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What do we know about innovation policy?

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This chapter reviews developments in both theory and practice across the different generations of science, technology and innovation (STI) policy with the aim to provide an overview of the growing STI literature and characterize the current status of STI policy. It shows that over time innovation policy has witnessed a cross-generational shift from a too simple to a too complex conceptualization of the innovation process. The chapter goes on to describes governance, coordination and change management challenges inherent in the design and implementation of transformative innovation policy and their implications for policy evaluation and impact assessment. Finally, it then moves on to review approaches characterizing impact evaluation in the three generations of innovation policies while paying specific attention to the evolutionary nature of innovation policy development and the co-existence of the three generations in contemporary evaluation practice.

2.1. Introduction and terminology

There has been a growing interest in innovation policy over the recent decades and in the relationship between innovation and economic performance. More recently, innovation has been called upon not only to improve economic performance, but also to support efforts to address a variety of problems across different sectors and policy areas, problems that are commonly referred to as societal challenges. Yet, both the concept and the practice of innovation policy as a type of public policy, although more recent, are not new. The terminology surrounding innovation policy is also influenced by the meaning of innovation, which according to a broad perspective, involves the development and/or implementation of a new policy, tool, service or method. Multiple definitions of innovation exist in both the academic literature and consultancy circles, which have influenced the understanding of innovation in both the private and public sectors (Dan, 2021; Edler & Fagerberg, 2017).

There is agreement that innovation is something that is created that adds value to the individual, organization or society (de Vries et al., 2016). On this basis, innovation is different from an invention, a recent technology, system, process or a new policy. These novelties can form the basis for innovation but are not necessarily innovations if they do not produce added value. It was Joseph Schumpeter, the founding father of innovation theory, who introduced this distinction which points out the importance of both the novelty of an idea and its practical implementation. Schumpeter argued that innovation results from 'new combinations' between existing resources, knowledge and skills that can have significant economic and social impact (Schumpeter, 1934). It was the application of inventions to economic and social processes that was important to Schumpeter. Although innovation typically involves providing something new, it does not need to be new to all recipients. It can also mean an offering that is new only to a specific geographic area, type of organization or user group. Moreover, innovation does not refer only to transformative change, but it can also include incremental and isolated change that does not revolutionize entire industries but can, nevertheless, bring about noticeable improvements (Edler & Fagerberg, 2017). These ideas imply that understanding the adoption and utilization of innovations in economic and socio-technical systems is essential to innovation policy.

In addition to innovation policy, there are other terms that are used to denote similar aspects, but with a different emphasis. Despite this, the construct innovation policy has become increasingly popular over the past two decades. These other terms include industrial policy, science policy, research policy or technology policy, as well as combinations between these terms such as research and development (R&D) policy or research, development and innovation (RDI) policy and science, technology and innovation (STI) policy (Steinmueller, 2010).

Innovation policies 'refer to government policies aimed at fostering the use of the best S&T to produce new and competitive "first-to-market" products and new production processes, and the innovative organizational approaches and management practices to support these activities' (Doern

& Stoney, 2009). Innovation policy is a broader term than the other terms that are used by both scholars and policymakers in that it also includes aspects related to commercialization as well as demand-side policies for innovation (Martin, 2015).

2.2. Innovation policy: A cross-generational shift from too simple to too complex

Based on the relationship between science, technology and innovation on the one hand and society on the other hand, starting from the post-Second World War era, the literature distinguishes between three main generations of innovation policy: the science and technology policy, national innovation systems and transformative innovation policy. These are known in the literature under different labels, and while some authors refer to them as generations of innovation policy (as we do, see for example Arnold et al., 2018), others see them as 'frames' or 'framings' (Schot & Steinmueller, 2018) or 'policy paradigms' (Diercks et al., 2019; Weber & Truffer, 2017). Regardless of the labels used, there is agreement among scholars that these distinct types of policies and instruments share similarities, while also having different emphases and being different in important ways. As they consist of partly contradictory elements and prescriptions, they compete with one another for policymakers' attention, who may incorporate a mixture of goals and objectives that stem from all three paradigms.

The three innovation policy paradigms are also products of their specific generations, and are anchored in the historical, socio-economic and technological context in which they were developed (Schot & Steinmueller, 2018). The science and technology perspective emerged in the aftermath of World War II in which particular attention was focused on innovation for growth. In this historical context, there was significant interest in the role of scientific discovery and technological development for providing economic and social prosperity and maintaining peace. The state emerged as an actor that governed these processes. Scientific efforts related to nuclear energy and space programs gave rise to government-led 'mission-oriented' innovation policies that centered on these industries yet created a sense of common purpose and scientific optimism (e.g., Sen, 2013). The national innovation systems paradigm emerged gradually in the 1980s in a new context defined by an acceleration of international competition and globalization that fueled both the prospect of increased prosperity and concerns about economic downturn and uncertainty.

The third perspective – transformative innovation policy – is also a product of its generation in which there has been a growing interest in the application of innovation to address societal challenges and global 'wicked problems'. Transformation refers to changes in socio-technical systems as understood in the sustainability transitions research (e.g., Kanger et al., 2020). Its origins go back the 1960s and 1970s when periods of social unrest and signs of environmental damage helped policymakers to start considering the societal implications of innovation in addition to the existing economic agenda (Kallerud, 2010). These challenges are captured in the UN's Sustainable Development Goals and range from poverty and inequality to climate change and sustainable production and consumption. The third paradigm also rests on the increased popular awareness of such challenges and multiple calls to act in a concerted way across geographic and sectoral boundaries to address them. These characteristics enable the third-generation innovation policy to capture a problem-centered approach more directly and aim to increase its societal impact.

Despite sustained criticism of particularly first-generation, and to a less extent of second-generation, innovation policy and the more recent trend towards an emerging transformative innovation policy paradigm, all three generations co-exist and contribute relevant elements that build upon each other. They constitute different layers that add to existing instruments and arrangements, but do not entirely replace them. However, although the three generations are best understood through the lens of policy layering, instead of policy replacement or policy drift (Kern & Howlett, 2009), this does not mean that the different co-existing layers are equally relevant at a given point in time. The post-Second World War era was dominated by the science and technology policy that followed a linear model of innovation. Later, however, this paradigm was challenged, starting gradually from the 1960s onwards by a partly alternative approach, crystallized in the 1980s, that centered on interdependencies and the need to build national innovation systems. Furthermore, this second policy paradigm was later challenged by voices which, from the early 2000s onwards, have started to call for a greater societal impact of innovations and the need to focus policy attention, across different sectors and actors, on societal challenges.

The degree of complexity of the innovation process and innovation space where innovation activity occurs has increased from one generation of innovation policy to another, impacting the range of factors that influence the results of innovation processes. There is a growing recognition that these processes are neither linear, as it was originally believed, nor mechanical and the behavior of innovation actors is influenced by a variety of economic, political, administrative and cultural factors.

The innovation studies literature has focused to a substantial extent on the benefits of innovation while analyzing to a lesser extent the negative consequences of innovation. Some authors recognize that there is a 'pro-innovation bias' (Diercks et al., 2019) in the literature that ignores that many of the challenges that innovation policies are currently seeking to address are a result of previous innovations and technological developments (Soete, 2013). Innovation can also lead to destructive creation, loss of jobs and social problems while its effects can be uncertain and both intended and unintended (Jalonen, 2012).

2.2.1. Science and technology policy: A linear model of innovation, fundamental research and scientific discretion

The first generation of innovation policy followed a linear model of innovation, according to which government funds science according to scientific principles to create technological progress and economic development. Fundamental scientific research, as opposed to applied research, and scientific discretion was, and still is, key in this perspective (Arnold et al., 2018). Although the linear model has been criticized for being too simplistic and detached from social goals, it has its advantages and innovation policy funding nowadays still partially follows its principles. These include the scientific and educational role of fundamental research which spans a variety of fields from across the scientific spectrum which may not directly contribute to economic goals, but still have an important societal contribution. Another advantage of fundamental research funded through the linear model is the belief that academic and scientific freedom are important principles for scientific development. Research councils occupy a prominent place in funding research in the first-generation innovation policy paradigm.

The basis for government intervention in research and innovation in the first generation centered on the concept of market failure. According to this idea, profit-seeking organizations do not have a strong enough financial incentive to produce a level of research and innovation that is socially optimal. As a result, they produce less than required, which has a negative effect on societal well-being. Given the market failure, the government intervenes to correct this failure, leading to the production of a socially optimal level of research and innovation. Closely related to the idea of market failure, the rationale for government intervention is also based on the nature of research and innovation, which are public goods and produce positive externalities for society (Edler & Fagerberg, 2017).

The research and innovation policy instruments used in the post-WWII years included, to a significant extent, grant funding to individual researchers that focused on fundamental research with little state interference regarding the direction of the research (Arnold et al., 2018). This type of instrument was complemented with mission-oriented policies that resonate in a sense with the mission-focused instruments used in the third generation of innovation policy, but they tended to focus on the defense sector.

2.2.2. National innovation systems: A nationally coordinated policy approach to innovation

The origins of national innovation systems approach are in the 1960s when an interest gradually developed to approach the relationship between science and society through national policy levels in a more integrated way to direct scientific and technological development towards national social goals. Thus, a national policy approach to scientific research, technology and innovation was in the making. Research agencies were created to complement the work of existing research councils and to direct funding towards socially relevant research, although this relevance was to a good extent related to research for industrial development with little practical application to societal challenges as they are presently understood (Edler & Fagerberg, 2017).

It was increasingly recognized that relationships between innovation actors are instrumental to innovation processes and growing interdependency led to critiques of the linear model and the adoption of a ‘national innovation systems’ approach (Freeman, 1987; Weber & Truffer, 2017). This more recently led to an emphasis on holistic innovation policy that accounts for the multiple independencies that define innovation systems (Borrás & Edquist, 2019). With the second generation of innovation policy, there has been a significant shift towards the key role that the state plays in governing and coordinating national innovation systems. Influential in this perspective was the OECD's contribution, which emphasized the systemic approach to innovation and the need for 'whole-of-government coordination' (OECD, 1999).

If the basis for government intervention in the first generation focused on market failure, in the second generation more emphasis is placed on system failure. System failure represents the inability of national innovation systems to operate in an optimal way, leading to various barriers (political, administrative, economic, governance, etc.) that hinder innovation and result in sub-optimal outcomes.

At the beginning, the second-generation funding schemes inherited the characteristics of the first-generation instruments, consisting of small research grants allocated to individual researchers to carry out fundamental research. These were used in addition to the schemes for funding large technology projects in the 1960s, such as the moon race and the Concorde supersonic airliner (Arnold et al., 2018). However, gradually there has been a transition, particularly evident in the 1980s, towards the competitive funding of more joint arrangements, such as clusters and networks of technologies, including information technology and communication programs.

2.2.3. Transformative innovation policy: Tackling societal challenges and socio-technical transitions

The third generation of innovation policy, which goes back to around 2000, is closely tied to the idea that research and innovation should be put to work to address societal challenges. This represents a normative shift (i.e., what innovation should be used for) in innovation policy that challenges the national innovation systems approach. Its core basis is that policy should not be directed only at optimizing the innovation system to produce economic benefits, but also at strategically directing and governing transformative change that results in desirable and agreed-upon societal goals (Diercks et al., 2019). The inclusion of societal challenges in the EU Framework Programme for Research and Innovation was instrumental to this end. To address societal challenges, it is believed that innovation policy should be 'transformative', which involves a significant, potentially radical, change in existing technologies, structures and processes in socio-technical systems (Schot & Steinmueller, 2018). The complexity of the challenges that transformative innovation policy is called to address stems from the multiple characters of societal challenges and socio-technical transitions, which involves notable change not only in technologies, governance and institutions, but also in social values and behaviors (Kanger et al., 2020). This increased level of complexity concerning the types of required changes raises questions about the feasibility and effectiveness of transformative innovation policy and the nature and range of policy instruments that need to be designed and applied to enact transformative change. It thus constitutes a greater challenge than under the previous generations of research and innovation policy.

The transformative innovation policy paradigm is based on a set of different discourses and theoretical assumptions that have in common a broad understanding of innovation that goes beyond its technical dimension. In this perspective, innovation is not solely based on expert-only scientific and technical knowledge that is produced in laboratory settings. These ideas recognize several types of innovation, as well as different innovation actors, activities and mechanisms that create and diffuse knowledge, including open and networked mechanisms to which a variety of actors can meaningfully contribute. As Diercks et al. (2019) outline, these theoretical discourses include social innovation (Mulgan, 2012), complex adaptive systems (Gunderson & Holling, 2001), eco-innovation (Kemp, 2011), grassroots innovation movements (Smith et al., 2014), inclusive innovation (Heeks et al., 2017), responsible research and innovation (Owen et al., 2012), open innovation (Chesbrough, 2003), user innovation (von Hippel, 2005) and innovation diffusion theories (Rogers, 2010). However, these theories do not constitute a consistent whole and may be based on contradictory premises that contribute to the eclectic nature of the third generation of innovation policy.

The basis for government intervention in this policy paradigm is less theoretically developed than in the previous two paradigms, and it is less clear to pinpoint why government might need to intervene (Arnold et al., 2018). However, a combination of reasons, including both market failure and system failure, coupled with the need for transnational coordination and alignment of interests and agendas may justify this intervention. Within the transformative innovation policy paradigm, Weber and Rohracher (2012) note that we are dealing with a transformational system failure and distinguish between four types of failure: directionality failure; demand articulation failure; policy coordination failure; and reflexivity failure.

The inability to develop, agree on, fund and implement a shared vision, strategy and goals concerning the direction of the transformation process explains the directionality failure. Demand articulation failure is related to insufficient attention allocated to understanding user needs and the uptake of innovations from the user's perspective. Lack of multi-level policy coordination across different administrative levels, from regional to international, or technological and sectoral systems, as well as between public and private actors, creates a policy coordination failure that hinders alignment between different systems and institutions and results in policy inertia. Finally, the reflexivity failure refers to an insufficient ability of the system for self-governance, which involves the capacity to 'reflect' on its own progress, anticipate future developments and monitor progress by creating feedback loops that feed into on-going processes and move developments to the next level.

The research and innovation policy instruments have expanded over the years in terms of size, duration and scope. If supply-side instruments dominated the first- and second-generation policies, demand-side schemes have gained renewed traction in the third generation and have been used in parallel with the latter (Edler et al., 2016). Examples of demand-side instruments include:

- private demand for innovation;
- innovation procurement and other public procurement policies;
- pre-commercial procurement;
- the set-up of lead markets;
- innovation inducement prizes;
- use of standards;
- integration on demand-side actors into innovation processes;
- technology foresight;
- commercialization of research results (Edler & Fagerberg, 2017; Arnold et al., 2018)

The goals of the instruments vary depending on the overall orientation of the instrument (demand side or supply side) while a specific instrument may have multiple goals (Edler & Fagerberg, 2017).

Established and widely used supply-side instruments, such as fiscal incentives for R&D and direct innovation support to firms, aim to increase R&D, while training and skills policies aim to develop human capital. Other goals of 15 innovation policy instruments identified by Edler et al. (2016) include improving access to expertise, increasing systemic capabilities and complementarities and supporting the demand for innovation.

The innovation policy instruments that need to be used to support transformation in socio-technical systems tend to be more complex than those used previously and this complexity stems from a larger number of stakeholders, including demand-side actors, and the nature of the goals envisioned. The goals of transformative change and socio-technical transitions mean that a variety of actors, policy levels and instruments need to be aligned over time to address 'transformational system failure' (Weber & Rohracher, 2012). However, the extent to which existing policy instruments are aligned with and suitable for addressing complex policy goals is debatable. Martin (2015) discusses this potential misalignment by considering four types of changes that have occurred as governments and regions are seeking to transition to a transformative innovation policy agenda:

- a change from linear to systemic thinking;
- a shift from national governments to multi-level governance;
- a transition from individual organizations and actors to collaborative arrangements and networks of actors; and
- a change from individual policies to policy mixes.

In delineating these shifts, it is argued that more research is required that makes use of the existing scholarship on policy instruments and applies it to innovation policy. In so doing, more attention is required to understand the interactions between multiple instruments, i.e., the policy mix and the policy goals they are intended to achieve (Martin, 2015).

These considerations regarding the transformative innovation policy paradigm point to a policy agenda that centers on achieving societal impact, which includes three general elements (Diercks et al., 2019, p. 890):

- a series of policy domains beyond economic and industrial policy;
- several policy goals related to a range of different societal challenges; and

- a policy logic that challenges a pro-innovation bias.

These elements and those that define the innovation process, i.e., actors, activities and ways of innovating, however, are contested and contradictory (Diercks et al., 2019; Schot & Steinmueller, 2018). This points to the eclectic nature of the transformative innovation policy paradigm, which can be understood, as Diercks et al. (2019) suggest, from both a narrow and a broad standpoint. The narrow perspective centers on techno-scientific objectives carried out by means of primarily company-based product innovations, whereas the broad perspective is more ambitious and targets societal transformations that involve not only technical and scientific, but also social transitions that involve a wider set of types of innovations, actors, activities and mechanisms that generate innovation.

2.3. Governing transformative change

2.3.1. Effective coordination for effective innovation policy design and implementation

Before discussing what evaluation approaches may be employed to assess third-generation innovation policies aimed at transformative change, we need to define what transformative change means. Transformation refers to change in socio-technical systems, as conceptualized in the growing sustainability transitions literature (Markard et al., 2012). This change in socio-technical systems cuts across different systems and policy areas, including energy, mobility, food, healthcare, production, consumption, etc. It is thus unusually broad in scope, complex and difficult to implement in practice. This is particularly the case under existing governance arrangements, which are not aligned to support socio-technical systemic transformation and themselves require transformation to guide and govern such broad and profound change (Arnold et al., 2018).

A whole-of-government approach, which has gained prominence in public administration and management studies more generally (Christensen & Laegreid, 2007; Perri 6, 2004; Pollitt, 2003), involves multi-level coordination across policies, sectors and institutions. Yet, such an approach is difficult to apply in practice since it requires a transformation of established structures, processes, interests, cultures and coordination mechanisms (Dan, 2017). Coordination, although as old as humanity itself, is notoriously difficult to achieve as an end goal, yet it is also difficult as an act and process that involves 'working together harmoniously' for a common goal (Malone & Crowston, 1990, p. 358). Lindblom (1965, p. 23) defines coordination as a 'mutual adjustment between actors or a more deliberate interaction which produces positive outcomes to the participants and avoids negative consequences'. Peters (1998, p. 296) refers to coordination as 'an end state in which the policies and programs of government are characterized by minimal redundancy, incoherence and lacunae'. The meaning and the goals of coordination, as found in the public administration and management literature, are presented in Table 1.

Table 1 about here

Coordination is required both horizontally between various central government agencies and institutions that operate at the same level of government, and vertically between government bodies that are situated at distinct levels of government nationally, regionally and locally. Moreover, since socio-technical transitions involve systemic change across different sectors and societal actors that are beyond the immediate control of government, coordination is also required between these sectors and actors to ensure alignment and concerted action. The global dimension of sustainability adds additional complexity as it requires multi-lateral, international coordination of political and economic interests and values across different nations and international alliances.

A whole-of-government approach can enable better coordination across government units and levels, yet in the case of sustainability transitions, coordination is required across different sectors (public, private, non-profit) and the society. Thus, coordination for sustainability transitions is more complex and difficult to achieve than coordination of large, systemic programs that are implemented within one sector only, be it public or private. Stakeholder involvement, including of actors on the demand side, is needed to encourage participation and seek the alignment of interests across different stakeholder groups. A transformed governance for sustainability transitions also requires finding practical and politically acceptable solutions to transformational system failure that may include a directionality failure, demand articulation failure, policy coordination failure and reflexivity failure (Weber & Rohracher, 2012). The multi-faceted nature and complexity of socio-technical transitions is reflected in the existing literature on transformative innovation policies. Transformation of socio-technical systems involves the 'co-production of social, behavioral and technological change in an interrelated way. Socio-technical system transformation (or transition) is about changing skills, infrastructures, industry structures, products, regulations, user preferences and cultural predilections' (Schot & Steinmueller, 2018, p. 1562).

In their assessment of complex programs for innovation and socio-technical transitions, Arnold et al. (2018, p. ii), recommend a 'dense' system of governance and evaluation that includes the following components and inter-relations:

- the set-up of a governmental unit that can monitor the accountability of complex innovation and socio-technical transition programs;
- the creation of a temporary implementation 'platform' to design, govern, monitor and evaluate complex programs and specific interventions that facilitate stakeholder engagement, yet maintain a clear leadership and accountability structure that monitors implementation and provides feedback in a participatory way;
- a separate evaluation platform that is directly accountable to government can monitor and evaluate program implementation in an objective way in collaboration with the implementation platform and the agencies that implement specific interventions that make up the programs; and
- a close collaboration and reporting lines between implementing agencies and the evaluation platform to ensure alignment between the strategic needs of the platform and evaluations carried out by agencies.

Moreover, to address coordination problems, such as redundancy, omission, contradictions and divergence (Dan, 2017) that can lead to coordination failure in implementing sustainability transitions programs, a 'tentative governance' approach may be effective (Kuhlmann & Rip, 2014). This involves integrating coordination mechanisms 'along the way' during the process of transformation (Schot & Steinmueller, 2018). Through open coordination and mutual adjustment of interests and values, it may be possible for different actors to construct change pathways together that may be mutually advantageous and acceptable to all. A tentative governance approach is 'provisional, revisable, dynamic and open and includes experimentation, learning, reflexivity and reversibility' (Schot & Steinmueller, 2018, p. 1563).

Strategic niche management has been another way to experiment with addressing coordination failure in the sustainability transitions studies (Schot & Geels, 2008). Its effectiveness, however, rests on the ability to go beyond technical demonstration to include an adjustment of actors' preferences towards a shared vision. This involves a process of 'deep learning', which involves a questioning of actors' underlying assumptions and preferences, which may lead to a willingness to try out alternative options (Schot & Steinmueller, 2018, p. 1563).

2.3.2. Effective change management

Behavioral change is required for sustainability transitions programs to be effective and change management processes may facilitate such change. Lewin's (1951) planned model of change posits that successful change requires going through a sequential process from unfreezing to moving and then refreezing. Unfreezing involves unlocking the current level of behavior by altering the balance of power between driving and restraining forces. Moving implies a step further towards enacted change and consists of a shift in the balance of power between competing forces, making room for new arrangements. Lastly, refreezing or institutionalizing involves embedding the new behaviors in practice so that change becomes institutionalized and lasting, rather than short lived. Based on his field theory, which was designed to be applicable to individuals, organizations or societies, Lewin found that reducing the factors that resist change is preferred to a strategy based on increasing the pressure for change, which can lead to tension and conflict. Addressing the underlying reasons that contribute to resistance to change can increase commitment and result in lasting change compared to a strategy based on applying pressure for change (Hayes, 2018).

Although new and more extensive teleological models of change have been proposed (Kotter, 1995, 2012; see also Hayes, 2018, pp. 23–24 for an overview), those who assume the purposeful nature of change tend to build upon Lewin's parsimonious model to develop it further and test its present-day relevance (Ford & Greer, 2006; Hendry, 1996). The three-step model, despite criticism (e.g., Burnes, 2004, pp. 992–995), has continued to be embraced by a considerable number of researchers who have based their theoretical framework for empirical research on its three main stages.

Successful change management, according to Lewin's model, requires unfreezing/unlearning existing organizational practices and behaviors and refreezing through adopting new practices. The literature suggests separate ways how this occurs and what it presupposes. Scholars, including Schein (1996), have found that unfreezing consists of three necessary processes which are all required to generate 'readiness and motivation to change' (Schein, 1996, p. 28): disconfirmation of the validity of the existing situation; induction of guilt or survival anxiety; and the creation of psychological safety or overcoming of learning anxiety. Disconfirmation refers to 'dissatisfaction or frustration generated by data that disconfirm our expectations or hopes' (Schein, 1996, p. 29). This can result from a crisis and can happen through disconfirming people's understanding of the benefits of the status quo by, for example, providing more accurate or comprehensive evidence or appealing to people's emotions. Survival anxiety is the 'feeling that if we do not change, we will fail to meet our needs or fail to achieve some goals or ideals', which leads to survival guilt (Schein, 1996, p. 29). Schein argues that for change to take place, a sufficient degree of psychological safety or overcoming of learning anxiety needs to be experienced, without which disconfirming information will not be accepted and survival anxiety will not be felt. Kotter (2012) claims that unfreezing can result from creating a sense of urgency about the need for change, which can raise awareness among societal members about the need to search for and find alternative solutions.

Moving presupposes a shift in the equilibrium and involves experimenting through a trial-and-error approach, which may enable organizations and societies to transition from less acceptable to more acceptable arrangements (Burnes, 2004). Movement can be achieved through a shift in attitudes and reorganizing structures, processes and systems (Hayes, 2018). Reframing problems in terms of opportunities and discussing them can lead to an analysis of alternative solutions that contribute to change and learning (Hendry, 1996).

Refreezing occurs through congruence between new behavior and existing behavior and the personality of the learner, which solidifies change and avoids sliding back to a new round of disconfirmation (Schein, 1996). This implies that a dynamic alignment between new learned arrangements and expected or hoped-for arrangements is likely to reinforce change. Positive feedback that supports the effectiveness of new practices, reporting relationships and incentive mechanisms that reward new performance levels can lead to the refreezing of new behaviors and practices (Hayes, 2018; Hendry, 1996).

2.4. Impact evaluation across the three generations of innovation policy

The first generation of innovation policy was characterized by the linear innovation model that is still (at least partially) present in contemporary innovation policy instruments, most visible in government funding for science and technology. This linear view of the innovation process has influenced the underlying policy theory and the understanding, measurement and evaluation of policy impact. The emphasis in the first generation of innovation policy was on the evaluation of individual policy instruments designed to boost science, research and technology, typically taking the form of R&D subsidies and innovation incentives utilized to safeguard intellectual property rights (Magro & Wilson, 2013). It is largely supply-driven, although not exclusively, due to the use of demand-pull models as a response to the observed limitations of the predominant supply-push approaches (Molas-Gallart & Davies, 2006). Supply-push approaches were the dominant policy tools in the aftermath of World War II, where Vannevar Bush's book *Science, the Endless Frontier* (Bush, 1945) was influential in both the US and Europe. The key argument was that scientific research was key to prosperity and security and would translate into the development of new products and processes. This model was deterministic in nature to the extent that it was expected that funding of science would produce results which focused on outputs related to technological progress and economic development.

Later on, in the mid-60s and 70s, the supply-push model was criticized for ignoring the role of market demand, and these criticisms gave rise to demand-pull models that emphasized the importance of market forces on innovation processes. Thus, although still following a linear thinking of innovation, this constituted early approaches to incorporating the users into innovation processes and directing R&D investments in response to demand-side forces (Molas-Gallart & Davies, 2006).

Impact evaluation in the first generation followed a summative approach that emphasized the final evaluation of results, rather than a formative approach that captures the iterative, on-going nature of evaluation processes. It relied on a largely positivist methodology to assess the effect of inputs on outputs, typically measured in quantitative economic terms. This approach used (quasi-)experimental techniques that are uniquely positioned to assess the impact of specific policy interventions that are homogenous and applied to a large population that exhibits few differences. These requirements, however, raise questions about the usefulness of positivist evaluation for innovation policy, considering that only a minority of research grants lead to exceptionally significant results that would warrant the investment in the entire instruments, while most produce insignificant outcomes (Arnold et al., 2018).

In using positivist principles, it relies on measurable outputs and the size of the effects while ignoring the causal mechanism that explains why a certain intervention leads to results. This leaves out important qualitative aspects of an intervention as well as an understanding of the context in which innovation policies are implemented. In so doing, it follows a simple intervention logic that does not adequately incorporate the complexity of the current innovation space.

The second generation of innovation policy builds on the key role of the state in governing and coordinating national innovation systems. At this phase, the scope of impact evaluation broadened to include not only individual policy instruments (one part of the system), but also the innovation system as a whole. This emphasis on evaluating national innovation systems continues to be carried out by national governments and notably by the OECD in its reviews of national innovation policies. It no longer exclusively follows a linear model of the innovation process, based on neoclassical policy rationale centered on market failure, but evolutionary, systemic rationales centered on the role of institutions and interactions within innovation policy systems. These rationales co-exist with neoclassical rationales (Magro & Wilson, 2013). Known as non-linear, coupling models of innovation, these models saw innovation as a two-sided process that includes, in a circular way, interactions between supply and demand. However, despite advances in innovation theory towards a systemic understanding of the innovation process, there is agreement in the literature that evaluation practice lags behind adopting a systemic approach (Molas-Gallart & Davies, 2006). It follows that there is a significant gap between the way in which impact evaluation is understood, based on theoretical developments, and the way in which impact is evaluated in practice.

There is agreement among scholars that evaluation practice is still following, at least in part, the linear model, despite calls to incorporate advances stemming from a systemic innovation process. However, different systemic approaches to evaluation have been proposed, such as:

- an emphasis on formative, rather than summative, evaluation (Kuhlmann, 2003;
- a systemic analysis that captures the role of multi-level evaluation and follows the principles of realist evaluation (Arnold et al., 2018). This includes individual policy instruments, the overall innovation system and a ‘bottleneck analysis’ that identifies the locus and type of problems that hinder policy development and the institutional factors and actors that operate at this level (Arnold, 2004);
- intelligent benchmarking;
- social network analysis (Molas-Gallart & Davies, 2006);
- developmental evaluation that follows social constructivism as its epistemological basis (Patton, 2010);
- behavioral impact to capture change in actor behavior in addition to quantitative measures of input and output;
- the need for triangulating methods to assess systemic and dynamic relationships using a mixture of evaluation methods, using positivist, realist and/or constructivist principles;
- meta-evaluation and evaluation synthesis that combines the results of multiple individual studies in a coherent and systematic way to identify policy effects and their influencing factors (Edler et al., 2016);
- ‘evaluation mix’ as a practical tool for policymakers that integrates multiple policy rationales, domains, instruments and administrative levels in a given innovation policy space (Magro & Wilson, 2013)

However, their application has remained limited and has not led to a considerable shift and paradigm change in evaluation practice. Molas-Gallart and Davies (2006) argue that this can be explained by a persistent tension between policymakers’ short-term interest in measurable results and the difficulty of incorporating systemic, long-term, downstream effects into such evaluations in a cost-effective and timely manner that satisfies policymakers’ interests and expectations. This is the case despite a growing recognition among the evaluation community of the necessity of a paradigm shift that allows for formative evaluation centered on learning, rather than being driven by a measurement rationale centered on the evaluation of ex-post impact. This status quo can also be explained by the difficulty of capturing complex cause-effect relationships and intangible benefits with established evaluation concepts and instruments (Magro & Wilson, 2013). The existing evaluation concepts and instruments need to be reconsidered in order to assess impact in the evolving innovation space.

In the third generation of innovation policy there is an emphasis on systemic governance and alignment, i.e., the process rather than the outcomes of innovation policy, seen through the lens of societal challenges. The third generation represents a normative shift as it builds on the premise that science should benefit society. However, the same argument persists, as in the case of the second generation: there is a notable difference between how impact evaluation is understood and how it is practiced in innovation policy evaluations. The systemic perspective of the second generation continues, but impact evaluation is broader in scope as it aims at transformative change and societal challenges that require multi-actor coordination and cross-cutting interventions.

The literature notes the main difference between the linear and non-liner model and the fact that systemic considerations are part of both the second and third generation and the latter is part of both generations. However, the complexity and rationales are broader in the third generation. The central question is whether there is evidence of a clear and distinct approach to impact evaluation in the third generation, as compared to the previous generations. The main shift is essentially away from impact measurement (summative, ex-post) to formative, co-produced learning that is continual and a part of the policy process itself. There has been a growing recognition of the importance of iterative approaches to evaluation focused on formative evaluation that incorporates on-going monitoring, learning and reflexivity (Bussels et al., 2013). Evaluation itself is seen as a transformative tool that is meant to improve policy learning along the way in the process of implementation of systemic innovation policies that have multiple rationales, employ a policy mix and are carried out at multiple governance levels (Magro & Wilson, 2013). This is distinct from impact evaluation in previous generations which emphasized the role of summative evaluation, yet it paid less attention to evaluating complex societal outcomes. At the same time, the emphasis of the third generation of innovation policy on multi-actor coordination and multi-level governance, i.e., on the governance process and system itself, may deter the need to focus on and achieve concrete outcomes and societal impact.

2.5. References

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