challenges, almost by definition, requires involvement of actors and policies across multiple sectors for the articulation of needs and demands as an ongoing process over time, reflecting the co-evolution of user needs and technological options. As actors should be as close to the challenge as possible, and as societal challenges are dealing with multiple issues and arenas, there is a new kind of policy development and delivery required to tackle grand challenges. The focus should be much more explicit on orchestrating the articulation of the challenge and its consequences for the demand for innovations than on the articulation of a specific demand for isolated innovations within the challenge. However, those actors orchestrating challenge policy should involve sectoral policy expertise to support mobilisation of the sectoral discourse for a cross-sectoral challenge discourse and to offer their operational intelligence. Equally, innovation policymakers may support challenge policies by analysing system failures both on the demand and supply side and offering their expertise regarding innovation systems requirements horizontally, supporting with adequate instruments for tackling failures.

Such a more eclectic and reflexive policy approach to challenges would also be able to cope with the tension between aggregation into large challenges for the sake of mobilising for the bigger challenge (e.g. energy systems transition) on the one hand and disaggregation into workable chunks to create concrete demand for distinct innovations (e.g. biomass). The principle of aggregation and disaggregation for the sake of challenge formation and challenge operationalisation concerns questions about the level of the specificity of policy in terms of problems and solutions (technology-specific or not). In addition, the principle would be to mobilise for challenges at the global level, but operationalise them at local and national levels, given the huge shortcomings in global coordination of challenge policies. This, against the backdrop of innovation and sectoral policymaking mostly being national, whereas challenge orientation happens at global, local, and national levels.

We do not argue for one holistic policy approach—a super-merger of responsibilities. There is ample justification for innovation policy that is horizontal and supports demand conditions across the economy or in areas with a specific economic interest. Equally, clear objectives and targeted support in specific sectors is and will remain essential to push for certain societally preferable individual solutions. There is even increasing room for a new type of intermediary organisations, for example, through public–private partnerships, which coordinate challenge-oriented endeavours. But the process to decide upon and design interventions for directionality at all levels can be hugely enhanced, and can gain legitimacy, by taking advantage of existing expertise across government and, more importantly, by creating learning joint opportunities. Policymakers and other actors should, thus, be aware of the nuanced and iterative character of demand articulation.

In terms of institutional set-up, the 'interventionist state' is just one actor of many dealing with societal challenges, but, as *primus inter pares*, can create better conditions and nurture better expertise to take up stakeholder knowledge and provide strategic intelligence at the levels needed. Directional policymaking cannot be a completely top–down, administrative exercise, but it will not organically grow bottom-up either. Intelligent demand policies might be able to create a space in-between top-down and bottom-up activities. The state has a special role in this space, because there is a need for a coordinating role (go beyond sectors), an inspiring role (go beyond incremental innovations), and a strategic role (go beyond easy solutions).

Notes

1. For example, an international inventory of evaluations of demand-side measures found twenty-eight evaluations, which is a very small number in light of the vast number of evaluations in innovation policy.
2. Many further examples can be found in Gillingham et al. (2004), Kemp and Pontoglio (2011); Nemet (2008).
3. As cited in: Wallner (2008).
4. http://www.ieadsm.org/iea-demand-side-management-programme/
5. For example, behavioural scientists protested in *The Lancet* against the medicalisation and dominance of pharmaceutical solutions to psychological disorders in health-related EU programmes. Concretely, they felt that the financing of the Innovative Medicines Initiative, which seizes 1.7 billion euros directly from the societal challenges part of Horizon2020 in the coming years, drowns out behavioural sciences (Galsworthy et al. 2014).

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