How novel is Transformative Innovation Policy?

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JEL: O30; O38

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1 Introduction

The focus and instruments of innovation policy have changed fundamentally over the last decades. Scholars have captured this by proposing various periodizations of innovation policy. For instance, OECD (1963) constitutes one landmark suggesting a shift towards increased interest for economic effect of science through innovation. Lundvall and Borrás (2005) suggest a transition from science, to technology, and finally innovation policy. Weber and Rohracher (2012) differentiate innovation policy depending on the failure framework it uses. In a recent attempt, Schot and Steinmueller (2018) argue for three frames for innovation policy based on the linear model, the systemic perspective of innovation, and the focus on transformative change.

In this chapter, we critically examine the various periodizations offered in the literature, and consequently debate the novelty of the most recent shift towards transformative innovation policy. A main point put forward in this chapter is that a periodization of innovation policy in a clear sequence where one frame precedes another, gives insufficient attention to the common elements of these different understandings of innovation policy. Thus, rather than very clear shifts between generations of innovation policy, it might be suggested that innovation policy evolves more gradually, for instance, transformative elements are foregrounded recently under the umbrella of "transformative innovation policy" but can also be identified in previous perspectives on innovation policy.

Even though grand challenges such as global warming and migration flows, as well as technological change such as artificial intelligence and industry 4.0 have fired the debate on transformative innovation policies in recent years, it has a long history – even going back to Schumpeter. Schumpeter (1911) distinguished path-breaking economic activities from such that follow existing paths, thereby foregrounding the role of innovations with transformative character for economic development. We also find a long and substantial debate on lock-ins (Grabher, 1993) and policy interventions for structural change (Hassink, 2005, Tödtling and Trippl, 2004). Following this tradition, and the work on regional path-dependency (Martin and Sunley, 2006), more recent studies have discussed mechanisms and sources for new industrial path development (Grillitsch et al., 2018).

In parallel, a new literature has developed focusing on sustainability transitions, which suggests that addressing current grand challenges requires substantial changes in the socio-technical systems that deliver core services such as mobility and nutrition. Due to the urgency of tackling these challenges, incremental innovations are arguably insufficient, and the sustainability transitions literature consequently emphasizes the importance of radical innovations (Markard et al., 2012). It is also underlined that transitions require not only innovations in new technologies, but also in social practices, regulations and infrastructures. These prioritizations have important implications for the objectives, instruments and overall design of innovation policy (Grillitsch et al., 2019, Kivimaa and Kern, 2016, Weber and Rohracher, 2012). In particular, directionality of innovation policy plays a central role because transformative innovation policies build on the explicit aim that change processes should support the achievement of sustainable development outcomes. Consequently, innovation is not viewed as an end, but is instead treated as a means to achieve transformative change. In this view, innovation policy is not merely focused on developing and diffusing new technologies, but also aimed at destabilizing and phasing out unsustainable ones (Kivimaa and Kern, 2016).

This book chapter unfolds the historical and conceptual roots of transformative innovation policy, compares critically the different strands of literature, and discusses policy implications as well as important questions for future research.

2 Science, technology and innovation policy – the technology-push approach

Policies for promotion of science, technology and innovation take many forms, but here we use the term to refer to a policy approach that implicitly or explicitly builds on a linear understanding of innovation processes, where scientific discoveries precede technology development activities, which eventually lead to the commercialisation of innovations. The development of this policy approach is often attributed to the report *"Science: The Endless Frontier"* commissioned by the US President Roosevelt and written by Vannevar Bush (1945). However, as examined in great detail by Godin (2017), the intellectual heritage of the linear model of innovation and the associated policy approach is considerably more rich and complicated, going back to anthropologist, rural sociologists and industrialists in the early 20th century, who all considered the question of how novelty arises, diffuses and changes our societies.

2.1 Model of innovation

The linear model of innovation describes the development of innovation as a process starting with scientific research, followed by product development, production and finally marketing. A central characteristic of this model, namely the sequencing of the different steps, is also found in early work on the relation between invention and diffusion of cultural practices and traits in anthropology, as well as in writings by rural sociologists on the development and diffusion of agricultural technologies among farmers. However, the first linear model of innovation was conceived by Maurice Holland of the US National Research Council (e.g. Holland, 1928), and further theorised by Maclaurin (1947). These contributions explicitly established an understanding of innovation as a sequential process developing from basic research, to applied research, product development, production and commercialisation. This linear conceptualisation of the innovation process has subsequently been reproduced in multiple forms, with significant influence on priority setting in science, technology and innovation policy (Godin, 2017).

The linear innovation model has entailed a rather limited focus of science, technology and innovation policy in terms of both actors and instruments. Central types of organisations include universities, research institutes and firms – in particular large firms with own research laboratories – who play different roles with regards to achieving scientific breakthroughs, technology development and commercialisation of new technologies. Correspondingly, policy instruments focus on supporting activities in the various steps of the linear innovation model: provision of public funding for basic research; subsidising applied research directly or indirectly through tax credits; and establishment of intellectual property right regimes, which allow innovators to profit from their research and development (R&D) investments. Implicitly, the rationale behind the introduction of such policy instruments builds on neoclassical economics and the existence of market failures (Laranja et al., 2008, Mowery, 1983): firms are disincentivised from investing in knowledge creation due to the difficulties of appropriating returns, leading to sub-optimal levels of investments in R&D from a societal perspective.

Complementary to these instruments, policymakers have since Holland (1928) and Maclaurin (1954) emphasised the importance of gathering statistics and intelligence about levels of investment in science and R&D (Godin, 2017). Important manifestations of this are the development of the Frascati Manual (OECD, 1963, now in its 7th version) for standardising methods for collection of R&D statistics, as well as the introduction of industrial classifications based on industries' investment levels in R&D. Essentially, the division of industries into categories ranging from high-tech to low-tech has been associated with an clear emphasis in policymaking on the small, R&D-intensive part of the economy,

comprising industries such as pharmaceuticals, electronics and aerospace, to the extent that increasing R&D investments has become a goal in itself. As quoted in Hansen and Winther (2011), the European Commission (2008) argues that (p. 11) *"[g]iven the weight of high-tech sectors in the overall level of business R&D intensity, a change should include the sectoral composition of the business sector, a move towards a higher share of high-tech companies"* and policy should (p. 16) *"change the balance of the industrial structure in favour of these research-intensive sectors"*. Policies for attracting high-skilled labour are also often specifically targeting high-tech industries (Hansen et al., 2014).

2.2 Evaluation and assessment

The literature abounds with critiques of the linear model of innovation and its associated policy implications, in particular concerning the mismatch between the model's emphasis on science and research as a driver of innovation, and empirical work highlighting the vastly heterogeneous character of innovation processes. Yet, from proponents of a transformative innovation policy approach, a main point of critique has been the assumption that innovation is automatically beneficial for society. Thus, Schot and Steinmueller (2018) suggest that traditional science, technology and innovation policy approaches have been overly focused on innovation as a means of achieving economic growth, thereby marginalising (p. 1561) *"broader implications for the environment or human health and welfare"*.

However, this perspective on the intentions of scholars responsible for early work on innovation appears inaccurate or at least partial. In fact, innovation was directly connected to societal progress not just in the form of increasing possibilities to consume, but also in terms of improving public health, limiting pollution and conserving natural resources. As argued by Giuliani (2018), while some scholars might have subscribed to a simple 'science → innovation → economic growth' logic, social and environmental concerns were not unanimously ignored. To exemplify, improved health and living standards were important arguments to Holland (1931) for supporting innovation; Bush (1945) emphasised multiple socio-economic benefits of science; and Maclaurin researched unemployment and social security measures in other work (Myers and Maclaurin, 1942).

Thus, rather than in intentions, the challenge of a linear perspective of innovation in terms of achieving transformative change is arguably found in the appropriateness of the derived policy instruments. Essentially, an emphasis on science-push instruments is adequate for 'solving' technical challenges as those associated with mission-oriented projects such as the Manhattan Project and the Apollo Program. However, addressing grand challenges such as climate change, biodiversity loss and aging societies are fundamentally different in being open-ended and highly complex, not only in technical terms. As pointed out by Mowery et al. (2010), the US government not only funded the Manhattan and Apollo projects, but was also the sole customer, effectively eliminating the need for demand-side policies. Further, the projects addressed technical challenges for which no existing solutions were in use, whereas addressing e.g. climate change requires replacement of existing technologies, which is associated with significant distributional consequences. Tackling these matters requires a different policy toolbox than the one derived from a linear model of innovation.

3 Innovation system policy – the institutional approach

Godin (2017) identifies the origins of innovation system policy in seminal work by Jack Morton and Freeman in the 1960s and 1970s, as well as OECD's effort to push a systemic perspective highlighting the importance of national innovation policy. The momentum further increased when Bengt-Åke Lundvall became deputy director of the OECD Directorate for Science, Technology, and Industry from 1992 to 1995 advocating for the innovation systems approach. The innovation system approach differs

from the science, technology, innovation (STI) perspective in its underlying theory of innovation, moving from a linear to an interactive model of innovation, in which a large variety of actors collectively engage in conceiving, developing, and introducing ideas to the society.

The system approach originated with an appreciation for the many shapes of innovation, which can but do not necessarily entail the commercialisation of new scientific knowledge. Innovation is also viewed as "counter-concept" to science, stressing that in the process of creating societal benefit many actors contribute in an inclusive process with science representing only one relevant type of actors (Godin, 2016). Innovation systems are conceived as open systems, allowing for a variety of perspectives to emerge with a focus on nations (Freeman, 1995, Nelson, 1993, Lundvall, 1992, Edquist, 1997), regions (Autio, 1998, Cooke, 1992, Asheim and Isaksen, 1997, Tödtling and Sedlacek, 1997), sectors (Malerba, 2002, Breschi and Malerba, 1997), technologies (Carlsson and Stankiewicz, 1991) and functions (Hekkert et al., 2007).

3.1 Model of innovation

The systemic perspective on innovation opposes the linear model of innovation. Rather than resulting from research and development, innovation processes often start with recognising or believing in a certain market opportunity (demand side), which is then followed by concept development (Kline and Rosenberg, 1986, Kline, 1985). Research and development comes in to solve technical problems associated with realising the concept and moving into production. The process described by Kline and Rosenberg is characterised by feedback-loops. For instance, results from research and development feed into concept development and opportunity discovery processes. The innovation system approaches therefore rests on a very different understanding of innovation processes, which is non-linear and interactive. Besides firms, universities, and research organisations, the importance of a larger variety of actors has been recognised, including customers, intermediary organisations, educational and training facilities, and public actors.

The early work on innovation systems in the 1990s highlights the importance of institutions, predominantly understood as set of formal and informal rules. Variations in national institutional configurations were linked to different patterns of innovation processes and outcomes. Closely linked to this literature is the varieties of capitalism concept, differencing in liberal market economies and coordinated market economies (Hall and Soskice, 2001, Vitols, 2001). It is argued that the institutional configuration of liberal market economies promote radical, breakthrough innovations in science-based sectors while coordinated market economies provide better conditions for incremental innovations based on interactive learning in engineering-based sectors. This also implies a broader understanding of innovation than present in the STI perspective.

Related to that, the innovation system approach provides a more differentiated spatial perspective, which resulted in a number of regional typologies. These typologies showcase systematic patterns that relate to i) key actors and governance (Asheim and Isaksen, 2002, Cooke, 1998), ii) the strengths in radical versus incremental innovations (Cooke, 2004), and iii) regional innovation system failures (Tödtling and Trippl, 2005, Isaksen, 2001). Essentially, this literature finds that innovation processes and outcomes do not only differ between nations but also between regions. Furthermore, the literature also highlights that innovation comes in many forms and that there is no single best-practice model that would suit all regions. However, innovation policy shall address the particular barriers identified in regional and national contexts.

Appreciating the interactive nature of innovation processes, the involvement of multiple actors in such processes, and the variegated shapes of innovation processes and outcomes at national and regional levels, the innovation system approach broadens the scope for policy intervention considerably as

compared to the STI perspective. Policy interventions are to be justified by innovation barriers or system failures. Woolthuis et al. (2005) differentiate in infrastructure, institutional, network, and capability failures and link those to a variety of types of actors including demand (consumers, large buyers), companies (small and large firms, start-ups), knowledge institutions (universities, technology institutes), and third parties (banks, intermediaries, sector organisations, employees). Policies in related to these various domains need to be coordinated to strengthen innovation systems (Lundvall and Borrás, 2005). At the regional level, Tödtling and Trippl (2005) associate regional types to main system failures. Accordingly, metropolitan regions typically suffer from a fragmentation of networks, old industrial regions from lock-in, and peripheral regions from organizational thinness. Borrás and Edquist (2013) argue that a mix of policies need to be mobilised in order to address specific failures in regions and nations covering regulatory instruments, economic and financial instruments, and soft instruments.

3.2 Evaluation and assessment

The innovation system approach has been criticized for being static and *"concerns structure or institutions rather than time or sequence"* (Godin, 2017, p. 139). According to this view, the innovation system approach is less concerned with changes over time (a process perspective) than with how different elements of the system play together at any point in time. This invites for a snapshot perspective, which is not suitable for an understanding of system change over time. Hence, historic or long-terms studies about how innovation systems have changed over time are rare but would add value to understand the transformative capacity or effects of innovation systems. Yet, this does not necessarily imply that innovation system policies do not promote transformative change because innovation is considered as key driver of change in the capitalist society (Schumpeter, 1911, Shane and Venkataraman, 2000). By providing the best possible preconditions for innovation, innovation system policy is about supporting industrial dynamics (Grillitsch and Trippl, 2018).

Furthermore, a strand of the innovation system literature has explicitly addressed structural change in old industrial regions (Hassink, 2005, Tödtling and Trippl, 2004, Coenen et al., 2015b). In essence, this literature investigates the barriers and possible instruments for such regions to overcome lock-ins (Grabher, 1993) and transform. Recent literature contributes to a dynamic perspective by emphasising new industrial path development, which is characterised by fundamental changes in actors capabilities, networks and institutions (Grillitsch et al., 2018, Grillitsch and Asheim, 2018, Isaksen and Trippl, 2016, Hassink et al., 2019). A virtue of the innovation system approach is that it offers policy implications for a variety of regions and types of innovation, including science-based, radical innovations, which typically emerge in knowledge-intensive urban areas, as well as incremental, engineering based innovations, which are often at the heart of more remote areas.

A fundamental challenge of the innovation system literature, linked to the focus on how elements play together in a system at the expense of a process perspective (Godin, 2017), is the lack of theorizing and insights on how actors bring about transformative change. The innovation systems literature explains how combinations of elements such as institutions, networks and actor capabilities affect innovation outcomes (top-down explanation) but does not tell us much how these elements are changed by the actions of individuals, groups of individuals, and organisations (bottom-up explanation) (Uyarra et al., 2017, Asheim et al., 2015). As transformations cannot be understood without the micro-processes producing structural change, this is an important shortcoming. This shortcoming is being addressed (but not yet resolved) in emerging literature about agency in regional development (Grillitsch and Sotarauta, 2019, Isaksen et al., 2019)

4 Transformative innovation policy – the challenge-driven approach

In recent years, numerous scholars have begun to describe yet another shift in the innovation policy domain. This shift marks the emergence of transformative innovation policy (Schot and Steinmueller, 2018) also sometimes referred to as challenge-driven innovation policy (Coenen et al., 2015a) or next generation innovation policy (Kuhlmann and Rip, 2018). The transformative innovation perspective is often described as a profound break with the STI perspective and the innovation system perspective (Kuhlmann and Rip, 2018, Schot and Steinmueller, 2018). While scholars are not claiming that transformative innovation policy is fully replacing previous innovation perspectives, the shift to a transformative innovation perspective is emphasised as more than an incremental change in the innovation policy domain (Diercks et al. (2019). We suggest that the novelty of the transformative innovation perspective should not be overstated. In the following sections, we unpack the novel elements of the transformative innovation perspective, but also highlight the ways in which the transformative innovation perspective evolves from previous perspectives. After this we go on to explore the novelty in the implementation of transformative innovation policy.

4.1 Model of innovation

We suggest that three aspects of the transformative innovation perspective represent novel elements in innovation policy. First, the aim to transition entire socio-technical systems, second, the emphasis on experimentation, and third, the deliberate intention to destabilize unsustainable regimes.

The transformative innovation perspective rests on the aim of transitioning entire socio-technical systems. Socio-technical systems describe the systems that deliver core services for society such as mobility, energy and nutrition (Markard et al., 2012), and transformative innovation policy sets out to address the challenges that contemporary society face with regards to the delivery of these core services. The transformative innovation perspective therefore involves radical innovation across entire systems of both production and consumption, which in turn requires *"novel configuration of actors, institutions and practices"* (Weber and Rohracher, 2012, p. 1037).

Despite a 'system-focus', this contrasts with the innovation system perspective: In the innovation system perspective, the notion 'system' refers to all the factors that influence the generation of innovation. In the framing of transformative innovation policy, 'system' refers to wider socio-technical systems delivering core services for society. Keeping this in mind, transformation challenges illustrated by Weber and Rohracher (2012) concern barriers to change in socio-technical systems, whereas market and system failures concern barriers to innovation performance. Arguably, two of these core challenges for transformative innovation policy – directionality and demand articulation – are qualitatively different compared with previous understandings of innovation policy, while the two remaining challenges – policy coordination and reflexivity – were also recognised before, but requires deepened consideration in the transformative perspective.

First, attention to *directionality* identifies the lack of deliberate attempts to address transformative change through innovation processes. Whereas innovation system policy is broadly oriented towards optimising the structural and institutional environment of the innovation system itself, transformative innovation policy is oriented specifically towards particular societal challenges in socio-technical systems and should proactively steer the direction of innovation towards addressing these. As elaborated below in the point on destabilization, this has substantial implications for policy formulation.

Second, *demand articulation* points to a lacking concern for market uptake of innovations and insufficient understanding of user practices and expectations. This reflects the innovation system

perspective's main focus on the production side of innovation and the transformative innovation perspective's much greater emphasis on the consumption and demand side of innovation. Although demand and the involvement of actors on the demand side (e.g. users, consumers) is mentioned in both perspectives, their role differs. In the innovation system perspective, the role of users and consumers is mainly to lead and provide inputs into innovation processes, whereas the transformative innovation perspective relies on consumer and users to make innovations part of their everyday practices and life. The goal is to achieve a wide uptake of innovations rather than to focus on a select group of lead users.

Third, *policy coordination* concerns the difficulty of achieving coherent and timely policy actions across vertical and horizontal policy areas as well as public and private sector institutions. The importance of policy coordination is also emphasised in innovation systems policy (Lundvall and Borrás, 2005). However, as transitions between socio-technical systems are complex and connect to multiple policy fields, breaking down policy silos and coordinating across a large number of authorities and organizations are arguably of even greater importance in transformative innovation policy.

Finally, *reflexivity* regards the need to engage with the long-term and uncertain nature of transformative change. Following from this, emphasis is placed on continuous attention to monitoring, anticipation and evaluation, as well as the establishment of policy platforms bringing together not only governmental representatives but also private sector and civil society actors (Weber and Rohracher, 2012). While integrating reflexivity in innovation policy in the form of monitoring, anticipation and evaluation instruments is arguably not reserved for a transformative approach, their importance is likely particularly large in transformative innovation policy: as policy sets a clearer direction for innovation, continuous reflections around the desirability of this direction are needed in government and beyond.

We see this shift in innovation policy articulated in OECD publications. The *System Innovation: Synthesis Report* (OECD, 2015) clearly articulates this changing perspective on the role of policy by suggesting that *"by and large, most innovation policies aim to foster incremental change; fostering wider system change is a new challenge for innovation policy makers, especially as many of the actions will fall in areas outside the direct remit of research ministries or innovation agencies but where their input, coordination and implementation actions will remain critical"*. The emphasis on policy for wider system change is arguably at odds with the OECD's traditional understanding of innovation.

In addition, the role of experimentation has been emphasised in different strands of literature relating to socio-technical transitions. It generally refers to *"an inclusive, practice-based and challenge-led initiative, which is designed to promote system innovation through social learning under conditions of uncertainty and ambiguity"* (Sengers et al., 2019). Thus, the starting point is the uncertainty and complexity of societal challenges, which calls for experimentation that creates a space for learning, reflexivity and failure (Schot and Steinmueller, 2018). This highlights the need for testing new technologies, but in a broader sense than previously conceptualised: focus is not only on laboratory tests and demonstration plants, but also on experiments with business models and the use of technologies in practice. Further, experimentation entails specific attention to learning about factors that make emerging technologies successful vis-à-vis established incumbent alternatives. The need for experimentation necessitates a different approach to innovation policy development, compared to STI and innovation system policy: rather than attempting to correct market and innovation system failures in order to 'optimize' innovation processes, transformative innovation policy puts greater emphasis on facilitating experiments, while acknowledging that many experiments will fail. One illustration of this is NESTA's innovation policy approach, including initiatives such as real-world testbeds (Arntzen et al., 2019, Morgan, 2018).

The role of experimentation points to an interesting discrepancy in transformative innovation policy between the desire to steer change towards societal challenges and the inherent difficulty of doing so due to the complexity of those same challenges. The extent to which transformative innovation policy can be planned is debatable. A key question in the debate surrounds the role of knowledge and the extent to which scientific evidence can guide policy under uncertainty. Views on this question are somewhat opposing. For example, Weber and Rohracher (2012) suggest that scientific evidence continues to play an important role in establishing visions for change, while Stirling (2008) to a greater extent abandons the idea of evidence based policy advice and instead encourages opening up and democratizing the construction and development of knowledge.

Although we suggest that the transformative innovation perspective's aim of transitioning entire socio-technical systems represents something new in innovation policy, it would be wrong to ignore the links to previous perspectives. For example, mission-oriented projects as described in the STI perspective share the challenge-driven nature of transformative innovation policy. Mission-oriented projects also exhibit a sense of directionality and deliberate steering, however, the challenges are of a technical nature, which is unlike the societal challenges addressed by transformative innovation, which are complex beyond the technical. Transformative innovation policy also stresses the importance of collaboration and interaction between different actors across value chains. These interactions and collaborations are believed to be key sites for innovations, which is similar to the innovation systems approach, but quite different from the STI perspective that highlight activities within firms and organisations as key sites of innovations (Bugge et al., 2019).

Beyond the socio-technical transition aspects, a third element sets transformative innovation policy apart from previous perspectives. The transformative innovation perspective departs from the understanding that many of the challenges faced by contemporary society are partly the result of unintended consequences of innovation (Soete, 2013). However, as shown previously in the chapter, scholars in earlier perspectives also considered the complex and sometimes contradictory effects that innovation has on societal progress. What is new in the transformative innovation perspective, however, is the proposed policy action in response to unintended consequences of innovation. Transformative innovation policy implies a deliberate destabilisation of the unsustainable regimes (Turnheim and Geels, 2012). Consequently, destabilization policies are argued to be a necessary component of transformative innovation policy mixes, even if actual policy portfolios are often heavily skewed towards 'creation' rather than 'destruction' policy instruments (Kivimaa and Kern, 2016). Further, 'phase-out' or 'exnovation' policies arguably play a central role for transition processes, which for instance is shown in the case study of the German Energiewende (Rogge and Johnstone, 2017, David, 2017). This focus on destabilization is a clear difference of transformative innovation policy vis-à-vis previous conceptualizations of innovation policy.

4.2 Evaluation and assessment

So far this section has focused on critically examining the novelty of the transformative innovation perspective, but we want to take the discussion beyond conceptual discussions and ask how radically different the transformative innovation perspective is when put into action on the ground? Critical engagement with this question has just begun, but researchers exploring the design and implementation of transformative innovation policy are generating insights that begin to nuance our understanding of transformative innovation policy and its assumed transformative effect.

In a recently published paper, Diercks et al. (2019) conceptualise transformative innovation policy as an emerging policy paradigm. Looking at the policy design of two global initiatives promoting transformative innovation policies, Mission Innovation, an initiative for enhancing innovation in clean energy technologies, and the Global Covenant of Mayors for Climate and Energy, an alliance of cities

working towards a just and climate-resilient future, the authors demonstrate that the transformative innovation policy paradigm is characterised by contestation, and that its practical expressions are diverse and even contradictory at times. Both initiatives share a social policy agenda for transformative change, but the respective initiatives differ in their understanding of the innovation process including the perception of relevant actors, activities and modes of innovation. Focusing on singular technological breakthroughs, Mission Innovation represents a narrow understanding of the innovation process that sits rather comfortably with conventional innovation policy, while the Global Covenant of Mayors for Climate and Energy with its more radical aims of reconfiguring urban systems represents a broader understanding of the innovation process that challenges conventional innovation policy.

Drawing on the policy paradigm framework, the authors try to make sense of this diversity. Seeing that the transformative innovation policy paradigm is only in the early stages of emergence it arguably has not yet institutionalised around a set of core ideas and concepts, which in turn makes space for diverse expressions. Diercks et al. (2019) anticipate that the coming years will see a political contest between these diverse paradigmatic expressions before we arrive at a more set understanding of what the transformative innovation policy paradigm entails.

The work by Diercks and colleagues suggests that the transformative effect of transformative innovation policy is not given. Similar conclusions are made by Grillitsch et al. (2019) that set out to generate theoretical and empirical insights by looking at the design and implementation of transformative innovation policies. Grillitsch et al. (2019) analyse two Swedish strategic innovation programmes, which are identified as examples of transformative innovation policy because they explicitly target system-wide transformation and address grand challenges through the coordination of diverse actors, networks and institutions.

The authors find that the design and implementation of the Swedish strategic innovation programmes struggle with some of the same key challenges that transformative innovation policy sets out to address in the first place. For example, conflicting interests between stakeholders in the programmes are not actively dealt with. As a result, the programmes are not steered by a collectively deliberated and well-aligned vision, but rather by a broad programme encompassing various competing agendas. This is an issue because it inhibits the strategic innovation programmes from providing clear objectives and directionality, which are otherwise considered key characteristics of transformative innovation policies. Another example relates to the programmes' intention to promote policy learning and coordination through the involvement of diverse actors. Although the programmes by design involve a broad range of stakeholders, challenges remain in terms of overcoming 'institutional mismatch' between actor communities such as academia and industry. The involvement of industry actors is low during implementation, which in turn weakens the programmes' abilities to promote policy learning and coordination.

While the transformative innovation narrative is attractive in policy, the research looking into transformative policy design and implementation shows that the emerging innovation policy's actual potential for change and its transformative effect is not yet determined and certainly not easily achieved.

5 Concluding discussion

Our account in sections 2 to 4 opens up for a more detailed discussion of the development over time of innovation policy. Rather than seeing transformative innovation policy as something that only recently materialized, one can find transformative elements in innovation policy back in time. Thus, the emphasis on innovation as a means for supporting substantial changes in society leading to social

progress or greater environmental sustainability is not a recent phenomenon. Rather than discussing entirely different frames of innovation policy, one can observe a gradual change over time where research on innovation policy becomes increasingly centered on the possibilities for innovation policy to deliver transformative change. This does not imply that this perspective was absent until very recently, however, it takes the central position in transformative innovation policy. Furthermore, the attention of transformative innovation policy to deliberately destabilizing unsustainable regimes also marks a significant change relative to previous understandings of innovation policy.

However, considering these changes, one may find it quite surprising that work on implementing transformative innovation policies has not progressed to a greater extent. While literature on transformative innovation policy has elaborated considerably on the inability of policy instruments with a foundation in traditional STI or innovation systems understandings to deliver transformative change, it has proven more difficult to give details on how transformative innovation policy instruments should be designed. This is not to argue that no progress has been made (see for example Kivimaa and Kern, 2016, Weber and Rohracher, 2012, Grillitsch and Hansen, 2019). However, the analyses of transformative innovation policy instruments (Diercks et al., 2019, Grillitsch et al., 2019) described in section 4.2 underline that even frontrunner countries and alliances are challenged in designing and implementing policy instruments delivering transformative change.

One aspect that sets innovation system policy apart from mission-oriented innovation policy such as the Manhattan or Apollo projects, and recent transformative innovation policy targeting system wide changes in production and consumption patterns is the lack of “grandeur”. Innovation system policy provided a framework for supporting both radical and incremental innovations, responding to the opportunities and addressing the challenges in each context. In that sense, it provided clear recommendations for different types of regions and countries, considering the variegated preconditions they possess. The lack of “grandeur” makes the innovation system approach accessible for all places to make the best out of the respective preconditions. In this vein, Grillitsch and Hansen (2019) discuss the opportunities and barriers, and resulting policy recommendation for green industry development in different types of regions. However, this way of thinking may also work against a transformative innovation policy, in particular if incremental innovations are seen as cementing existing, unsustainable development paths.

Furthermore, the embedding of transformative innovation policy in a capitalist system might need further reflection. Taken all unintended consequences of capitalism aside for a moment, it has proven to be a powerful force of disruptive creation where actors seek new profitable opportunities and take risks to realize them. Maybe, this force is not utilized to the highest possible extent for dealing with grand societal challenges? For instance, by changing incentive structures and creating demand for new products and solutions that contribute to the desired development outcomes, it may be possible to initiate bottom-up experimentation without the need of complex coordination of multiple stakeholders, which is encouraged in many of the current transformative innovation policies. In other words, while experimentation is at the core of transformative innovation policies, such policies may underestimate the degree of (potentially ill-directed) experimentation that exists in modern capitalist societies.

A difference between STI policies, resting on a linear model of innovation, and innovation systems policy and transformative innovation policy, both resting on an interactive model of innovation, is the role of agency. According to STI, the role of agency is relatively clear and positive. Scientific discoveries and thereby scientists are the key agents of change fueling the innovation process. Innovation systems and transformative innovation policy remain rather silent about the role of agency. Structural elements and global forces are the key explanations for innovation, and the unfortunate situation we are in with

grand challenges threatening our societies. Human agency manifests mainly as the unintended consequences of the actions of generations leading to powerful lock-ins that transformative innovation policy is trying to combat. The problem with this lack of theorizing and insights on agency are profound because structures are not changing by themselves. It needs agency to change structures and achieve transformative change.

Based on this concluding discussion, we propose three avenues for future research. First, research on transformative innovation policy still has some way to go in providing policymakers with a clear understanding of the types of (mixes of) policy instruments and processes they need to put in place. This also includes an improved understanding of the balance between 'creation' and 'destruction' instruments in policy mixes, and how this might differ between transitions depending on the characteristics and challenges of transition processes.

Second, some insights on change agency are developing now, partially related to the innovation system approach and partially to transformative change (Grillitsch and Sotarauta, 2019, Isaksen et al., 2019, Dawley, 2014, Simmie, 2012, MacKinnon et al., 2019, Jolly et al., 2020, Sjøtun and Njøs, 2019). However, it remains unclear what role agency plays in the transformation process and how it may be mobilized through policy.

Finally, we note that while innovations systems research has for decades enjoyed fruitful cross-fertilization with the field of economic geography, there is still a significant lack of geographical sensitivity in transformative innovation policy. To exemplify, there are very few insights on opportunities for transformative innovation policies at the regional scale (Capasso et al., 2019) and a very limited understanding of how transformative innovation policy can and should take different forms in different geographical contexts (Grillitsch et al., 2019). Thus, in these respects, transformative innovation policy remains considerably under-developed compared to innovation systems policy.

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