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An innovation system framework for system innovation policy: the case of Strategic Innovation Programs (SIPs) in Sweden

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Papers in Innovation Studies

Paper no. 2017/08

This is a pre-print version of a paper that has been submitted for publication to a journal.

This version: April 2017

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http://www.circle.lu.se/publications

WP 2017/08

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Keywords: System innovation; transition theory; innovation systems; policy; strategic innovation porgrammes

JEL: O30; O33; O38

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Word count: 8679

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Funding: This work was funded under the Vinnova project "Policy for system transition: the case of Strategic Innovation Programs"

Acknowledgement: We are thankful for insightful comments received at several workshops with Vinnova and OECD.

1. Introduction

Grand societal challenges such as climate change, ageing population and food security feature increasingly on the agenda of policymakers at all scales. Innovation policies that directly target these challenges are in particular advocated by supranational organisations such as the OECD and the European Union (EU), but are gradually also taken on board by local, regional and national authorities (Cagnin et al. 2012; Coenen et al., 2015). This orientation towards grand societal challenges can be seen as a new wave or paradigm for innovation policy.

In this context Schot and Steinmuller (2016) have recently suggested three historical framings of innovation policies. Innovation policy 1.0 has been primarily directed to R&D-based innovation, drawing on a linear model of innovation that priviliges the technological discovery process. Innovation policy 2.0 aims to make better use of knowledge production, support commercialisation and bridge the gap between discovery and application, drawing on the concept of systems of innovation. Innovation policy 3.0 involves the explicit mobilisation of science, technology and innovation for meeting social needs. It addresses the issues of sustainable and inclusive societies at a more fundamental level than previous framings or their associated ideologies and practices. Drawing on socio-technical transition theory it explicitly calls attention for the directionality of innovation.

In light of the above grand societal challenges, Schot and Steinmuller (2016) argue strongly for the importance of innovation policy 3.0 – innovation policy for transformative change – as ”innovation policy should focus much less on products, processes, firms, and R&D, but on the achievement of systems wide transformations, since optimization of existing systems will not be a sufficient answer” (p. 17). Similarly, the OECD (2015) observes 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” (p. 9). This challenge, in turn, requires so-called system innovation policy understood as “a horizontal policy approach that mobilises technology, market mechanisms, regulations and social innovations to solve complex societal problems in a set of interacting or interdependent components that form a whole socio-technical system” (OECD 2015, p. 7).

Even if policies start to be aimed at addressing these challenges, as many governments are presently doing, this third framing is currently under-developed and it is unclear how to implement such policies (Kuhlmann and Rip, 2014; Schot and Steinmuller, 2016). In this paper we seek to contribute to both gaps. Firstly, we develop an analytical framework that allows to specify the conditions that enable and constrain system innovation. Secondly, we illustrate its use to identify and assess system innovation policy in practice focusing on the Strategic Innovation Program, a recent policy initiative by Vinnova, Sweden’s Innovation Agency, targeting system innovation. Correspondingly, the objective of this paper is to explore how system innovation policy is implemented and to analyze how system innovation policy practice corresponds to the challenges set out by the transformative change implied by system innovation.

Insights from transition studies have already provided novel rationales for policy action in science, technology and innovation policy to address system innovation (Weber and Rohracher, 2012). However, these studies provide little guidance as to which policy instruments are effective in addressing system innovation. To translate and concretize the challenges of system innovation towards scope for policy action, we relate these challenges to three generic dimensions of innovation systems, i.e. (1) interests and capabilities of actors, (2) networks and network dynamics and (3) institutions and institutional change. These dimensions will allow us to analyze whether and how innovation policy instruments can be used to foster and expedite system innovation.

Our analytical framework for system innovation policy will be empirically illustrated with reference to two initiatives in the Strategic Innovation Program (SIP) of Vinnova, Sweden's Innovation Agency, namely BioInnovation and Re:Source. Over the past years, Vinnova has increasingly endorsed a more societal challenge driven logic for innovation policy, not only in discourse but notably also in terms of resource allocation. In various ways SIP has subscribed to the notion of system innovation policy. It aims for transformative change through system-innovation rather than optimising existing systems. It is explicitly geared to fostering radical and disruptive innovation. It targets technological innovation as well as social innovation. Moreover it acknowledges the need for interdependent institutional and technological change to foster system innovation.

This paper proceeds as follows. The next section outlines the conceptual foundations for systemic innovation policy. Section three introduces the empirical case, the Strategic Innovation Program. Section four provides the analytical framework illustrated by examples from the Strategic Innovation program. In usual fashion, the paper ends with conclusions.

2. Conceptual foundations

Systemic perspective on innovation policy

The rationale for policy support in systemic approaches to innovation is to address system failures (Laranja, Uyarra, and Flanagan 2008). A system perspective on innovation goes beyond the neoclassical economic rationale that policy intervention is only legitimate and needed due to market failure because of sub-optimal resource allocation by firms. Rather, it builds on the notion that innovation processes are social learning processes that take place in a context of networks and institutions, and which can be pro-actively influenced to enhance the innovation capacity of firms, regions and nations. This implies that public intervention is legitimate and needed if the complex interactions that take place among the different organisations and institutions involved in innovation do not function effectively. Primarily concerned with innovation policy 2.0 goals such as economic growth and competitiveness, various authors (Klein Woolthuis, Lankhuizen, and Gilsing 2005; Smith 2000) have identified a number of structural system failures which inform and shape system-oriented public policy support for innovation:

- Actor capabilities' failures: The lack of appropriate competencies and resources at the firm and organisational level may limit and/or prevent the generation of, access to, and exploitation of knowledge.
- Network failures: Intensive cooperation in closely tied networks leads to myopia and lack of infusion of new ideas or too limited interaction and knowledge exchange with other actors inhibits exploitation of complementary sources of knowledge and processes of interactive learning.
- Institutional failures: Absence, excess or shortcomings of formal institutions such as laws, regulations, and standards, in particular with regard to IPR and investment and lack of informal institutions such as social norms and values, culture, entrepreneurial spirit, trust and risk-taking that impede collaboration for innovation.

One of the main contributions of the IS approach has been to specify what kind of innovation policy is needed to fit and address the specific characteristics and challenges of a particular region, country or industry. There is no single permanent 'best practice' policy, or mix of policy instruments, available for each and every situation, as regions, nations and sectors are very different. Thus, instruments and policy systems have to be context sensitive in order to provide tailored policy support beyond 'one-size-fits-all' (Tödtling and Trippl, 2005). While the relevance of these types of failures is generally accepted, this framework has been criticised for being geared primarily to system optimization while challenges of system transition have been relatively neglected (Alkemade et al. 2011).

System transformation: insights from transition theory

Conceptually system innovation policy has been heavily influenced by the burgeoning literature on socio-technical system transitions (Geels, 2005). Drawing on the Schumpeterian notion of creative destruction, research on socio-technological transitions has emphasized technological niches as quasi-experimental incubation spaces for radical novelty that challenge and are challenged by relatively stable regimes (Schot and Geels 2008). Here, a regime refers to an entrenched socio-technical system whose institutional logic structures perception and behavior of actors, thus favoring incremental change and innovation. The distinction between niches and regimes has been proven to be a useful heuristic to capture processes of new path creation in the emergence of radically new technologies while at the same time accounting for processes of path-dependence and resistance when such technologies start to substitute and dislodge existing socio-technical systems (Smith et al. 2010).

Various advances have been made that suggest how the above innovation system failure framework can be extended to address not only system improvement but also system transformation (Weber and Rohracher, 2012; Kivimaa and Kern, 2016). Weber and Rohracher (2012) provide a comprehensive framework that informs policies for transformative change drawing on a combination of market failures, structural system failures and transformational system failures. The four transformational system failures can be regarded as a direct extension of the structural system framework outlined above. These include: directionality failure, demand articulation failure, policy coordinate failure and reflexivity failure. Similarly Kivimaa and Kern (2016) found inspiration in the transition literature to suggest a modified system failure policy framework for transformative change. But whereas Weber and Rohracher (2012) primarily draw on the multi-level perspective and its concepts of niches and regimes, Kivimaa and Kern (2016) have added theoretical notions from the functions perspective on technological innovation systems and transitions (Hekkert et al., 2007; Bergek et al., 2008) but also raise attention for so-called destruction-oriented policies targeting regime destabilization (such as reduced support for dominant regime technologies).

Even though both contributions have substantially advanced systemic innovation policy approaches in light of challenges of transformative change, there is a risk that the suggested frameworks remain schematic and, in doing so, remain mute concerning several important questions. By simply categorizing systemic failures along different dimensions, there is a lack of understanding how these failures are interconnected and whether they all are of equal importance. Moreover, cause-effect relationships remain black-boxed. Finally, even though this critique is also acknowledged by Weber and Rohracher (2012) the semantics of 'failures' may follow too closely the neo-classical market-failure framing and legitimizing of policy intervention, thus discounting for more pro-active and developmental approaches to innovation policies (Asheim et al., 2011; Mazzucato, 2015). To address the latter critique we substitute a concern with system failures with system challenges while solving questions related to the interconnections between the different transformation challenges requires better embedding in a theoretical framework.

A starting point for developing such a theoretical framework is to focus on the essence of societal challenge driven system innovation policy, which in our view is primarily related to the question of directionality. The previous wave of innovation system policy has been directed to improving the generic capacity of countries, regions and/or industries for innovation and, ultimately, economic growth (i.e. innovation policy 2.0). Transformative change and challenge-driven policy is explicitly linked to the question of directionality and requires the setting of collective priorities (Steward, 2012). The main thrust of system innovation policy is to steer the direction of innovations to addressing key societal issues such as climate change rather than being industry or technology driven. One important building block of the theoretical framework relates thus to the conditions and mechanisms through which directionality is provided. In transition terminology, this refers to a regime-shift of socio-technical system, incorporating co-evolving structural changes in production and consumption patterns. Existing research on transitions suggests that experimentation plays an important role in this respect.

Experimentation is particularly emphasized in the MLP framework. Experimentation is at the core of innovation activities carried out in niches and foregrounds its agentic qualities. It refers to processes that enable the alignment of a heterogeneous set of actors, institutions and technologies in order to establish socio-technical “configurations that work” through processes of interactive learning (Callon 1998; Rip and Kemp 1998). Here experimentation is understood as an iterative construction process where networks of distributed actors jointly create new market segments and user profiles, adapt regulations, lobby for subsidies, or define new technical standards and thereby ultimately create the conducive environment that helps a new industry develop and mature (Garud and Karnøe 2003; Garud et al. 2007). This requires entrepreneurship, not only to be proficient in the relevant knowledge fields but also to be capable of embedding new ideas in a wider institutional environment. Such understanding of experimentation as an entrepreneurial discovery process is in fact emphasized in the policy framework of smart specialization (Foray et al. 2009, 2011).

Experimental projects in real-life contexts are seen to be critical by bringing together actors from variation and selection environments in shared networking and learning activities. In these experiments, firms, research institutes, universities and governments search and explore the best possible combinations of innovations and their social and institutional embedding (Bulkeley and Castan Broto 2013). Experimental projects are showcases for the feasibility of new technologies and institutional arrangements, whether they are workable solutions to given problems and can create sufficient demand.

The third building block captures the system effects of experimentation, i.e. to what extent it gives rise to transformative change, understood as a change of directionality in systemic patterns of consumption and production. Here we distinguish between two system effects, closely related to the Weber and Rohracher (2012) framework. On the one hand, experimentation affords for demand articulation, i.e. anticipating and learning about user needs to enable the uptake of innovations by users.On the other hand, through experimentation feedback (both positive and negative) is generated about existing and prospective institutional arrangements for innovation thus giving rise to policy learning and coordination.

The importance of demand for innovation has always been integral in much of the literature on innovation systems and for innovation policy 2.0, ever since Lundvall (1988) stressed the significance of user-producer interaction for learning and innovation. However, in this initial context, use and users have been largely confined to business-to-business or university-to-business relations. The shift to challenge-driven innovation reaches beyond (yet includes) market-based innovations and, thus, recognizes not only ‘pull’ from business but also from citizens and consumers in more direct ways (Steward, 2012). It explicitly acknowledges that (end-)user-practices are an integral part of innovation (Pantzar and Shove, 2010). Demand articulation is particularly emphasized in experimental approaches such as living labs not only to anticipate and learn about user needs but also to raise awareness of new possibilities through more open and co-creative innovation models (Bulkeley et al., 2017).

Policy learning and coordination is necessary for challenge-driven innovation policy as the problems that are addressed tend to be wicked problems that require solutions with long gestation periods (Rittel and Webber, 1973). One solution (innovation) at one point of time may generate new, additional problems later on or elsewhere. Moreover, challenges, solutions and innovations are contested: many different actors are involved that represent different interests, have different problem perceptions and advocate different solutions. Rather than planning for optimal policy design, policy is supposed to be adaptive and reflexive. As such governing processes are seen as "shaping, interlinked with and open to feedback from broader social, technological and ecological changes, both in terms of innovative action and structural change" (Voss et al., 2009).

Empirical illustration: Strategic Innovation Programmes (SIP) in Sweden[1]

The Strategic Innovation Program (SIP) was launched by the Swedish Government in 2012 as a mission to Sweden's Innovation Agency (Vinnova), the Swedish Energy Agency (Energimyndigheten) and the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas). The initiative has a twofold objective, (1) to improve international competitiveness and (2) to address global societal challenges. While previous innovation policy initiatives in Sweden have largely focused on exploiting and furthering specialization in established or emerging strengths in Sweden's innovation system (in terms of sectors, technologies and/or regions), the initiative explicitly sets out to enhance interaction between different actors in the innovation system by transcending sectors and territorial boundaries. The rationale for this has been the recognition that interaction and collaboration between diverse and sometimes unrelated sets of actors is increasingly important for innovation in modern economies (Boschma et al., 2017). Such interaction needs to be enhanced by policy because it did not seem to take off despite big investments in research and innovation (OECD, 2016).

The aims and objectives of the SIP program – to create preconditions for sustainable solutions to global societal challenges and to increase competitiveness in areas of high relevance to the Swedish economy – are broadly formulated, allowing for fairly open-ended interpretation and adaptation by the participating actors. In addition to stressing the need for interaction and broad participation of actors of different types, Vinnova highlights the ambition to draw on pre-existing strengths in the innovation system (in terms of industries, competences, profiles, scientific themes etc) and at the same time stimulate industrial and technological renewal. During the course of the programme, the initial focus on international competitiveness in areas of high importance for the Swedish economy has, according to the program representratives interviewed in this study, been increasingly combined with a focus on addressing global challenges, in particular challenges connected to sustainability. In

[1] The empirical data has been collected through an extensive desk-based document analysis combined with nine semi-structured interviews. The document analysis has covered policy reports and other policy documents, newspaper articles and documents guiding the operative work within the programs. The latter were provided by the interview partners. The interviews were taken during spring 2016 and included program managers, chairmen and other board members, and members of the so called 'strategic committees' or 'expert teams' of both programs. In addition, respondents were selected to cover not only the different functions within the program, but as representatives of different stakeholder groups. By using a snowball sampling method, combined with insights gained from the document analysis, we have strived for a balanced selection of interview partners. Each interview lasted approximately one hour.

the most recent descriptions of the SIP program (Vinnova, 2016) the main aim has even shifted and forefronts now the focus on sustainable solutions to global societal challenges.

Due to the complexity of global challenges for sustainability, the broad range of actors representing academia, business and other private and public sector organisations is one of the key characteristics of the inititiative. While this opens for potential cross fertilization across previously separated domains and knowledge bases, it also raises challenges with regard to coordination and alignment of interests and expectations. The complexity of problems set out to deal with emphasises the need for both technological and non-technological innovations as well as institutional change, and spans severeal technological and sectoral domains. To handle this wide span from a policy point of view, the SIP program is organized as a joint initiative between three agencies. The remainder of this paper provides examples of system innovation challenges derived from the SIP program, as well as responses to those challenges, particularly focusing on two sub-programs Bioinnovation and Re:source.

The guiding vision underpinning the BioInnovation SIP is that Sweden should make the transition to a bio-based economy in the first half of the 21st century. The mission of the initiative is to create conditions to increase the added value in the Swedish bio-based sector. Expected effects are new innovations leading to bio-based materials, products and services that give increased international competitiveness for Swedish enterprises and increased export value for Sweden. The BioInnovation consortium is currently composed by more than 60 organisations from different sectors, representing industry, academia and the public sector. The explicit ambition with BioInnovation is to promote cross-fertilization of competences and experiences by stimulating interaction and collaboration across sectoral boundaries. A percieved precondition for achieving such cross-fertilization, is to work towards bridging the gaps between the sectors by way of coordinating and, when possible, integrating standards, norms, traditions and business cultures.

The guiding vision for Re:Source is that Sweden by 2030 should be the world-leading country in minimizing and utilizing waste. With this vision comes an ambition to contribute with innovative solutions to face the grand societal challenges of resource demand, material supply, and a sustainable energy system. The initiative sets out a number of strategies to achieve these aims. The overarching strategy is to establish Re:Source as a central platform and arena for interaction among actors from industry, academia and the public sector involved in resource- and waste management. Similar to the BioInnovation initiative the complexity of challenges for Re:Source presupposes that such interaction and collaboration takes place across sectoral and territorial boundares. Some of the immediately involved sectors (e.g. chemicals and energy) are the same as in the BioInnovation program. However, due to the generic nature of resource- and waste management, one could argue that all parts of the Swedish economy (both on the production and consumption side) are involved in one way or another. While this underscores the relevance and potential impact of the program, it also underscores the complexity of challenges it faces, not least with regard to coordination and alignment of expectations and interests. Being recently initiated, the scope and scale of Re:Source is not yet as large as BioInnovation, but there is an expectation that this will develop during the course of the project. The first phase (three years) was initiated 2016, but already from the start the consortium plans for twelve years duration of the program.

3. Analysis: Systems innovation challenges and responses from SIP

Directionality

Actors provide directionality through institutional entrepreneurship, which is a process of breaking with existing structures and taking actions to institutionalize alternative ones (Garud, Hardy, and

Maguire 2007; Battilana, Leca, and Boxenbaum 2009). Defining characteristics of institutional entrepreneurs are intentionality, the pursuit of a specific interest, as well as the capability to mobilize required resources (DiMaggio 1988). Intentions and interests, however, evolve over time as institutional entrepreneurs, understood as reflective change agents, promote change while, at the same time, adapt to changes in their environment (Sotarauta and Pulkkinen 2011). Institutional entrepreneurship is conditioned by different types of power agents have and use in the pursuit of their interests. Sotarauta (2009) distinguishes between formal powers to change and create new institutions or commit resources as well as network and interpretative power. Network power enables actors to draw on distributed resources, to control and facilitate the flow of information, and to build trust among partners. Interpretative power relates to the ability to alter or create new meanings and interpretations, as well as to articulate potential future visions.

In the case of SIPs, directionality has been provided in a two-step process. First, vision-development and agenda-setting exercises laid the basis for strategic innovation agendas. Second, a number of different and relative narrow innovation agendas were combined into broader more encompassing programs, which ensured a broad interest by and engagement of a variety of stakeholders. Key individuals from research organizations and associations of public organizations and private industry with significant experience in drafting proposals for funding were driving the formulation of the agendas as well as the strategic innovation programs. They acted as “boundary spanners” and used their network and interpretative power in order to mediate between different interests, synthesize the individual agendas, and formulate embracing visions.

Smith et al. (2005) argue that the ability and power to intervene in socio-technical regimes and promote system innovations depend on regime membership and the distribution of resources. Members of regimes capture broadly all actors that contribute to reproducing regime functions. Some members will be more central than others, thus have more power to promote or prevent change. Such distribution of power and resources between members of regimes gives raise to conflicts, which was one of the key problems identified in the SIPs. For instance, in the case of Re:Source the waste recycling industry and the municipality-owned waste-handling companies compete for the same waste. The public waste-handling companies in Sweden enjoy by law a monopoly on handling waste produced by households, thus are in a strong position as compared to private firms. It has turned out that a range of concrete objectives and actions were not feasible due to conflicting interests between key stakeholders. In such a situation, program managers are tempted to diverge from the strategic goals in order to formulate objectives and actions that receive sufficient buy-in and are achievable. This is because the performance of program managers relates to the success of the strategic innovation program. Rather than not absorbing funds and implementing fewer activities, from a program manager’s perspective it may be the better option to promote collaborative activities that only weakly contribute to the strategic goals. Therefore, it is important to promote incentive mechanisms that promote addressing the root of the problem (i.e. in this case the unresolved conflicts) and an open discussion about how to address it.

Actors also need to acquire new competences because system innovation policies require different forms of governance as compared to traditional innovation policies. Loorbach (2010) emphasizes the ability to cope with a high level of uncertainty, to balance short-term actions with long-term visions, as well as to involve, interact, experiment and learn with a variety of actors. Furthermore, new competences are also required due to the specific functions of actors in promoting system innovations, which differ from or complement traditional functions as becomes apparent in the case of states and higher education institutes. The state provides directionality through its capacity to establish niches (Dawley 2014), facilitate collective learning processes (Rotmans, Kemp, and Van

Asselt 2001), and fund research, development and education (Tanner 2014; Mazzucato 2015). Higher education institutes contribute as potential change agents among others by modelling sustainable practices for society, by introducing students to system-thinking and educate them to solve complex problems, and by promoting exchange and interactive learning within and outside the higher education sector (Stephens, Hernandez, Román, Graham, and Scholz 2008).

The relevant networks in the context of system innovation are highly complex, erected at different spatial scales and stretching across different institutional domains (Geels 2002). Comparing the development of the wind turbine technology in Denmark and the US, Garud and Karnøe (2003) illustrate the importance of networks in the process of new path creation. The authors attribute the Danish success to interactive and cumulative learning processes between producers, users, evaluators, and regulators. This promoted quick feedback, step-by-step improvements of a simplistic design from the 1950ies, and the co-evolution of a supportive regulatory environment in relation to R&D funding and certification.

Globalization of production and the global nature of grand challenges imply that global actor networks play an important role in providing directionality. Among others, global actor networks comprise intergovernmental organizations, states, transnational cooperations and global civil society organizations (Dicken 2011). Negotiations of global climate objectives and treaties, orchestrated by intergovernmental organizations, involve nation states but indirectly also interest groups including fundamental environmentalists as well as climate change deniers (Raskin et al., 2002). At a more operational level, Rock et al. (2006) show how directionality can work in a concert of global civil society organizations, transnational cooperations and local actors, and how the diffusion of environmental standards in global production networks depends on interactions between these different types of actors.

As regards institutions, shared visions are considered essential for providing directionality (Weber and Rohracher 2012) and feature prominently in transition management approaches (Rotmans, Kemp, and Van Asselt 2001; Loorbach 2010). A shared vision forms when core elements of the visions in different sectors and social groups align, i.e. when certain values, norms, and strategic objectives about future pathways converge (Raven, Bosch, and Weterings 2010). Shared visions co-evolve with the variegated interests of the concerned social groups and tend to be created in participatory processes in order to ensure the required ownership and engagement for working towards the vision (Hodson and Marvin 2010). A shared vision contributes to system innovation by identifying plausible future scenarios, by formulating the technical, institutional, and behavioural problems that are to be solved, by providing a stable point of reference for target setting and monitoring, by providing a metaphor that can unit different actor groups and focus capital and resources (Smith, Stirling, and Berkhout 2005).

In the case of the SIP, the attempt to achieve shared visions among many stakeholders led to broad, catch-all agenda setting, which has been identified as problematic because it weakens the power of the SIPs to provide direction in a concrete and actionable way for the involved stakeholders. It remains questionable whether and to what extent the SIPs have achieved an institutional change in the form of aligned values, norms and strategic objectives. This may have to do with a lack of understanding of challenge driven innovation programs. Some stakeholders held the expectation that the SIPs would fund traditional innovation projects addressing individual actors' needs as opposed to the more comprehensive and collective activities required to target a societal challenge. Consequently, the investigated SIPs were designed rather as umbrella of several agendas, representing different actor interests rather than as a collectively forged, well-aligned and integrated program.

Experimentation

Regarding actors, an underlying explanation for challenges related to experimentation may be a shortage of entrepreneurship, since experimentation with new technologies, markets and organisational forms is central to the activities of entrepreneurs (Stern 2006). Historically, the experiments of entrepreneurs have played significant roles for transformative change, e.g. Edison for electricity distribution (Hargadon and Douglas 2001). Thus, new entrants are arguably the most important sources of disruptive innovation since incumbents are bound by existing organisational routines and values, and profit from current technologies (Leonard-Barton 1992; Chandy and Tellis 2000). However, some incumbents do still engage significantly in experimentation efforts (Rosenbloom 2000; Roy and Sarkar 2016), and incumbents may potentially play an important role for transformative change due to their access to capital and technical capabilities (Chandy and Tellis 2000; Hockerts and Wüstenhagen 2010). In particular, incumbents with loosely coupled, stand-alone divisions focused on experimentation activities may make important contributions to transformation processes if these new divisions have sufficient resources and authority (Hill and Rothaermel 2003; Chang, Chang, Chi, Chen, and Deng 2012; Hansen and Coenen 2016). Thus, the absence of intrapreneurs and new divisions in incumbents may also lead to insufficient experimentation. Finally, recent work on urban sustainability experiments highlights the core role played by, in particular, local government actors, but also community-based organisations in leading these efforts (Bulkeley, Broto, Hodson, and Marvin 2011; Bulkeley and Broto 2013). Consequently, challenges related to experimentation may also be caused by a lack of engagement of non-firm actors.

On the network-side, predominance of relations between homogenous actors is a main underlying explanation for insufficient experimentation. Experimentation requires not only interaction and collaboration across disciplines (Lyall, Bruce, Marsden, and Meagher 2013; Rekers and Hansen 2015), but also between firms, users, policymakers and interest groups (Geels and Raven 2006; Coenen, Hansen, and Rekers 2015). In line with this, the SNM literature stresses the importance of networks that are broad (covering multiple types of stakeholder, including traditional outsiders) and deep (involving actors who can mobilise resources) (Schot and Geels 2008). However, while the core argument is that diversity in actor-constellations is of primary importance in experimentation activities, Schot and Geels (2008) also acknowledge that too much diversity may make it difficult to reach consensus and lead to resource fragmentation.

In BioInnovation, issues related to insufficient experimentation were considered to result from both a shortage of SMEs focused on experimenting with new technologies (actor-side)[2] and closed collaboration networks, which prevent the development of such firms (network-side). A main approach taken by BioInnovation to address this issue has been to form so-called expert teams made up of representatives with a background in R&D from firms, industry organisations, universities and research institutes. Expert teams are established for a number of thematic areas such as "materials"

[2] The SNM literature emphasises the importance of including civil society and other non-firm actors in experimentation processes, however, in the current geographical and sectoral context, which is heavily dominated by large incumbents from e.g. the forestry industry, it is in itself ambitious to strive for a large inclusion of SMEs.

and “chemicals and energy”, and have the responsibility for intervening in the formation of project consortia. Consequently, when proposals for projects are submitted to BioInnovation, the relevant expert teams may for instance suggest to combine project proposals or to include new actors to ensure that existing collaboration patterns between incumbent actors are not reproduced over time. Thus, expert teams broker to facilitate experimentation. In addition to introducing expert teams, BioInnovation also, firstly, provide training to members on how to work in innovation projects involving diverse partners, since many lack such experience, and, secondly, develop template agreements that are intended to guide the process of establishing such consortia.

In terms of formal institutions, Government policies may provide room for experimentation in multiple ways, directly in the form of funding and other forms of support for test and demonstration projects (van der Laak, Raven, and Verbong 2007; Nill and Kemp 2009; Klitkou, Coenen, Andersen, Fevolden, and Hansen 2013; Frishammar, Söderholm, Bäckström, Hellsmark, and Ylinenpää 2015) and indirectly through support for entrepreneurship and firm diversification (Feldman, Lanahan, and Miller 2011; Neffke and Henning 2013). The SNM literature stresses the importance of issues associated with insufficient policy support for experimentation, but also that too large and/or long policy protection for specific experiments will lead to lack of incentives for eliminating negative side-effects and, potentially, expensive failures (Kemp, Schot, and Hoogma 1998; Schot and Geels 2008). To exemplify, Nill and Kemp (2009) mention the case of the Dutch wind turbine industry where producers were not incentivised to develop internationally competitive designs due to generous policy support (see also Kamp 2002). Thus, while policy support for experimentation is important for transformative change, experiments also need gradual exposure to selection pressures.

The case of RE:Source illustrates such gradual exposure to selection pressures. Few restrictions applied to the first call for projects, which consequently resulted in a large number of smaller pre-projects that covered a large variety of topics being funded. Yet, according to interviewees, upcoming calls will be narrower and guided by the results of the pre-projects. Consequently, the expectation is that much fewer – but larger – projects will be funded. This will allow RE:Source to set a clearer direction in its activities, but will necessarily also limit the opportunity for experimental activities.

Informal institutions may also lead to challenges related to experimentation. Engagement in experimentation activities is influenced by cultural aspects such as risk-taking behaviour, acceptance of failure and esteem for entrepreneurialism, which have been found to vary significantly between innovation systems (Shane 1993; Efrat 2014; Turró, Urbano, and Peris-Ortiz 2014). To exemplify, Näyhä and Pesonen (2014) demonstrate that transformative change in the forestry industry in Scandinavia and North America is significantly hampered by a conservative organisational culture, which constrains experimentation with new technologies and business models.

Demand articulation

On the actor-side, an underlying explanation for this may be a lack of lead users or users that modify existing usage practices (Schot, Kanger, and Verbong 2016). By definition, lead users have needs that are radically different from existing offerings on the marketplace (von Hippel 1988) and they may destabilise existing socio-technical arrangements by inventing, co-developing and testing radical innovations. Thus, while the actions of regular users will generally stabilise socio-technical regimes (see e.g. Shove, Walker, and Brown 2014), the presence of lead users may have the opposite effect.

For instance, the initiation and development of the car sharing niche in Switzerland was fully led by users (Truffer 2003). While lead users in this way can commercialise radical ideas on their own, the conditions for transformative change may be even better if firms are also able to benefit from lead users' needs. However, this requires significant changes in the capabilities of firms' marketing departments (Von Hippel 1986).

An additional possible underlying explanation for challenges related to demand articulation on the actor-side is the lack of competent innovation procurement departments in public sector actors to work strategically with demand as a tool for transformation. Innovative public procurement can be understood as "the purchasing activities carried out by public agencies that may lead to innovation" (Guerzoni and Raiteri 2015, p. 729). While the main rationale of public sector procurement has traditionally been lowering of prices, procurement focused on stimulating innovation for higher order public policy goals such as sustainability necessitates significant changes in the needed competences of procurement officers (Edler and Georghiou 2007), who for instance must learn to procure using functional requirements (Edquist and Zabala-Iturriagagoitia 2012).

In the case of the two analysed SIPs, lack of innovation procurement capabilities was an important challenge, which was addressed by both programs, albeit in very different ways. While RE:Source has simply established an innovation procurement platform for interaction between policymakers, industry actors and academia, BioInnovation has launched a call for projects specifically on biobased innovation and public procurement. This followed analyses by BioInnovation of the market and political conditions for biobased products, which highlighted the lack of attention towards the possibilities for new solutions in public procurement. Consequently, it was concluded that improved knowledge on innovation procurement and biobased solutions in public sector actors may stimulate future demand. Thus, BioInnovation is directly financing the establishment of innovation procurement capabilities in public sector actors. Seven projects have been funded, which are concerned with development of biobased products to e.g. the health care sector and the construction industry.

On the network-side, a main underlying explanation for the lack of uptake of radical innovations in markets is a lack of user-producer interaction. User-producer interaction is very important for the development and diffusion of innovations (Lundvall 1988; Gertler 1995), thus, the absence of such relations between niche firms and their customers may hinder transformative change. Conversely, intense user-producer interaction enables bidirectional flows of information and feedback leading to market establishment for emerging technologies such as solar PV (Dewald and Truffer 2012).

Insufficient user-producer interaction was particularly identified as an important challenge in the case of BioInnovation. Knowledge about biobased products is lacking among users, which disincentivises upstream firms from including firms downstream in the value chain in innovation projects. Consequently, the market relevance of new biobased products is often uncertain.

BioInnovation has addressed this issue by establishing user-producer interaction as a highly prioritised topic of the program. Firstly, this implies that collaboration between actors from different parts of the value chain, and between different industries' value chains, is given particular attention. Such collaborations may allow e.g. pulp and paper firms to learn from e.g. textile firms, which have a greater knowledge about consumer patterns in emerging markets for biobased products. Secondly, BioInnovation has stipulated that inclusion of users as work package leaders is an important evaluation criterion for potential new projects. Consequently, innovation projects that do not involve users are unlikely to obtain funding through BioInnovation. According to interviewees, this approach has been effective for product areas where lead users with specified demands are available, yet, it was also highlighted that this is not always the case. Thus, an unfortunate consequence of this approach is that more radical innovation projects where no lead users exist will be less likely to receive funding through BioInnovation.

This unfortunate consequence reflects that while lack of user involvement in innovation processes, leading to insufficient consideration for user practices and expectations, is arguably a main source of challenges related to demand articulation (Weber and Rohracher 2012), too strong user-producer networks may also hamper transformative change. In particular, it has been argued that overemphasising the needs of regular users may lead to "technological incrementalism" (Fischer 1995, p. 146) and that market needs are unable to drive the foundation of new technological paradigms (Dosi 1982). As allegedly said by Henry Ford: "If I had asked people what they wanted, they would have said faster horses."

Regarding institutions, a variety of formal institutions influence demand articulation by for instance subsidising private demand for specific goods and services (e.g. through feed-in tariffs). Large attention has recently been given to the importance of innovative public procurement policies, which are found to increase firms' investments in innovation more than traditional supply-side measures such as R&D credits (Guerzoni and Raiteri 2015). Thus, the absence of innovative public procurement policies will likely lead to both less innovative firms and a reduced ability of policymakers to steer development in the direction of transformative change. Innovative public procurement policies are arguably particularly important for the radical innovations, since entry costs of producers and switching costs of users increase with radicalness (Edler and Georghiou 2007). Thus, a strong initial demand caused by public procurement may be especially important for transformative change.

Demand articulation challenges may also stem from characteristics of informal institutions. While proven technologies have built up legitimacy among users over decades, emerging technologies need to attain such social acceptance (Bergek, Jacobsson, and Sandén 2008). However, informal institutional differences may lead to significant divergence in the possibilities for emerging technologies to appear as desirable and convincing substitutes for existing solutions. To exemplify, variations in professional cultures among farmers have been found to explain differences in the extent and character of biogas technology diffusion (Wirth, Markard, Truffer, and Rohracher 2013).

Policy learning & coordination

It is well documented that failure to learn and adapt in the support structure of an innovation system may render a situation of institutional and political lock-in (Grabher, 1993; Hassink, 2010), which in turn hamper transformation and emergence of new growth paths (Lundvall, 2010). Given the broader view on policy in terms of actors applied in the system innovation approach, this urge for learning and coordination should be expanded beyond the support structure. Weber and Rohracher (2012) underline the importance of both vertical and horizontal coordination in order to ensure "coherent policy impulses from different policy areas in order to make sure that indeed the necessary goal-oriented transformative changes for tackling major societal challenges can be achieved" (p. 1043). Coordinated policies thus provide strong governance guidance in a transformation process. This requires a broad involvement at the level of actors, beyond those that traditionally have been perceived as policy makers. While adaptive policy may handle lock-in situations in a reactive manner, the proponents of policy learning suggests a proactive approach in which policy learning actually drives transformation through changes in the collective perception of change agents (Bennet and Howlett, 1992; Borrás, 2011). Among the main challenges to such learning and coordination are lack of or weak leadership, as well as conflicting interests among actors and thereby following weak coordination capabilities.

The initiation of SIP as such can be seen as recognition of these challenges, and as an example of policy learning and coordination in the sense that the Swedish government, by lessons learned from previous experiences and experimentation, adapted its policy to strengthen leadership and bridge conflicting interests instead of underpinning them through further specialization into sectors and/or regions which used to be the preferred approach in Sweden during the 1990s and early 2000s (Cooke and Eriksson, 2011). Following almost two decades in which such sectoral and territory focused policy programs had been gradually refined, Vinnova, through SIP, turned attention towards sector- and geography-transcending programs unified by thematic focus, spanning sectoral and spatial domains, with an explicit challenge-based rationale for policy intervention. This shift was justified by the acknowledgement of the multi-faceted nature of the challenges in combination with the identified difficulties to achieving the integration and coordination which is necessary for addressing complex transformation. Through this new approach, the government thus catered for both horizontal and vertical policy coordination (Weber and Rohracher, 2012).

Drawing on a a three-fold typology proposed by Bennet and Howlett (1992) Borrás (2011) makes a link between policy learning and organisational capacity by suggesting three intertwined levels of policy learning. The first, government learning, relates to learning and coordination within and across public government organisations. The second, network learning, refers to collective learning taking place in the support structure of an innovation system through broadening of the competence base and new combinations of experiences and practices, including stakeholders such as firms, universities and NGOs. The third dimension, governance learning, encompasses state-economy-civil society relations broadly understood and basically refers to the emergence of new policy paradigms. All three types of policy learning and coordination play essential roles for system innovation, although in complementary ways. Government learning reflects administrative capacity in the support structure and policy domain (e.g. effectiveness, professionalization), network learning reflects analytical capacity among actors throughout the system (e.g. absorption and adaptation to changed preconditions), while governance learning reflects major reflexive and institutional capacity going beyond actor networks or groups of actors. The maintained requirement of a triple helix composition of initiatives within SIP aims to stimulate such learning. A problem, however, is that the variety of stakeholders included in programme and project applications substantially reduces in the implementation process. This challenge was observed and addressed also in SIP. While the first round of activities within BioInnovation were largely about financing research designed and implemented by academic actors, with little involvement by industry, the second round evolved towards better defined problem oriented projects clearly targeting solutions and with broader involvement from industry. Part of the explanation to this development was the coordination efforts carried out in the project consortium. It was acknowledged that industry representatives perceived a challenge for engagement based on the structure of the program, in particular the difference in size and financial resources and the divergent time horizons of industry and academia.

On a related note, with regard to *network dynamics*, the abilities for learning are partly dependent on the scope of the networks and partly on their composition in terms of internal hierarchies (Burt, 2005; Battillana, 2011). The more closed and localized the networks, the higher the risk for lock-in and weak learning capabilities because such networks are not much exposed to alternative technologies, norms and routines. Furthermore, in such closed networks actors with strong power position remain largely unchallenged, which make vested interests a more serious concern than in open and diverse networks. Divergent trajectories, which are basic preconditions for system innovation, are thus in many cases suppressed before they even start because of such vested interests and skewed distribution of power in the networks. Although broadening of networks and the formation of entirely new constellations of actors with more or less coordinated agendas were used as criteria from the agencies evaluating SIP, both BioInnovation and Re:Source experienced problems of low commitment from industry representatives in the early stages of implementation. During the course of the program industry representatives gradually showed more commitment, at the same time as the program developed towards being more relevant for these actors. The government learning of the funding agencies and program management was thus combined with network and governance learning in industry and academia in general, as well as at the concrete program level of BioInnivation and Re:Source.

Conformism and weak policy learning capabilities may be challenged or further underpinned by the *institutional structure* in which these actors and networks are embedded. Regulations, norms, standards and routines that influence economic development are often based on best practice logics, which indicates that those institutions that evolve in economies tend to foster stability and continuity rather than change and disruption (Martin and Sunley, 2006: Glückler and Bathelt, 2017). This implies that actors, although possibly being initially inclined to contribute to system innovation by embarking on diverging trajectories, are pushed back into mainstream routes by institutionally based pressures which hampers policy learning capabilities both by blocking alternative shared visions and demand articulation (i.e. awareness) and by providing incentives for maintaining status quo through conformist strategies, sometimes referred to as institutional hysteresis (Setterfield, 1993). In one of several attempts to address this challenge, BioInnovation launched a so-called "Innovation Race": a 60 hour long workshop aimed at identifying ideas for promoting the bioeconomy in Sweden and – importantly – communicating these to decision-makers such as the Minister for Enterprise, who participated. The ambition with this was to generate learning through awareness of the potential and relevance of alternative applications of biomaterials and – technologies, and to gain legitimacy. The underlying assumption is that such learning will trigger institutional change towards better harmonization of incentives and regulations.

4. Conclusion

System innovation policy aims at promoting innovations that help solving grand societal challenges such as climate or demographic changes. In transition theory this requires a system change in the form of regime shifts, implying a change in the patterns of production and consumption. Transition theory has provided insights about the main mechanisms of such transformation processes but remains relatively silent as to which policy mixes and instruments are effective in promoting system change.

Addressing this gap, this paper proposes an analytical framework rooted in the innovation system approach for the identification of main transformation challenges, thus providing a rationale for developing system innovation policy mixes and instruments. The analytical framework builds on three generic dimensions, i) actor interests and capabilities, ii) networks, and iii) institutions. These three dimensions are discussed in relation to directionality, experimentation, demand articulation, and policy learning and coordination and the main challenges for each dimension are summarized in Table 1.

The analytical framework is informed by work on transition theory and innovation systems as well as the experiences and challenges observed in the design and implementation of the so-called Strategic Innovation Programmes funded by Vinnova, Sweden's Innovation Agency. These programmes are novel in their attempt to promote system change. In principle, these programmes are thought to deal with many of the aspects foregrounded in the literature such as a broad inclusion of actor types bound together with a shared vision (directionality) or promoting radical innovation projects among these actors with the goal to contribute to e.g. reducing CO_2 emissions (experimentation). However, it became clear that both programme managers and actors participating in the programmes are facing new challenges as compared to traditional innovation programmes.

This paper thus contributes by moving beyond the identification of generic transformation processes and transformation failures to the concrete challenges that are faced when implementing such a policy. This leads to a qualification of the general arguments and triggers reflection about the concrete issues when designing system innovation policy. One example is the idea that a shared vision among a variety of actor types is needed for providing directionality, i.e. make sure that all actors work towards a common goal. In practice, it has turned out that this is a delicate point as the more actors are included the larger the variety of interests and the more hollow an overall shared vision may become. Hence, establishing mechanisms and approaches for dealing with conflicting interests between actors surface as one of the critical factors in system innovation policies. In this regard, it has to be recalled that conflicts are not per se problematic. No conflicts would imply that interests and worldviews are aligned among all actors, implying a high degree of homogeneity, which is a typical source of lock-in and constrains radical innovations.

While this paper is a step towards more concrete guidance for the development of system innovation policy mixes, the analytical framework evidently needs to be further tested and developed as the practical experience with such policies has been limited so far. However, the analytical framework allows to systematically identify and order the transformation challenges observed in designing, implementing and evaluating system innovation policies. The analytical framework can thus be extended, corrected and also lessons learned added about concrete policy measures that addressed the challenges. In that way, the analytical framework can serve as a foundation for cumulative policy learning and for improving our understanding of transformation processes.

	Transformation challenges			
	Directionality	Experimentation	Demand articulation	Policy learning and coordination
Actor interests and capabilities	• Mediate conflicting interests • Deal with skewed distribution of power and resources • Enable institutional entrepreneurs • Develop capabilities in new forms of governance	• Stimulate entrepreneurs hip • Support development of new capabilities in incumbents • Promote an interest in experimentati on among non-firm actors	• Support identification of lead users • Develop innovation procurement capabilities in public bodies	• Possess strong leadership; act as role models • Overcome conflicting (vested) interests • Stimulate interaction within consortia

Networks	• Connect and integrate directionality exercised from multiple types of actors, locally and globally	• Encourage collaboration between heterogeneous actors • Assist new actors in entering collaboration networks	• Stimulation interaction between producers and lead user	• Widen the scope and diversity of consortia • Encourage deeper commitment among different stakeholders • Challenge established hierarchies
Institutions	• Develop shared visions that promote institutional change • Set objectives that provide direction in a concrete and actionable way	• Support test and demonstration projects • Gradually increase exposure of experiments to selection pressures • Promote risk-taking behavior and acceptance of failure	• Balance attention to supply- and demand-side policy instruments • Promote social acceptance for emerging technologies	• Challenge best practice logics • Provide incentives for embarking on diverging trajectories • Promote alignment of expectations

Table 1: Concrete challenges that are faced when implementing system innovation policy mixes.

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