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Innovation Policy: What, Why & How

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Abstract

During the last two-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 for 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.

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Introduction

During the last two-three decades policy-makers have increasingly became concerned about the role of innovation for economic performance and the solution of challenges that arise.[1] The view that policy may have say for 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. 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 three 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 that these approaches have provided legitimation to. 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 four looks in more detail on 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 five considers the lessons for innovation policy practice.

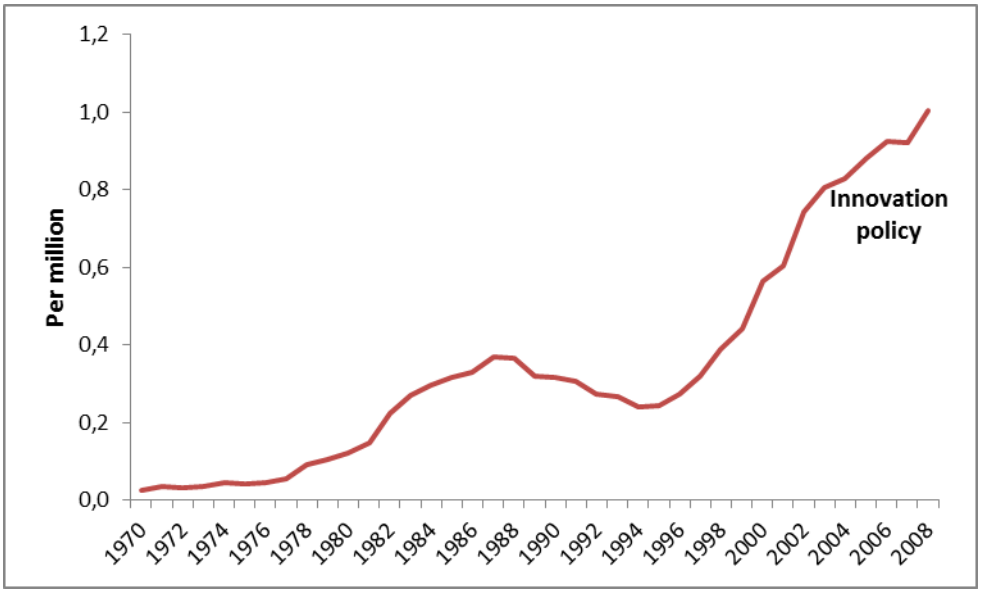
What

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.

[1] See, e.g., 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 October 10, 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), national and - to some extent –supra-national level (Soete and Arundel 1993), the primary focus here will be on the national level. Moreover, we will not elaborate on innovation oriented policies/strategies of private firms, associations, NGOs or other non-state actors.

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 May 31, 2016

Does this mean that innovation policies did not exist before that time? That depends on what we mean with 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 policy as policies 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, 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 to 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, e.g., Fagerberg et al 2004). Following 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 (Rubalcaba et al 2012, Gallouj and Djellal 2011) 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, that 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 (e.g., a new engine that is 10% 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: 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 that 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 defense 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 (Mazzucato 2013, Mowery 2011). Today, with the world population facing the threat from global warming, such policies may be as relevant as ever (Fagerberg, Martin and Laestadius 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, fueled by the belief among policy makers at the time about 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 channeling 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 notion 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 OECD in policy-advice and evaluations (see the next section for details).

Thus , innovation policy, in the sense of policies affecting innovation, consist 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 meaning as innovation policy.

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 & how a policy works (or not), and in so doing underpin the process of designing, implementing and revising policy.

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 2nd World War. Both in the US and the UK the governments had during the war invested heavily in innovation in technologies of relevance for the 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 payoffs 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 payoffs 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 2nd 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

[4] See Hounshell (2000) for details.

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 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").

(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 2010b) 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 failure", see e.g., Bach and Matt 2005). The possibility for 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 a 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 understand 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 with 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 sake), 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 search 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 2016a), 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. 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

[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).

inadequate to justify and guide the design and implementation of innovation policy more broadly.

The innovation-system approach to innovation policy

With hindsight the period between the end of the 2nd 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, e.g., Dosi et al 1988, Romer 1990) and policymakers (OECD 1992), and policymakers started to become more concerned about how (and if) policy can contribute to raise innovation activity and thereby revitalize 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 policymakers, not the 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. For example, empirical research had portrayed innovation as an

[6] As Godin (2009) notes, the «system» term - research system for instance - was used in OECD documents in the early 1970s already. 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.

interactive phenomenon, highly dependent on firm's (often imperfect) abilities to engage with other actors in the innovation system. 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 labeled functions, processes or activities (Edquist 2004, Bergek et al. 2008, Hekkert and Negro 2009). 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 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 2016a).

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 as a good idea at the time, and maybe 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 has an almost monopoly in the market, with an unrivalled infrastructure supporting it. How to mobilize innovation policy in support such socially desirable transformations in the face of path-dependency is a huge challenge for policy makers that has received considerable attention already (see, e.g., Kemp et al 1998, Rip and Kemp 1998, Rotmans et al 2001, Bergek et al 2008, Bergek, Hekkert et al 2008).

Path dependency is not something that only is 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 flavor, 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.

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 and Rayner 2011, Martin 2016). The design of such instruments may be influenced by our (theoretical) understanding of the subject matter, lessons from

[7] For example, as Fagerberg (2016b) shows, Norway and Finland are industrial latecomers in Europe, and their nation-states are of recent origins. 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 neighboring Sweden, with a longer history as an independent state, the university system was well developed already a century ago and continues to play a very central role in Sweden's national innovation system, while PROs of the Finnish/Norwegian type hardly exist.

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.

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 (Borrás and Edquist 2013; Edler and Georghiou 2007; Edler, Gök, et al. 2016; Gök et al. 2016). For the purpose of this paper we will in Table 1 below make use of a typology developed by Edler et al. (2016) based a comprehensive synthesis on existing evidence on innovation policy instruments.

Table 1: Taxonomy of innovation policy instruments

Chapter Title and Instruments	Overall orientation		Goals						
	Supply	Demand	Increase R&D	Skills	Access to expertise	Improve systemic capability, comple-mentarity	Enhance demand for inno-vation	Improve frame-work	Improve discourse
1 Fiscal Incentives for R&D	●●●		●●●	●○○					
2 Direct Support to Firm R&D & 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	●●○	●●○							●●●

●●● = 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, Gök, et al., 2016, p. 11

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. 15 major innovation policy instruments are included in the table. Many of these instruments relate to more than one goal and vice versa. 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, including cluster support, which has received much attention from policymakers (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 (Edler, 2016 ; Guerzoni and Raiteri, 2015) 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), while a final instrument, 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 have emerged, reflecting different theoretical rationales and political priorities. We now turn to what is known about the impacts of these instruments.

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 (Edler et al., 2012; Edler.J. et al., 2010; Georghiou, 1998; Molas-Gallart and Davies, 2006; Papaconstantinou and Polt, 1997). 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 shown in the previous section, 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 sought introduced. This raises serious questions regarding the usefulness of evaluations of individual policy instruments (Flanegan et al 2011) and has led to a call for more systemic evaluations (Arnold, 2004; Smits et al., 2008). 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) 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, Shapira, et al., 2016). 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), 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 2016a), 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.

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, specalized public sector organisations dedicated to innovation support have emerged in many countries. One study claims to have identified around fifty such "national innovation foundations" (Ezell et al. 2015). Many of these, such as the Swedish Vinnova (OECD 2013, Fagerberg 2016b), 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 identify large differences in their structure and priorities (Glennie and Bound 2016), reflecting to a some extent the characteristics of the national systems to which they belong. For

[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.

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 on 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 these to be very risk averse as politicians generally are. Innovation projects are inherently risky, 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 to solve 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, so that the initiatives of different stakeholders complement rather than contradict each other in coordinated policy mixes (Magro et al., 2014; OECD, 2010a).[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 to achieve more coordination in innovation policy is the establishment of innovation councils - existing in several countries already (OECD 2010b, Serger et al. 2015) - in which representatives of relevant

[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).

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 (Kuhlmann and Rip 2014; Borrás and Edler 2014). 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 takes 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. 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, e.g., 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 can be seen as global public goods[13]).

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

Lessons

Innovation policy as a distinct policy area is a relatively new addition to policy makers' agendas. As shown in this paper the term did only come into frequent use around the turn of the millennium, reflecting the increased attention at the time from policy-makers and scholars on the role that innovation play in long run economic and societal change. However, innovation as 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

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

[13] We owe the idea of a lack of international arrangements to support the production of necessary public global goods to Keith Smith (2016).

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, 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 for innovation policy has, as this paper has shown, led to a rapidly increasing body of knowledge on the development and impact of innovation policy (Edler at al 2016). In the following we will do an 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 firm's innovation efforts 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 Lie 2015), their wider societal effects, e.g., on innovation, productivity and jobs, are much less certain (Larédo et al 2016). 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 harsh 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 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 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 knowledgebase 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 (Jacobsson and Lauder 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 e.g., 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 fulfill 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 needs 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 are likely. Such policies may therefore become more contested politically than innovation policies have been hitherto, which underlines to the need for more reflexivity and capability in innovation policy making at all levels.

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