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Innovation policy: what, why, and how

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Abstract: During the last two to three decades policy-makers have increasingly became concerned about the role of innovation for economic performance and, more recently, for the solution of challenges that arise (such as the climate challenge). The view that policy may have a role in supporting innovation has become widespread, and the term innovation policy has become commonly used. This paper takes stock of this rapidly growing area of public policy, with particular focus on the definition of innovation policy (what it is); theoretical rationales (why innovation policy is needed); and how innovation policy is designed, implemented, and governed.

Keywords: innovation, innovation system, innovation policy

JEL classification: O32, O38

I. Introduction

During the last two to three decades policy-makers have increasingly became concerned about the role of innovation in economic performance and the solution of challenges that arise.[1] The view that policy may have a say in innovation has become widespread, and the term innovation policy has become commonly used. This paper attempts to take stock of this rapidly growing area of public policy,[2] with particular focus on the definition of innovation policy (what it is); theoretical rationales (why innovation policy is needed); and the design, implementation, and governance of innovation policy.

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[1] See, for example, the 'Innovation Action Plan' agreed by the G20 countries in their Hangzhou Summit in September 2016, http://www.g20.utoronto.ca/2016/160905-innovation.html, consulted on 10 October 2016.

[2] This article focuses on public innovation policy, whereby state actors, often in interaction with other stakeholders, design and implement policy. Although state actors operate on multiple levels, e.g. local, regional (McCann and Ortega-Argilés, 2013; Isaksen and Trippl, 2017, this issue), national, and—to some extent—supra-national levels (Soete and Arundel, 1993; Smith, 2017, this issue), the primary focus here is on the national level. Moreover, we do not elaborate on innovation-oriented policies/strategies of private firms, associations, NGOs, or other non-state actors.

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The next section, which considers the meaning of the term, notes that innovation policy, in the sense of policies affecting innovation, has a much longer history than the term itself, and that there are several different types with varying primary goals/motivations. Section III considers the development of theoretical rationales for innovation policy, from the so-called 'market failure' approach of the early post-war period to the more recent innovation-system framework, and the various policies and policy instruments to which these approaches have provided legitimation. However, in reality policies are not derived exclusively from theory. In fact, as pointed out above, many policies/policy instruments predate the theoretical approaches justifying them. Section IV looks in more detail at policy process, i.e. the design, implementation, evaluation, and revision of policy, the actors involved, and the different types of policy instruments that have evolved in different contexts. Finally section V considers the lessons for innovation policy practice.

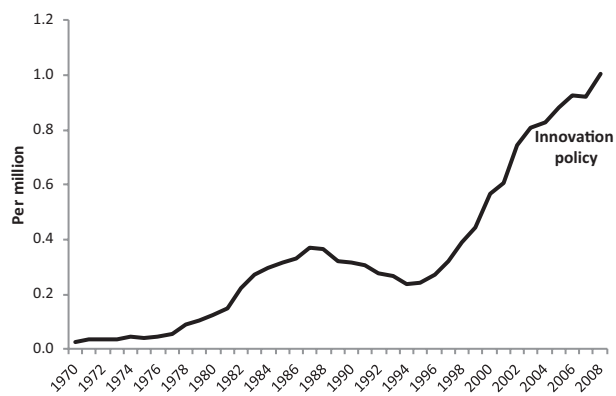
II. What

Innovation policy is, as mentioned in the introduction, a relatively new item on policy-makers' agendas. As Figure 1 shows, the term innovation policy wasn't much used a few decades ago. It is only from the mid-1990s onwards that the term became popular among users.

Does this mean that innovation policies did not exist before that time? That depends on what we mean by innovation policy. If a policy has to have innovation in the label to qualify (as innovation policy) the answer would probably be yes. But if we define innovation policies as those that have an important impact on innovation, as suggested by among others Edquist (2004, 2011), the answer may well be different. In fact, although the term innovation is used much more frequently today than a few decades ago, innovation is a phenomenon as old as mankind itself. From this perspective innovation policies (meaning policies that affect innovation) may have existed for centuries.

The answer to the above question may also depend on what we mean by the term innovation. In popular discourse it is often associated with highly qualified personnel,

Figure 1: The frequency of the term 'Innovation Policy' according to Google



Source: Own calculation based on information from https://books.google.com/ngrams, consulted on 31 May 2016.

working in sophisticated environments, exploiting the latest advances in science, etc. If this interpretation is adopted, only a tiny fraction of the global population, mostly located in high-income countries, would be taking part in innovation and in many if not most contexts the economic effects might be fairly limited. However, contemporary innovation studies apply a much broader perspective on innovation (see, for example, Fagerberg *et al.* (2004)). From this perspective, innovation is understood as the introduction of new solutions in response to problems, challenges, or opportunities that arise in the social and/or economic environment. In the innovation studies literature, such innovation, which is the result of 'new combinations' (Schumpeter, 1934) of existing knowledge, capabilities, and resources, is regarded as a major source of change in all economic activities, in poor as well as rich countries (Fagerberg *et al.*, 2010), in low-tech as well as high-tech (von Tunzelmann and Acha, 2004), in services (Gallouj and Djellal, 2011; Rubalcaba *et al.*, 2012) as well as manufacturing, in the public (Osborne and Brown, 2013) as well as the private sector, and so on.

It was the founding father of innovation theory, Josef Schumpeter, who introduced the distinction between invention (a novel idea for how to do things) and innovation (carrying it out into practice). This perspective points to two aspects of innovation: novelty and implementation. However, novelty may not necessarily mean 'new to the world', it can also refer to something that is new to those that produce or use the innovation. Moreover, novelty does not have to be of the radical kind, offering new functionalities and/or disrupting existing practices (for example, a driverless car), it may also refer to an incremental improvement of a process or a product (for example, a new engine that is 10 per cent more energy efficient).

For Schumpeter, a main reason for his distinction between invention and innovation was the realization that what matters economically and societally is not the idea itself but its exploitation in the economic and social system. Hence, if we want to maximize the contribution of innovation to economic and social change, it is not sufficient to focus on what explains the occurrence of a novelty, we also need a thorough understanding of its adoption and subsequent exploitation. The importance of the exploitation phase was emphasized by the economic historian and innovation scholar, Nathan Rosenberg, who pointed out that:

> most important innovations go through drastic changes in their lifetimes—changes that may, and often do, totally transform their economic significance. The subsequent improvements in an invention after its first introduction may be vastly more important, economically, than the initial availability of the invention in its original form. (Kline and Rosenberg, 1986, p. 283).

Many of these improvements, Rosenberg pointed out, occur in the diffusion phase, through interaction with various involved parties, such as customers and suppliers. Hence, according to this view, innovation policy needs to focus both on the creation of new solutions and their exploitation and diffusion, including the many feedbacks back and forth that occur between the various phases of the innovation process.

Hence, there are different perspectives on innovation, and this is also reflected in policy. There is a narrow perspective, considering invention only, and there is a broader, more holistic perspective, which emphasizes the importance of looking at the entire innovation cycle from the creation of novel ideas to their implementation and diffusion.

Moreover, there is the question of whether one should limit the analysis to policies designed with the explicit intent of influencing innovation, or also take into account policies primarily created for other purposes, but which may have a significant impact on innovation activity.

On the basis of these distinctions three main types of innovation policy may be distinguished.

Mission-oriented policies (Ergas, 1986) are aimed at providing new solutions, which work in practice, to specific challenges that are on the political agenda. Since the requirement is that the suggested solution works in practice, policy-makers need to take all phases of the innovation process into account when designing and implementing policy (broad approach). Policy-makers have adopted such policies for a number of years, for defence purposes, for example, long before innovation policy or even innovation became part of their standard vocabulary, using a variety of labels. Many important innovations, with great economic impact (the internet, for example), have come as the result of such policies (Mowery, 2011; Mazzucato, 2013; Mazzucato and Semieniuk, 2017, this issue). Today, with the world population facing the threat from global warming, such policies may be as relevant as ever (Fagerberg *et al.*, 2015, 2016).

Invention-oriented policies have a narrower focus, in the sense that they concentrate on the R&D/invention phase, and leave the possible exploitation and diffusion of the invention to the market. Such policies became popular in many countries in the early part of post-Second World War period, fuelled by the belief among policy-makers at the time in the potential benefits that advances in science and technology might have for society as a whole (Bush, 1945). This also led, particularly from the 1960s onwards, to the creation of new public organizations, such as (technical) research councils, for channelling such support to firms and public research organizations of various types. Such support was in the past usually considered as part of R&D, research, or science policy, but is today often classified as innovation policy.

System-oriented policies are of more recent origin and focus, as the term suggests, on system-level features, such as the degree of interaction between different parts of the system; the extent to which some vital component of the system is in need of improvement; or the capabilities of the actors that take part. The development of such system-level policies is related to the emergence of the so-called 'national innovation system' (NIS) approach around 1990 and its subsequent adoption by the Organization for Economic Cooperation and Development (OECD) in policy advice and evaluations (see the next section for details).

Thus, innovation policy, in the sense of policies affecting innovation, consists of a range of different policies (and policy instruments) that have been introduced at various points in time, with different motivations, and using a variety of labels, including, increasingly, innovation policy. Some of this may have to do with terminological shifts (Lundvall and Borras, 2004; Boekholt, 2010). For example, much of what is called innovation policy today may previously have gone under labels such as industrial policy, science policy, research policy, or technology policy.[3]

[3] However, the fact that the term innovation policy has become more common does not mean that the older terms have gone completely out of use. For example, Steinmueller (2010), in a recent survey, uses the notion technology policy more or less in the same sense as innovation policy.

III. Why

What are the theoretical rationales that have been advanced for innovation policy? As pointed out above, some innovation policies, such as policies supporting innovation in military technology and certain other activities of vital importance to the state, have been pursued for centuries. This holds for the 'mission-oriented' policies mentioned above, but also for investments in knowledge creation and diffusion in areas considered to be of high importance, such as agriculture. In other words, the modern state has always, as part of its core policy missions, supported the generation of scientific knowledge, technology, and innovation. The implication is that these policies emerged before the birth of the modern social sciences, economics included. It is therefore not surprising that elaborate theoretical constructs, justifying these policies, came (considerably) later, and generally can be seen as *ex post* rationalizations of already existing practices. However, this does not necessarily mean that these constructs are not useful. They provide legitimation (which is always important for policy), they help to shed light on why and how a policy works (or not), and in so doing underpin the process of designing, implementing, and revising policy.

(i) The market-failure approach to innovation policy

An important instance of such *ex post* rationalization was the creation of what became known as the 'market failure' approach to innovation policy in the decades following the end of the Second World War. Both in the US and the UK the governments had during the war invested heavily in innovation in technologies of relevance for warfare—and seemingly with great success. Academics, often with a background in natural sciences, argued that greater public investments were warranted also in other areas of science, and could be expected to have large positive pay-offs for society (Bernal, 1939; Bush, 1945). However, economists, especially those influenced by neoclassical economics (which came to be the dominant perspective), were trained to believe that free markets would produce the optimal result for society. From this perspective such large public investments were difficult to justify. A natural question was: if the pay-offs are so large, why don't private firms undertake the investments themselves?

An answer came as the result of a research effort on the economics of invention and innovation conducted (mainly) within the RAND Corporation in the US, a research arm of the US military establishment, during the early post-Second World War years (Nelson, 1959; Arrow, 1962).[4] This research assumed that the most importance source of innovation was the creation of new knowledge. However, it was argued that in many cases the economic gains of this knowledge could not be fully appropriated by those creating it. Knowledge, being a so-called public good, could be accessed and exploited by anyone everywhere free of charge, dramatically reducing the financial rewards—and hence incentives—to invest in the creation of knowledge. Thus, although the returns to society as whole could be very high, private returns—and hence investments—may be low, leading to underinvestment in the creation of new knowledge in relation to what

[4] See Hounshell (2000) for details.

would be desirable for society as a whole. Such 'market failure', it was argued, may justify policy intervention aimed at increasing the investment in science towards the socially optimal level.

This reasoning lends support to three types of policy instruments in particular (all of which existed well in advance of the theoretical perspective justifying their existence).

(a) Especially for basic research, for which commercialization opportunities lie far into the future and are highly uncertain, private firms lack incentives to invest. The state therefore needs to invest in the *public production of knowledge*, in, say, universities and other public research organizations to safeguard innovations based on science in the future.
(b) *Subsidizing R&D in private firms* is another option as this may induce the firms to undertake more R&D than they otherwise would have done (in the literature this is dubbed 'additionality', see, for example, Pierre Mohnen, Arthur Vankan, and Bart Verspagen (2017, this issue)).
(c) Finally, since the nature of the problem was identified as incomplete legal protection of knowledge and its exploitation, i.e. incomplete property rights (IPR), *strengthening the IPR regime* may be seen as another possible avenue.

The market failure approach to innovation policy is appealing in its simplicity and continues to be influential among policy-makers (OECD 2010*b*) and leaders of organizations that depend on public R&D support (for example, university deans). It has nevertheless been criticized for being theoretically flawed and inconsistent with what is known from empirical research on innovation processes.

First, it has been pointed out that even if market failures of the type considered by the theorists significantly depress innovation activity, it does not follow that governments are capable of improving the situation by designing and implementing adequate policies. Indeed, by doing the wrong thing they may well make the situation worse (so-called policy or governance failure; see, for example, Bach and Matt (2005), Mazzucato and Semieniuk (2017, this issue)). The possibility of such failure is arguably compounded by the vagueness of the policy advice coming out of the market-failure approach. For example, what is the (socially optimal) level that R&D investment should be raised to in, say, a particular country, region, or industry? Without answers to such questions policy-makers are left in limbo.

A perhaps even more fundamental criticism of the approach is that it mistakenly conflates information and knowledge (Metcalfe, 2005). It is pointed out that having access to some information, a manual for example, and understanding how things work and being able to act upon it may be quite different things. The latter is obviously much more demanding. Hence, while information may be easy to access, the same does not necessarily hold for knowledge, in contrast to what the market-failure theorists assume. Moreover, mastery of many different types of knowledge may be required. Not all knowledge is scientific and codified. Much economically useful knowledge is practical and contextual. Knowledge is also widely distributed across actors and contexts. Hence, as emphasized already by Hayek (1945), it is totally impossible for any actor, being a person or a firm (or a government for that matter), to know 'everything' that may be relevant for the solution of an economic problem (what is often called 'perfect knowledge'). In fact, just to identify what the relevant

areas of knowledge are and how these can usefully be approached may be quite challenging (Nelson and Winter, 1982). Arguably, that is why giant firms devote large resources to searching for knowledge of relevance for their activities (Cohen and Levinthal, 1990).

Finally, the strong focus in the market-failure approach on appropriability problems during the early stages of the innovation process[5] has been criticized for being at odds with both established theory and empirical evidence. This focus is clearly not in accordance with Schumpeter (1934)'s innovation theory, which pointed to the implementation (commercialization) phase and inert selection environments at the most challenging (Fagerberg, 2003). It also conflicts with the findings of a series of historically oriented studies which emphasize the importance of improvements (i.e. continuing innovation) that take place long after the first introduction of the innovation in its original form (Kline and Rosenberg, 1986), often as the result of feedback from users (von Hippel, 1988). Moreover, it is inconsistent with evidence from empirical surveys of innovation activity, such as the European Union's community innovation survey (CIS), conducted regularly from 1991 onwards (Smith, 2004). The picture that comes out of the CIS (Fagerberg, 2016*a*), as well as available evidence from elsewhere (Cohen, 2010), shows that firms in most industries are not much concerned about the lack of appropriation mechanisms for the innovations they undertake, probably because the capabilities that underpin their innovative performance are not easily copied (Mark Dodgson, 2017, this issue). Nor are they nervous about interacting closely with other relevant parties during the innovation process. Rather, they see such knowledge exchange, especially with customers and suppliers, as essential for their innovative performance.

Thus, while the market failure argument continues to be invoked as a rationale for policy, particularly as a justification for funding basic public research, it is increasingly seen as inadequate to justify and guide the design and implementation of innovation policy more broadly (Mariana Mazzucato and Gregor Semieniuk, 2017, this issue).

(ii) The innovation-system approach to innovation policy

With hindsight, the period between the end of the Second World War and the early 1970s was a 'golden age', with high growth in productivity and incomes and close to full employment all over the Western world. The decades that followed, however, were much more troublesome, and the view that the new, fresh perspectives on policy were needed became more widespread. Scholars realized that countries do not only differ in terms of economic performance but also with respect to patterns of creating and diffusing innovation and the national institutional frameworks supporting it (Freeman, 1987). The role of technological innovation in long-run economic growth received increased attention from scholars (see, for example, Dosi *et al.*, 1988; Romer, 1990) and policy-makers (OECD, 1992), and policy-makers started to become more concerned about how (and if) policy can contribute to raising innovation activity and thereby

[5] This emphasis on the early stages, i.e. invention, has led to the approach being called 'the linear model' of innovation (Kline and Rosenberg, 1986).

revitalizing the economy. The national innovation system (NIS) approach to innovation policy emerged during the late 1980s and early 1990s (Freeman, 1987; Lundvall 1988, 1992; Nelson, 1988, 1993) in response to the need for a new framework to discuss these challenges.[6] It quickly became popular among policy-makers, not least through its adoption by the OECD (OECD, 1997, 1999, 2002) in subsequent advice and evaluations of innovation policy.

There has been a discussion about whether the NIS approach should be characterized as a theory, framework, approach, etc. (Lundvall, 2007). Arguably, it is best understood as a policy-relevant synthesis of several bodies of research of relevance for innovation: Schumpeter's classic works; several decades of empirical work on what influences innovation; and, to some extent, the 'new' evolutionary economics that surfaced around 1980 (see Fagerberg (2003) for an overview). The emphasis on innovation as the driving force of economic and social change was obviously taken from Schumpeter, as was the view of innovation as a social phenomenon, the consequences of which depend not only on what happens inside firms but also on the broader social and economic environment (into which the innovation is introduced). However, while Schumpeter tended to see the environment as highly inert and constraining for innovation, the advocates of the innovation systems approach—informed by an accumulated body of empirical research (see Freeman (1974) for an early synthesis) and post-Schumpeterian evolutionary theorizing (Nelson and Winter, 1982)—chose instead to focus on how the environment can function as a resource (or enabler) for firm-level innovation—and how policy may contribute to this (Edquist, 2004; Matthias Weber and Bernhard Truffer, 2017, this issue). For example, empirical research had portrayed innovation as an interactive phenomenon, highly dependent on firms' (often imperfect) abilities to engage with other actors in the innovation system (Dodgson, 2017, this issue). Hence, supporting such interaction and the capabilities underpinning it became central policy advice derived from this approach.

National innovation systems are more than frameworks for interaction, however, they are also repositories of various resources that firms depend on in their innovation activities and home to various institutions influencing these. Empirical research had shown how successful innovation depends on a number of different factors, such as knowledge, skills, financial resources, demand, and so on, which to a large extent have been regarded as being provided within the nation—hence the term 'national' innovation systems. Subsequently, the provision of these various factors, which are often seen as complementary, has in the innovation-systems literature invariably been labelled functions, processes, or activities (Edquist, 2004; Bergek *et al.*, 2008*a*; Hekkert and Negro, 2009; Weber and Truffer, 2017, this issue). Arguably, if the system does not sufficiently provide for those factors—such as demand for innovation (Edler and Georghiou, 2007), access to complementary knowledge and skills, or supply of finance—we may speak of a 'system failure' hampering innovation activity. The suggestion from the literature, therefore, is that the state should not limit itself to provide funding for basic knowledge and help to protect innovation

[6] As Godin (2009) notes, the 'system' term—research system, for instance—was already used in OECD documents in the early 1970s. However, Freeman (1987) was the first to apply it to the study of innovation at the national level. Sharif (2006) and Fagerberg and Sapprasert (2011) trace the development of the innovation systems literature.

through implementation of IPRs, as the market failure perspective would suggest, but also identify and rectify such systemic problems (Metcalfe, 1994, 1995, 2005). As the responsibility for the different components of the system is distributed across different areas of government, such a systemic understanding of innovation policy necessitates a 'holistic' perspective on policy (Edquist, 2011) as well as an effective coordination between different parts of government, such as the ministries responsible for knowledge creation, skills-production, finance, and so on (Braun, 2008; Fagerberg, 2016*a*).

(iii) Innovation, path dependency, and policy

Evolutionary economics, on which the innovation system literature draws, emphasizes the crucial role that the balance between creation of new variety, i.e. invention/innovation, and selection play for long-run economic development (Metcalfe, 1998). While variety-creation is the source of long-run growth, selection processes, by eliminating the least promising solutions, contribute to much-needed efficiency. However, if variety-creation for some reason dries up, the economic system may be heading for stagnation. Therefore, following this perspective, preserving the right balance between variety-creation and selection emerges as an important goal for innovation policy.

Selection processes promote economic efficiency but may give raise to path-dependency, particularly where so-called network externalities prevail (David, 1985; Arthur, 1994), which make it difficult to change course at a later stage. This is not necessarily a problem, as long as the conditions that led to the original selection of the key technology, standard, etc. are still valid. But if these conditions change a problem may occur. For example, more than a century ago electric cars were as common as petrol-driven cars, but the selection processes led society to concentrate on the development of the latter, which hence became gradually better, more appealing to users. That probably seemed a good idea at the time, and perhaps was, given the knowledge they possessed. But now we know better because the greenhouse-gases petrol-driven vehicles emit destroy the climate. A century later it is much more difficult to change course, since the petrol-driven car almost has a monopoly in the market, with an unrivalled infrastructure supporting it. How to mobilize innovation policy in support of such socially desirable transformations in the face of path-dependency is a huge challenge for policy-makers that has received considerable attention already (see, for example, Kemp *et al.*, 1998; Rip and Kemp, 1998; Rotmans *et al.*, 2001; Bergek *et al.*, 2008*a*,*b*; Kemp and Never, 2017, this issue).

Path dependency is not something that is only relevant for technology. Arguably, it may be at least as relevant for social, political, and institutional processes (Rose, 1990; Pierson, 2000). This arguably also holds for the evolution of national innovation systems and, hence, innovation policies. National innovation systems typically evolve though interaction between a country's economic system (dominant industries etc.) and its political and institutional system (Fagerberg *et al.*, 2009). Since countries differ economically, and different industries have different requirements with respect to knowledge, skills, finance, etc., the 'knowledge infrastructure' that evolves in response to these needs through interaction with policy-makers tends to get a distinct national flavour,

which may be further strengthened by historical differences in political and institutional systems.[7] This is not necessarily a problem as long as the country's specialization pattern doesn't give reasons for concern. However, if change is needed, such inherited patterns may easily turn counter-productive.

IV. How: innovation policy in practice

While policies refer to goals that policy-makers have for society's development, making it more innovative, for example, policy instruments may be defined as techniques developed in order to achieve such goals (Howlett, 2011; Martin, 2016). The design of such instruments may be influenced by our (theoretical) understanding of the subject matter, lessons from practice, and the involvement of stakeholders at different levels in society. In the following we consider the development of innovation policy instruments, attempts to measure their impact, and how the process of policy design and implementation is governed.

(i) Innovation policy instruments

As our understanding of innovation and its role in social and economic development have progressed, so have the number and characteristics of innovation policy instruments. To assist policy-makers, particularly in Europe (European Commission, 2013), a number of different typologies of innovation policy instruments have been suggested (Edler and Georghiou, 2007; Borrás and Edquist, 2013; Edler *et al.*, 2016*b*; Gök *et al.*, 2016). In Table 1 we make use of a typology developed by Edler *et al.* (2016*b*) based on a comprehensive synthesis of existing evidence on innovation policy instruments.

The table distinguishes between instruments focusing on the supply of or the demand for innovation. It also takes into account a range of innovation policy goals, and shows how the various innovation policy instruments relate to these goals. Fifteen major innovation policy instruments are included in the table. Many of these instruments relate to more than one goal and several goals are tackled by more than one instrument. The first two focus on the creation of new knowledge and innovation through financial support to R&D and innovation, including fiscal incentives for R&D, applied in a number of countries and with a huge variety of designs (Larédo *et al.*, 2016). At least three instruments (3–5) focus on the support of capabilities and skills to generate and commercialize innovation, taking into account the constant need for learning in innovation systems. The next three policy instruments support various forms of interaction and learning at the national and/or regional level (Arne Isaksen and Michaela Trippl, 2017,

[7] For example, as Fagerberg (2016*b*) shows, Norway and Finland are industrial latecomers in Europe, and their nation states are of recent origin. As a consequence, their university systems developed relatively late, and played a limited role in these countries' economic development. What happened instead was that powerful actors geared towards the economic system's needs, so-called PROs (or 'institutes'), developed outside the university system, and this continues to be case. In contrast, in neighbouring Sweden, with a longer history as an independent state, the university system was well developed already a century ago and continues to play a central role in Sweden's national innovation system, while PROs of the Finnish/Norwegian type hardly exist.

Table 1: Taxonomy of innovation policy instruments

Innovation policy instruments	Overall orientation		Goals						
	Supply	Demand	Increase R&D	Skills	Access to expertise	Improve systemic capability, complementarity	Enhance demand for innovation	Improve framework	Improve discourse
1 Fiscal incentives for R&D	●●●		●●●	●○○					
2 Direct support to firm R&D and innovation	●●●		●●●						
3 Policies for training and skills	●●●			●●●					
4 Entrepreneurship policy	●●●				●●●				
5 Technical services and advice	●●●				●●●				
6 Cluster policy	●●●					●●●			
7 Policies to support collaboration	●●●		●○○		●○○	●●●			
8 Innovation network policies	●●●					●●●			
9 Private demand for innovation		●●●					●●●		
10 Public procurement policies		●●●	●●○				●●●		
11 Pre-commercial procurement	●○○	●●●	●●○				●●●		
12 Innovation inducement prizes	●●○	●●○	●●○				●●○		
13 Standards	●●○	●●○					●○○	●●●	
14 Regulation	●●○	●●○					●○○	●●●	
15 Technology foresight	●●○	●●○							●●●

Notes: ●●● = major relevance, ●●○ = moderate relevance, and ●○○ = minor relevance to the overall orientation and stated innovation policy goals of the listed innovation policy instruments.
Source: Adapted from Edler *et al.* (2016*b*, p. 11).

this issue), including cluster support, which has received much attention from policy-makers (Uyarra and Ramlogan, 2016).

While the instruments considered so far may be seen as focusing mostly on the supply of innovations, recently the role of demand for innovation has got more attention (Guerzoni and Raiteri, 2015; Edler, 2016) at national and regional levels (Kaiser and Kripp, 2010; OECD, 2011; UNU-MERIT, 2012). Consistent with this, there are three types of policy instruments (10–12) which focus on influencing demand for innovation in

one way or another. Regulation and standardization influence both supply and demand conditions and incentives (Blind, 2009, 2012). The final instrument in the list, technological foresight, is an approach for policy-makers and stakeholders to understand future technological trajectories and develop policies to support and benefit from such trends.

Thus, over time a rather diverse set of innovation policy instruments has emerged, reflecting different theoretical rationales and political priorities. We now turn to what is known about the impacts of these instruments.

(ii) Innovation policy impact

Policy-makers are naturally concerned about the extent to which innovation policy instruments have the expected impact and, from the late 1980s onwards, there have been numerous attempts to evaluate the effects of innovation policy interventions (Papaconstantinou and Polt, 1997; Georghiou, 1998; Molas-Gallart and Davies, 2006; Edler *et al*., 2010; Edler *et al*., 2012). However, such attempts are beset with difficulties. First, while it may be possible to assess the immediate effects, such as whether R&D support leads to more R&D performed or not, it is much more challenging to assess the wider effects, for example on innovation, productivity, and jobs, which presumably is what policy-makers are interested in. This has to do partly with the fact that innovation is notoriously difficult to measure (Smith, 2004) but also with the very long lags that often exist between innovation and its social and economic impact (Kline and Rosenberg, 1986). Furthermore, as pointed out above, different policy instruments may interact, making it difficult to distinguish their individual effects. Moreover, the impact of any innovation policy instrument is likely to depend on the working of the wider innovation system into which it is introduced. This raises serious questions regarding the usefulness of evaluations of individual policy instruments (Flanagan *et al.*, 2011) and has led to a call for more systemic evaluations (Arnold, 2004; Smits and Kuhlmann, 2004). Nevertheless, although the OECD has made some attempts in this direction,[8] the overwhelming majority of evaluations continue to focus on a single instrument only.[9]

The above-mentioned survey by Edler *et al.* (2016*a*) identified more than 700 academic publications and evaluation reports providing evidence on the impact of various innovation policy instruments. The number of studies varied a lot across instruments, with well-established instruments such as regulation, R&D support, and support to training/skills receiving a lot of attention, while there were only a handful studies on the impact of public procurement. In general the study by Edler *et al*. showed that the immediate effects of innovation policy instruments were in most cases as expected, but that there was much more uncertainty about the wider effects. Differences in context were found to be important—in fact, even identically named policy instruments of the same design were found to lead to very dissimilar outcomes in different countries, and at different times (Edler *et al.*, 2016*c*). The study identified a large number of variables influencing the impact of innovation policy instruments, such as interaction with other interventions (which policy-makers often tended to be unaware of),

[8] For information on 'OECD Reviews of Innovation Policy' see http://www.oecd.org/sti/inno/oecdreviewsofinnovationpolicy.htm.

[9] See Spaapen and Van Drooge (2011) for a discussion of the wider, societal impacts of innovation policy.

conditions for implementation, local and national capabilities, economic structure, the profile and performance of the national science base, the development of financial markets, and cultural factors, e.g. attitudes towards openness, interaction, risk taking, experimentation, etc.

Hence, the available evidence on innovation policy impacts at the national level seems to suggest that a holistic—or systemic—perspective in policy is important (Fagerberg 2016*a*), that sensitivity to context is essential (Flanagan and Uyarra, 2016), and that mechanical transfer of policy practice from one national system to another (without concern for contextual factors) is highly problematic.

(iii) Innovation policy governance

Innovation policy traditionally lies within the remit of industry, education, or economy ministries. As policy-makers' attention to innovation and policies affecting it has increased, specialized public-sector organizations dedicated to innovation support have emerged in many countries. One study claims to have identified around 50 such 'national innovation foundations' (Ezell *et al.*, 2015). Many of these, such as the Swedish Vinnova (OECD, 2013; Fagerberg, 2016*b*), grew out exisiting public-sector bodies supporting science, research, or industry, often as the result of reorganizations, while others, such as UK's Innovate UK (Glennie and Bound, 2016) are of more recent origin. A study of a selected number of such agencies identifies large differences in their structure and priorities (Glennie and Bound, 2016), reflecting to some extent the characteristics of the national systems to which they belong. For example, while the US DARPA supports the development of cutting-edge, high-risk research and innovation projects of potential relevance for the US military, many European innovation agencies have support to small businesses and entrepreneurs, capability-building, and various forms of cooperation/networking at the top of their agendas. The division of labour between the policy principal and the agencies also differs across countries. While in some cases the agencies have considerable independence, reducing the role of the responsible ministry to providing broad guidelines (in the form of an 'innovation strategy', for example) and exercising oversight, in other cases agencies are reduced to mere implementers (administrators) of policies designed at the ministerial level. While strong involvement of government in the shaping of innovation policy may be a good thing, lack of independence at the agency level may be a problem if it leads to these policies being very risk averse, as politicians often are. Innovation projects are inherently risky (Mazzucato and Semieniuk, 2017, this issue), avoiding risk may easily lead to not very innovative projects being selected for support (projects that perhaps could have been financed in other ways), thereby making the policy less effective and undermining its basic rationale.

Another tendency is the increasing involvement of a number of different ministries in innovation policy governance. This partly reflects the increasing importance attached to innovation for economic development at various levels. But it also has to do with the increasing emphasis in several ministries on innovation as a means of solving other challenges that arise, for example with respect to the climate, energy, health, etc. (Edler and Nowotny, 2015). Thus, many (sectoral) ministries have stakes in certain parts of a country's innovation policy, broadly defined, and this may also hold for policy-makers at lower administrative levels (e.g. local and regional) as well as non-governmental actors

(e.g. trade unions, business associations, other NGOs; see Kuhlman and Rip (2014)). The many actors with stakes in the shaping of innovation policy point to the question of how to align the various interests (René Kemp and Babette Never, 2017, this issue), so that the initiatives of different stakeholders complement rather than contradict each other in coordinated policy mixes (OECD, 2010*a*; Magro *et al.*, 2014).[10] This is known to be challenging to achieve, as it tends to conflict with the established structures, practices, and routines in public administration (Flanagan *et al.*, 2011; Flanagan and Uyarra, 2016).[11] Another suggestion for achieving more coordination in innovation policy is the establishment of innovation councils—existing in several countries already (OECD 2010*b*; Serger *et al.*, 2015)—in which representatives of relevant ministries, public research organizations, business, and NGOs come together to discuss guidelines for innovation policy.[12]

The idea that innovation policy may contribute to solutions for urgent societal challenges has further led to an increased involvement of non-state actors in innovation policy decisions and design, co-financing and implementation of innovation policy instruments (Borrás and Edler, 2014; Kuhlmann and Rip, 2014; Mazzucato and Semieniuk, 2017, this issue). This trend has been accompanied by calls for more 'responsible research and innovation', i.e. better governance principles (and processes)—such as anticipation, participation, deliberation, transparency—to ensure that the process and direction of R&D and innovation better take into account societal preferences and concerns around ethics, sustainability, etc. (Hellström, 2003; Owen *et al.*, 2012; Stilgoe *et al.*, 2013; Von Schomberg, 2013).

Finally, there is a persistent governance problem in innovation policy, which has to do with a lack of concern for the international dimension (Keith Smith, 2017, this issue). In fact, while many challenges as well as major innovations and their impacts are transnational by nature, public innovation policy is still largely organized nationally. With some exceptions, notably at European level (see, for example, Soete and Arundel (1993)), there is a lack of international or supranational arrangements to design and implement innovative, systemic policies in areas that ignore political borders (policies that, as Smith (2017, this issue) suggests, may be seen as global public goods).

Innovation policy governance, arguably very important for the design and implementation of effective innovation policies, is an under-researched topic, on which more work, benefitting from an interdisciplinary perspective (including political science/public administration), is needed.

V. Lessons

Innovation policy as a distinct policy area is a relatively new addition to policy-makers' agendas. As shown in this paper the term only came into frequent use around the turn

[10] The available evidence indicates that there are few deliberate attempts to create innovation policy mixes (Cunningham *et al.*, 2016). However, some prominent examples exist within the remit of energy policy, see Neij (1998).

[11] Flanagan *et al.* (2011) therefore express some reservations with respect to how much can realistically be achieved through deliberate design of policy mixes. They suggest seeing innovation policy design and implementation as an interactive process, with constant feedback loops and learning of all actors concerned, and with a high sensitivity to contexts and changes over time (Flanagan and Uyarra, 2016).

[12] Finland is a pioneer in this regard, see Pelkonen (2006) for the history and Fagerberg (2016*b*) for a discussion and comparison with other Nordic countries.

of the millennium, reflecting the increased attention at the time from policy-makers and scholars on the role that innovation plays in long-run economic and societal change. However, innovation as a phenomenon is not at all new, and it can probably be safely assumed that the same holds for policies affecting it. Hence much of what is today classified as innovation policy consists of policies—or policy instruments—with a much longer history than the innovation policy term and that were previously called something else and mainly pursued with other objectives in mind. The perhaps most influential academic proponent of the term innovation policy before it became commonly used, Roy Rothwell, therefore put it well when he characterized innovation policy as a 'fusion' of previous policies/policy instruments carried out under different labels (science policy, research policy, technology policy, etc.; Rothwell, 1982).

However, there is more to innovation policy than that just a shift of terminology. In parallel with the increasing attention to innovation from policy-makers, scholars have—sometimes in interaction with policy-makers—developed a new, systemic approach to the analysis of innovation and policies affecting it (Weber and Truffer, 2017, this issue), and this has among other things led to an increased emphasis on the development of 'systemic' innovation policy instruments (Smits and Kuhlmann, 2004), targeting the interaction of the actors in national innovation systems as well as their capabilities for doing so (which according to the approach cannot be taken for granted but need to be nurtured). The growing interest in innovation policy has, as this paper shows, led to a rapidly increasing body of knowledge on the development and impact of innovation policy (Edler *et al.*, 2016*a*). In the following we attempt to summarize some of the main lessons for policy from this work.

First, innovation is not primarily about generation of new ideas, the traditional focus of science and research policies, but about trying to exploit such ideas in practice in order to enhance competitiveness and respond to problems or challenges that arise. It is this 'problem-solving' nature that potentially makes innovation a relevant force for dealing with important social and economic issues that politicians care about. Innovation policy is therefore particularly relevant when politicians are able to clearly define problems that they want innovation to contribute to the solution of. An effective innovation policy is one that provides direction to a firm's innovation efforts (Mazzucato and Semieniuk, 2017, this issue) and that is credible and not subject to frequent, unpredictable changes. Understood in this way, innovation policy may be a powerful tool for transforming our economy in fundamental ways, e.g. away from its dependence on burning of fossil fuels (Fagerberg *et al.*, 2016; Schot, 2015).

Second, in order to transform economies and cope with societal challenges through innovation, policy-makers may need to adjust their instrumentation. In many countries general subsidies to R&D expenditures in firms (often through the tax system) have been considered as a central element of innovation policy. However, while such subsidies may have some positive effects on firms' R&D investments, particularly in small firms (Castellacci and Mee Lie, 2015), their wider societal effects, e.g. on innovation, productivity, and jobs, are much less certain (Larédo *et al.*, 2016; Mohnen *et al.*, 2017, this issue). To make innovation policy more effective, policy-makers may therefore have to consider changing the policy mix away from generic R&D subsidies in the direction of policy instruments associated with the solution of important challenges (or 'problems') that are high on societal and political agendas. This may well require increased emphasis on policy instruments that hitherto have received less attention,

such as policies affecting the demand for innovative solutions—use of public procurement, for example—and regulation. A correct choice of policy instruments will require thorough understanding of the systemic bottlenecks that hinder the generation and diffusion of innovations, ranging from inadequate skills/capabilities, lack of interaction, or uncertainty about (future) demand.

Third, as numerous entrepreneurs have learnt the hard way, the most difficult challenge in innovation is to survive 'the valley of death', i.e. the phase between idea generation and exploitation. Therefore, an effective innovation policy needs to place emphasis on supporting experimentation, implementation, and exploitation, particularly at an early stage, while at the same time allowing different approaches to the solution of a problem to co-evolve and compete. Fundamental uncertainty about what in the end will be the best solution is an inherent property of innovation, and it is of vital importance that promising experiments are not aborted prematurely, i.e. before a sufficient knowledge base has been developed and robust conclusions can be drawn. A good example in this respect is the German Energiewende, which supported the evolution of several different green technologies, at different degrees of maturity and costs (Lauber and Jacobsson, 2015), rather than focusing on what at a particular point of time appeared as the most promising (cost-effective) solution.

A fourth lesson is that innovation is not only relevant in a narrow range of science-based (or high-tech) activities or in manufacturing industry, but may be a potent force of change in all parts of society (Martin, 2013), including, for example, services industries, creative industries (Benaim and Tether, 2016), and the public sector, or in the form of social innovation (van der Have and Rubalcaba, 2016). Thus, innovation policy should not be a reserve for a single ministry or governmental organization. Arguably all ministries (and government at all levels) should be concerned about how innovation—and innovation policy—may affect their ability to fulfil their mandate. Hence, the responsibility for innovation policy needs to be broadened across different parts/levels of government (Edler and Nowotny, 2015). Moreover, an effective innovation policy, supporting societal challenges and transformation of economies, cannot rely solely on traditional state-centred intervention but requires the development of appropriate forms of coordination among all actor groups, including non-governmental actors (Kuhlmann and Rip, 2014), that influence the trajectories of innovations and their diffusion.

Finally, developing effective innovation policies in the way just outlined is a demanding task, which requires a deep understanding of the context, e.g. the national innovation system, into which the policies are introduced. This requires capabilities among policy-makers that cannot be taken for granted but need to be nurtured. Therefore, a major challenge for innovation policy in the years to come will be to increase the capabilities of policy-makers and other stakeholders involved in innovation policy-making. Moreover, a challenge-driven policy aimed at systemic innovation (OECD, 2015) of the type outlined here will require a long-term perspective, and set-backs and failures are likely (and to some extent unavoidable, as Mazzucato and Semieniuk (2017, this issue) point out). Such policies may therefore become more contested politically than innovation policies have been hitherto, which underlines the need for more reflexivity and capability in innovation policy-making at all levels.

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