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Moving innovation systems research to the next level: towards an integrative agenda

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Abstract: The concept of innovation systems has been a guiding paradigm of innovation research and strongly influenced research and innovation policy since the early 1990s. In spite of this success, criticisms have been raised in recent years about whether it is still a suitable framework for addressing the innovation-related challenges of the future. In the present paper we claim that systemic explanations of innovation success have still a very important role to play. In order to address the rising criticism, however, we have to reconsider the conceptual core of the family of innovation systems (IS) approaches and sketch out a path for renewal. The paper retraces the conceptual roots of IS approaches, assesses their uptake in different policy circles around the world, discusses the conceptual core and explanatory ambition, and finally formulates a future-oriented research agenda for a more integrative innovation systems framework.

Keywords: innovation systems, innovation policy, research agenda

JEL classification: L16, O33, O38

I. Introduction

The innovation systems (IS) approach has been a guiding paradigm of innovation research and has strongly influenced research and innovation policy since the early 1990s. By departing from the then prevailing neo-classical thinking in economics, it recognized the essential, but inherently dynamic and non-equilibrium nature of innovation in modern economies. Without doubt, it has acquired merits in guiding both research and policy. It was developed on the basis of a more sophisticated understanding of innovation processes, which emerged in the 1980s, but also in response to new phenomena at the macroeconomic level, which could not be explained by prevailing theoretical perspectives and for which scientifically sound policy responses were missing. The IS concept was thus developed at a boundary zone between academics and policy-makers (in particular the Organization for Economic Cooperation and Development (OECD)) and has quickly found a lot of resonance in policy circles (Sharif, 2006).

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In spite of this apparent success in both guiding research and inspiring policy, criticisms have been raised in recent years about whether the IS approach is still a suitable framework for addressing today's challenges, or whether it is rather a remnant of the 1990s. The reasons for this critical stance are manifold (DRUID, 2014). First of all, the practices and contexts of innovation have changed over the past years, but have not been sufficiently taken account of in large parts of the IS literature. The increasingly open, interactive, and globalized nature of much research and innovation activity raises the question of whether and to what extent territorially and sectorally delimited innovation systems are still adequate to capture reality.[1] Second, the political frame of reference for innovation policy has been changing as well, and with it the requirements for conceptual approaches to underpin innovation policy. The initial emphasis on innovation as a means of enhancing competitiveness—first at national, later at regional and sectoral levels—has given way to growing concerns about the contribution of innovation activities to tackling major societal, environmental, and developmental challenges. And finally, not least as result of the two previous arguments, many IS studies are regarded as too descriptive in nature, and thus lack the explanatory and normative power expected from a conceptual framework with the ambition to guide policy.

The latter point of criticism may be based on an all too narrow reading of the IS literature and primarily testify to some historical developments in how the system concepts were applied. Its conceptual basis, however, is not limited to descriptive applications nor is it only applicable to problems of the 1980s. The two first points of criticism are more fundamental in nature, by questioning the relevance of IS approaches for today's policy challenges.

This argument is important because of the strong mutual influence of IS research and innovation policy. In fact, IS research has influenced innovation policy as much as innovation policy served as a source of inspiration for IS research. For any future advances in IS concepts, it will be important that they are suitable to respond to emerging requirements of innovation policy.

Against this backdrop, we argue in this paper that the IS approach still has a huge potential to offer for future research and policy, but that a reframing of the conceptual core of IS and a definition of a renewed research agenda is needed to move the field forward. In other words, we pursue the ambition of exploring avenues for making the IS framework 'future-proof'. More specifically, the guiding question of the paper is how the conceptual core of the IS approach needs to be amended in order to take account of the changing nature of research and innovation (R&I) and provide a framework suitable for informing an R&I policy that is more responsive to societal needs and challenges.

To accomplish this task, we revisit the intellectual roots of IS research and reconstruct its different generations that could be subsumed under the innovation systems frame[2] in relation to each other (section II). Next, we highlight the past merits of IS

[1] Several of the proponents of the national innovation systems (NIS) concept argue that national borders and institutions still matter most, even for innovations that have a strong regional or border-crossing dimension (see, for example, Sharif, 2006).

[2] We somewhat extend the focus of analysis to strands of research that may not necessarily make explicit use of the innovation systems headline, but nevertheless carry similar conceptual ideas and serve as important sources of inspiration. Examples are innovation networks, innovation ecosystems, or various concepts from science and technology studies (STS).

research in terms of its close interactions with innovation policy-making, and elaborate the newly emerging challenges and opportunities for IS research, resulting from recent developments in the practice and organization of R&I activities on the one hand, and from new political requirements with regard to R&I on the other (section III). This will enable us to extract the conceptual core that is shared by all different systems views on innovation; an understanding that should allow positioning the wider family of systemic innovation concepts (section IV). This leads us to propose some major research lines that would contribute to moving IS research to a 'next level' and countering the existing criticism (section V). Section VI concludes.

II. The origins of innovation system concepts

(i) Intellectual roots

The emergence of the IS approach needs to be seen against the backdrop of the coincidence in the 1980s of a growing discontent in policy-making with prevailing (economic) theories to guide growth-oriented policies and of new conceptual developments at the margins of established social science disciplines, most notably economic history, innovation studies, and science and technology studies (STS).

First of all, the IS approach has its origins in the criticism of 'linear thinking' in innovation research and (technology) policy, be it inspired by science and technology (S&T) push (Bush, 1945) or by demand-pull approaches (Schmookler, 1966). This criticism of the linear model of innovation was also a key element of evolutionary economics, which rejected the idea of technological determinism and stressed the importance of interactions between supply and demand sides for guiding technological change.

An important step towards devising more integrated concepts of innovation at the micro-level were made in the late 1970s and early 1980s, by proposing an integrated chain-linked model of innovation, which combines demand-pull and S&T-push factors (Kline and Rosenberg, 1986). This interactive understanding of innovation is also central to innovation systems, which are to be positioned at the meso-level, but it has major consequences for macro-level perspectives on innovation. Due to non-linearities, it puts into question the fundamental principle of neo-classical economics that macro-level phenomena can be understood as an aggregation of micro-level decisions ('methodological individualism').

Closely tied to lines of reasoning in evolutionary and institutional economics, a second and related cornerstone of innovation systems thinking must be seen in the rejection of the rational actor paradigm and the abandonment of thinking in terms of economic equilibria.[3] As argued by Nelson and Winter (1977; 1982), economic behaviour should rather be interpreted as being guided by rules and routines; it is thus much more stable than decision models of rational utility maximization would suggest. Mechanisms of variation, selection, and continuity are at play at the micro-level to overcome the stability of prevailing routines (Nelson and Winter, 1982). They give rise to non-linearities

[3] In essence, economic models and theories based on equilibrium assumptions are inappropriate for understanding innovation processes which are by definition about moving systems out of an equilibrium state.

and lead to the emergence of new structures at the meso-level, such as technological trajectories and paradigms (Dosi, 1982), network externalities (Katz and Shapiro, 1994), 'soft' and 'hard' institutions (Williamson, 1985; North, 1990; Scott, 2014), and other kinds of path-dependent phenomena. Institutions and paradigms are in turn important determinants of innovation, as they guide the strategies of various actors in the variation and selection of new technological options. Recognizing the importance of (national) institutions for innovation performance of countries was actually one of the foundational contributions of the innovation systems literature (Freeman, 1987).

A third important source of inspiration for IS thinking resides in general systems theory and systems thinking more broadly speaking, but this link is largely restricted to the adoption of qualitative notions of 'systems' and 'emergent properties'. The reference to systems thinking was nevertheless important in order to underpin theoretically the departure from the individualistic perspective of neoclassical economics, which regards collective phenomena mainly as an aggregate of individual behaviour and decisions. Systems approaches, on the contrary, stress that the non-linearity of interactions between individual components of a system leads to the emergence of qualitatively different higher-order properties that cannot be explained by simple aggregation. These insights from system theory were key to overcoming the mechanistic thinking about innovation dynamics. Evolutionary (Nelson and Winter, 1982; Dosi *et al.*, 1988) and—to a more limited extent—complexity-inspired ideas (Silverberg, 1988; Anderson *et al.*, 1994; Lane *et al.*, 2009) were very influential in this regard. They enabled a better understanding of how new paths emerge, either at the level of individual technologies, meso-level institutions, or macro-level systems (e.g. Dosi, 1982; Arthur, 1988; Freeman and Perez, 1988). Overall, however, it is fair to say that the IS approach did not draw extensively on any of the elaborated systems theories—for example, synergetics (Haken, 1983; Weidlich, 1991), theory of social systems (Luhmann, 1988), and autopoiesis (Maturana and Varela, 1980). As a result, the IS approach should not be interpreted as a 'strong' systems theory, even if it adopts some important elements.

However, in spite of this widespread recognition of non-linearities and systemic effects, it is fair to say that the IS approach, until rather recently, was mainly restricted to providing analytical categories, but did not use the enhanced understanding of system dynamics, not least for predictive purposes.[4] The criticism of being largely descriptive rather than explanatory in nature has its roots in this apparent lack of explicitly addressing how the interplay between the different elements of innovation systems at meso- and micro-levels gives rise to non-linear dynamics of change.

(ii) Revisiting major strands of innovation systems thinking

The main trigger for the rise of innovation systems thinking was the recognition in the early 1980s that Japan was about to acquire a major competitive advantage over the US and Europe (ultimately leading to the eradication of several industries in Europe and the US). This advantage was due to specific institutional settings in Japan, which

[4] Recent developments in the modelling of innovation systems and networks, enabled by enhanced computing power, promise to overcome these limitations (Lane *et al.*, 2009; Pyka and Scharnhorst, 2009).

facilitated cooperation in innovation between research organizations on the one hand and industry on the other (Freeman, 1987).

Subsequently, the two dominant approaches to analysing *national* innovation systems (NIS) were proposed by Lundvall (1992) and Nelson (1993), stressing respectively the role of linkages, interaction, and learning, and of institutional arrangements. Other authors, in particular Edquist (1997), made attempts to reframe the initial concepts of the pioneers in a unified way.

The IS approach also attracted a lot of interest in *emerging and developing economies*, as a source of inspiration for how countries could embark on an innovation-led path towards economic growth and competitiveness. This, however, required substantive adjustments of the NIS framework to the specific conditions of emerging economies; which is one of the ambitions of the Globelics movement (Lundvall *et al.*, 2009). In particular, the emphasis on high-tech and science-driven innovation was not suitable for most emerging economies.

As it was increasingly recognized, in particular in a number of leading European regions, that regional institutions matter for innovation performance, several authors suggested an adaptation of the NIS approach in order to give justice to this growing prominence of regions (e.g. Cooke *et al.*, 2004). The *RIS* (regional innovation systems) literature emphasizes the importance of space and proximity, and it is linked to a broader stream of literature on territorial innovation systems in economic geography, encompassing concepts such as industrial districts, innovative milieus, clusters, or learning regions (Moulaert and Sekia, 2003).

Similarly, by recognizing that sectoral specificities and institutions matter for innovation performance, the concept of *sectoral systems* of innovation and production (SSIP) was introduced by Malerba (2004). He stressed the importance of production systems as the demand side for innovation, and the specific technological, organizational, and institutional requirements that production systems impose on innovation activities. Overcoming these constraints is key to the realization of system innovations and socio-technical regime shifts, which are essential elements for processes of transformative change at sector level and beyond (Geels, 2004).

This opening up of the innovation systems perspective to the demand side of innovation has also been further expanded recently under the headline of *(national) innovation ecosystems* (Wessner, 2005, 2007; Edler and Georghiou, 2007). Inspired by the idea that innovation needs to be understood much more broadly than in terms of technologies and production systems, they argue for including a broader range of demand- and supply-side actors within the system frame of reference. Together, they provide the institutional environment in which innovation can flourish. More recently, the term 'innovation ecosystems' gained some prominence also in the management literature, mostly focusing on the wider environment in which companies were embedded, however without making much of an explicit reference to earlier innovation systems literature (Oh *et al.*, 2016). Associated to this stream of the management literature, companies and organizations are also interpreted as innovation systems (Adner, 2008; Hauschildt and Salomon, 2011; Tidd and Bessant, 2013).

Over the past few years, efforts have been made to generalize the insights into how innovation systems operate, independently of any geographical or sectoral delimitation. Based on early concepts proposed by Carlsson and Stankiewicz (1991), functions or key activities in innovation systems have been suggested in various forms, most prominently

under the heading of *technological innovation systems* (TIS) (Hekkert *et al.*, 2007; Bergek *et al.*, 2008). While the notion of 'functions' of innovation systems was already introduced by Edquist (1997) as a means to harmonize different IS concepts in a more rigorous way, the recently introduced concepts of 'cumulative causation' and 'motors of innovation' aim in particular at analysing the dynamics of IS beyond mere description (Suurs and Hekkert, 2009).

However, these efforts of capturing the dynamics of IS in a systematic fashion are restricted to how innovations emerge in a system context. More recently, a growing interest can be observed in how systems transform. System innovations, implying significant changes in technological, organizational, behavioural, and institutional terms, can give rise to such *system transformations*. This kind of research draws on earlier work by Freeman and Perez (1988) on techno-economic paradigm shifts, but also on the literature on socio-technical transitions (Rip and Kemp, 1998; Geels, 2004; Markard *et al.*, 2012; etc.), thus providing a link with science and technology studies.[5] It is with regard to system transformations that the innovation systems concept seems to reach limits, at least in its current form.

III. Political impact and new requirements

As there was a widely felt discontent about the poor explanatory power of prevailing economic growth theories in the 1980s, innovation studies concepts seized a window of opportunity for strongly inspiring innovation policy. The influence of the NIS concept, in particular, was very strong because it was positioned in opposition to the prevailing neo-classical approach to economic policies for enhancing the competitive advantage of countries (Sharif, 2006). Ultimately, it was due to the influence of the OECD that several countries shifted emphasis from policies focused on individual (research) organizations and specific technologies to policies aiming to strengthen ties in the innovation system, in particular science–industry relations (OECD, 1992, 1999, 2002, 2005*a*; Sharif, 2006).

It is important to stress that the NIS concept was developed in close interaction between academia and government bodies (among which we would count the OECD as well). This process of co-creation was facilitated in social terms by the double role that several key academics played in formulating scientific concepts on the one hand and shaping policy discourses on the other.[6] In substantive terms, the interpretative flexibility of the innovation systems concepts, i.e. the possibility of tying different meanings to key terms, also facilitated a widespread uptake of the concept in the policy context. Of course, this success in policy terms came at the price of limited academic rigour and, as a result, of a certain degree of fuzziness of some of the key concepts.

[5] It is important to stress that 'systemic thinking' was not only emerging in the economics of innovation, but similarly also in adjacent disciplines which cross-fertilized advances in IS thinking. Particularly noteworthy are STS, in particular with the work by Hughes (1983) and Mayntz and Hughes (1988) on large technical systems, but also in political sciences, where the notion of political steering was increasingly substituted by 'governance regimes', thus reflecting a systemic understanding of the role of government in governance processes (Kohler-Koch, 1989; Voss *et al.*, 2006).

[6] The roles played by Freeman, Lundvall, Smith, and others in the OECD context is reconstructed in Sharif (2006). They, as well as other academics, were also influential in transferring IS thinking to the national level.

One major influence that can be attributed to the prominence of the NIS concept concerns the methodology of policy-oriented analysis. With NIS, it became acceptable to present a much broader spectrum of key determinants of techno-economic development than was hitherto common in neo-classically inspired economic analyses. As a consequence, the range of rationales regarded as acceptable to justify policy intervention was broadened. Emphasis was put on the importance of systemic connectivity, evolving institutions, and organizational capabilities (Dodgson *et al.*, 2011), as well as on the need for systemic processes such as foresight to strengthen the legitimacy of priority-setting (Martin and Johnston, 1999). This also led to the elaboration of differentiated analytical frameworks for comparative analyses of NIS and their influence on the competitiveness of countries (OECD, 1992), pointing, for instance, to the importance of strengthening science–industry linkages as a means to foster economic competitiveness through innovation (OECD, 1999).

Through the OECD, but also by way of the policy advisory role of leading IS researchers, the IS framework exerted a major influence at national level, too. The earliest adopters were Finland and Sweden, with Finland seeking inspiration for moving out of its economic crisis in the 1990s, and Sweden establishing VINNOVA as 'The Swedish Governmental Agency for Innovation Systems' in 2001 (but already promoting innovation systems in the 1990s). Other, in particular smaller, economies pursued IS-inspired initiatives, often as an outcome of debates in the OECD context. The Austrian Competence Center programmes, for instance, were developed as a response to the systemic deficit in science–industry relations[7] and proved successful in bridging that gap (Schibany *et al.*, 2013).

Over the years, it became obvious that innovation policy had high relevance and major repercussions for other policy areas, up to the point of regarding innovation as the remedy of many problems and deficits in different policy fields. IS approaches turned out to be quite compatible with the concepts used in other policy fields, and it became influential well beyond the realm of innovation policy. At a regional level, for instance, cluster policies and, more recently, smart specialization strategies were derived from IS concepts (Foray *et al.*, 2009). The renaissance of regional innovation policies (e.g. the Four Motors for Europe regions) has, of course, also other roots (e.g. the work on industrial districts), but was conceived along systemic lines (Moulaert and Sekia, 2003).

The rediscovery of sectoral industrial policy followed similar patterns. In particular, the European Commission's Directorate General for Enterprise and Industry (Reinstaller and Unterlaß, 2008; Montalvo and van der Giessen, 2012), but also recent policy developments in France (*poles de competitivité*) were inspired by systems thinking at the regional and sectoral scale.

Based on an adaptation of IS concepts, several emerging economies embarked on a high-tech growth path (in particular in some Asian countries such as Korea and Malaysia), sometimes following a more planning-based philosophy than may be common in Europe or the US (Lundvall *et al.*, 2009). In Latin America, the attempts to foster competitiveness by building high-tech clusters tended to be moderately successful only, for being set up in isolation from the prevailing economic and research tissue of the countries (Bortagaray and Tifflin, 2000; Giuliani *et al.*, 2005; Aguirre Bastos *et al.*, 2017).

[7] In fact, the Austrian Competence Centers were regarded as a good-practice model by the OECD (see OECD, 2004).

Interestingly enough, the IS approach was less influential in the US, at least when it comes to explicit references in policy debates and documents. However, this may not come as a surprise when taking into account that the IS approach opened up a new rationale for justifying policy interventions in the economy by identifying system failures in relation to innovation. This was rather at odds with the *laissez-faire* philosophy that prevailed in the US in the 1990s and early 2000s. However, some initiatives, such as the widely praised SBIR programme (Small Business Innovation Research) had their roots in a systemic understanding of innovation (Audretsch, 2003).

It is interesting to observe these differences in attention for IS approaches around the globe. Having its origins in Europe, where many countries advocated a strong role for the state in governing innovation, IS provided lines of reasoning ('system failure') that allowed the legitimization of such a role. Interest was equally high in many Asian and developing countries, where the state was assigned a key role in promoting economic and industrial development. The situation is different in the US, probably due to the more restricted role assigned to government in fostering innovation, even though public funding of research plays a very important role there. What this shows is that the political impact of the IS approach is not only a matter of its inherent qualities, but also of the resonance with the respective national political context and culture.

The possibility of absorbing the IS framework in different cultural contexts was also enabled by the aforementioned interpretive flexibility of the concept, but it came at the price of a high diversity of interpretations and limited coherence. In practice, it also meant that the initial scientific ambitions of the IS approach degenerated somewhat in the policy discourse. This development can be exemplified by the increasing substitution of thorough comparisons of national innovation systems by standardized indicator-based benchmarking exercises, both by the OECD and the EC, which tended to neglect the qualitative dimensions of innovation systems. The scoreboards of the EU are a particularly noteworthy example (EC, 2015), which tends to lead to oversimplistic rankings of what were formerly thorough interpretations underpinned by a systemic understanding of research and innovation policy.

In the meantime, however, the world of research and innovation has been moving on, and it is time to consider whether the IS approach is still suitable for addressing recent developments in R&I and policy. These new developments are of two kinds. First of all, the nature of research and innovation activities has been changing since the turn of the millennium. While the growing importance of service innovation is now recognized, even in the *Oslo Manual* (OECD, 2005*b*), the advent of digitalization and virtualization has accelerated the pace of innovation activities, and also given rise to completely new models of research and innovation (OECD, 2016), associated for instance with notions like Science 2.0 (Burgelman *et al.*, 2010), the widespread use of big data techniques (Szkuta and Osimo, 2016), digital platforms (Kenney and Zysman, 2016), and various forms of experimental and 'open' approaches to innovation (Chesborough, 2006; Leitner *et al.*, 2016). The latter in particular has brought with it enhanced collaboration and cooperation between a much broader range of actors than in the past, including not only science and industry, but also public administration, end-users, and civil society. The new digital opportunities also facilitated the further internationalization of scientific collaboration and cooperation in innovation along global value networks (Dachs *et al.*, 2014).

Second, new requirements for innovation policy have also been raised by the re-contextualization of science and innovation in society (Siune *et al.*, 2009; Weber *et al.*, 2016). This re-contextualization refers primarily to the roles that science and innovation are expected to play in society. Demands have been growing that public investment in R&I must ultimately lead to demonstrable social and economic impacts, reflected, for instance, in the recognition that innovation is essential for our ability to tackle 'grand' societal challenges (EC, 2013), thus raising the expectations of what R&I are supposed to deliver.[8] Addressing these challenges is often tied to long-term processes of transformative social change, which require taking into account the social dimension of innovations in a much more prominent manner than in the past. As a consequence, institutional structures cannot be treated as unmoved explanatory variables anymore—a view that was implicitly held by many classical IS approaches—but has to be seen as being an integral part of the co-evolutionary dynamics of socio-technical systems. Another implication is that there is need for more attention to 'downstream' aspects related to a wider uptake of innovations and institutional changes. Taking into account demand conditions and user perspectives is increasingly recognized as crucial for enhancing competitiveness, and this may require paying much more attention to the symbolic value than to the technological capabilities that get more and more widespread and can be less shielded from competition (Huenteler *et al.*, 2014; Jeannerat and Kebir, 2016). As a result of these developments, the scope of innovation policy also needs to be reconsidered, and the coherence between innovation policy and other thematic policy improved. This implies incorporating actors that go well beyond the range of 'usual suspects' and puts much more emphasis on actors on the demand side of innovation. It also coincides with growing claims and possibilities for participation of society in research and innovation activities; citizens can play a much more active role in R&I, and not only as data providers but also in shaping agendas and conducting research themselves (The Royal Society, 2011; Schaper-Rinkel *et al.*, 2012; Weber *et al.*, 2016). Ubiquitous access to scientific knowledge in conjunction with better education is enabling deeper scrutiny of scientific results by so-called 'lay' people, who are now able to question scientific claims for 'truth'. All this finally culminates in the quest for a more process-oriented understanding of conditions for innovation success, compared to the traditional structural approach emphasized in IS approaches.

IV. Specifying the conceptual core of the innovation system framework

The variety of forms in which IS concepts have been spelled out over the years resembles more a heterogeneous family of perspectives than a clear-cut programme. In order to identify how recent critiques of the IS perspective could be addressed and how an innovation system inspired framework could contribute to a better understanding of emerging innovation phenomena, we are going to work out the shared conceptual core of this family in the present section. As a preparatory step, we characterize the main established innovation studies approaches in terms of the delimitation of system

[8] These claims do not deny, but acknowledge that basic and frontier research are necessary to create sufficient variety and ensure that socio-economic benefits will continue to arise in the longer term.

boundaries, the extent to which they focus on the key system elements (i.e. actors, networks, resources, and institutions), and how they relate to policy-making (see Table 1).

System boundaries are chosen according to the nature of the problem to be analysed. A focus on understanding conditions for competitiveness of specific countries or regions leads naturally to looking for how systemic structures differ among territories (NIS and RIS approaches). Interests in industry dynamics on the other hand imply a focus on system configurations that emerge within specific sectors or around new technologies, and which may transcend any predefined territorial boundary (SSIP and TIS) (Carlsson and Stankiewicz, 1991). Due to having started as a joint project of academics and policy-makers it is also small wonder that the different IS variants seem to speak to different policy realms. In general, all have some bearing on national science, technology, and innovation policy. But each has its specific focus (or blind spot) in realms such as regional, sectoral, economic, or environmental policy.

As a consequence, the different approaches have emphasized some of the system elements over others (see Table 1). The NIS tradition, following the work of Freeman (1987) and Nelson (1993), emphasized the role of institutional arrangements that could be found in different countries (originally mostly related to the US, Germany, and Japan) in order to explain the rapid catch-up of Japanese industry. NIS analyses in the Lundvall tradition instead highlight the learning processes for companies in specific countries, thus focusing on actors and interactions. RIS approaches have been inspired by the NIS approaches but have claimed the importance of sub-national institutional arrangements, additionally stressing the role of actor networks for the ability of regions to innovate successfully and over long time spans. Sectoral innovation and production system approaches (SSIP) follow a more balanced approach among the system elements but focus more strongly on actor dimensions, especially for the case of companies. TIS analyses have finally been strong in analysing the roles of different actors in building up system resources, whereas institutional arrangements and networks have been less intensely elaborated (Musiolik *et al.*, 2012). While all approaches, at least implicitly, refer to collective resources that are emerging in the specific system contexts, only the

Table 1: Profiling different innovation system approaches regarding their core interests and orientation

	Actors	Institutions	Networks	System resources	System boundary	Policy realm
Core family of IS approaches						
NIS (Freeman, Nelson)	+	+++	+	++	National	Research, Economic
NIS (Lundvall)	++	+	++	+	National	Innovation
RIS	+	+++	++	++	Regional	Regional
SSIP	++	++	++	++	Sectoral	Industrial
TIS	+++	++	+	+++	Technology/ Industry	Technology, Environment
Kindred literatures						
Entrepreneurial innovation ecosystems	+++	+	++	+	Firm context	Economic
Innovation networks	++	+	+++	+	Networks	Regional, Value chains
Socio-technical systems	+	+++	+	+++	Sectors	Sectoral, Transition

TIS scholars have started to elaborate how these could be identified and even measured in some more detail (Musiolik *et al.*, 2012). Regarding the technology focus, the different approaches may be distinguished with regard to whether they are interested in explaining how actors maintain a competitive edge in established product sectors and therefore focus more on success conditions for incremental innovation (NIS, RIS, and SSIP) or whether potentially radical innovation and newly emerging industries are in the focus (mostly recent TIS literature).

Given this characterization of the family of IS approaches, one may add three related fields of scholarship, which share some aspects of a systems view on innovation, but which depart in important respects from the core family. A first literature adopts the label of innovation ecosystems, either from the perspective of individual company strategies and how they interact with their environment (Adner, 2008),[9] or from a national institutional and policy perspective (Wessner, 2005, 2007). The first strand of innovation ecosystems literature looks through the lens of an individual company at innovations system structures, constituted of networks of suppliers, customers, and institutional actors which may provide important resources for successful innovation activity of the firm, often seen as embedded in a sectoral or cluster environment. While a wide variety of these approaches have appeared recently, only very few of the proponents (e.g. Wessner, 2005, 2007) have elaborated the relationship of their approaches to the more established IS frameworks, while many others have therefore been accused of not providing too much novel insight (Oh *et al.*, 2016).

A second stream of literature claims that innovation systems can be represented by innovation networks (Pyka, 2002; Scherngell, 2013). While social network analysis provides a powerful tool to represent and analyse linkages and knowledge flows between different types of actors in an innovation system, the interplay with institutional conditions tends to remain under-conceptualized (Boschma and Frenken, 2010).

A third literature stream has criticized IS approaches of being too focused on explaining technology dynamics as the result of specific (but essentially given) institutional contexts (Geels, 2004; Smith *et al.*, 2010). In order to tackle the emerging new innovation challenges, an explicit conceptualization of the mutual shaping of institutional context conditions and new technological alternatives is elaborated by these authors under the label of 'socio-technical' systems. Furthermore, they advocate for the analysis of longer-term and more fundamental sectoral and technological transition processes, such as those needed for confronting the challenges of sustainability.

Given this broad variety of inroads and perspectives on innovation systems, the recurrent critiques can be more explicitly understood as relating to strengths or weaknesses connected to adopting a particular approach within the IS family instead of a fundamental defeat in the IS approach as such. NIS and RIS analyses may all too often have stopped short of providing descriptions of specific institutional arrangements in the science, innovation, and technology field in yet another country or region, without working out in much detail what sort of underlying factors and mechanisms could lead to better or worse performance. It is certainly also true that a strict delimitation of system structures along predefined territorial lines (national borders or regional boundaries) may miss out on capturing the increasingly globalized innovation dynamics. Also the strong focus on technological innovation may have deviated attention from a deeper

[9] Sometimes also referred to as corporate or organizational innovation system.

understanding of new challenges related to shifts in the competitive structure of modern economies having more and more to cope with radical, systemic, or value-oriented innovations (Jeannerat and Crevoisier, 2016). IS may thus be accused of having missed out on some of the more recent trends in industrial dynamics and needing to show how they can contribute to a broader class of phenomena such as social innovation, service innovation, or even to larger shifts in how industrial sectors are transforming as socio-technical systems. All this may be condensed in the statement that IS approaches have been overly descriptive, static, and hardware focused (Uyarra and Flanagan, 2010).

However, in our view, the aggregated weight of these individual lines of critiques also risks throwing out the baby with the bath water. Most of these criticisms adopt a very partial, almost caricature view of the state of some specific variants of innovation system research and by this misrepresent the actual potential of the approach as a whole. We therefore have to outline some fundamental shared traits of the IS concept before providing a more future-oriented agenda in the next section.

At the very core of the IS field of scholarship resides an understanding that innovation success in complex contexts—such as emerging industries or specific territories—depends on the balanced interplay between heterogeneous elements (actors, networks, institutions, technologies). In other words, the different elements jointly generate emerging properties that cannot be produced or controlled by any of the individual actors alone. They provide so-called system resources (Musiolik *et al.*, 2012; Binz and Truffer, 2016). The 'system' can be said to exist in a specific realm (be it territorially or thematically delimited), if higher-order resources are created that are key to the further success of an innovation and which may only be accessible to the actors operating in the same realms. For instance, a regional innovation system in the Emiglia Romagna may exist due to a high-quality labour pool in certain industries, which provide firms in the region with the necessary human capital without having to train each and every new employee in the specific trade.

The IS approach therefore provides a counter narrative to the one of methodological individualism, such as neo-classical economics or vast strands of the management or public policy literature. The latter would as a rule look for the decisive elements as factors for explaining innovation success. IS approaches instead emphasize that the constellation of factors and their development over time give rise to qualitatively new properties; they focus much more on interaction terms.

In terms of policy advice, a systemic approach can provide decision-makers with a broader view on how to support innovation processes. Instead of solely focusing on market failures as justifications for intervention, IS perspectives propose scrutinizing deficiencies in the core elements of innovation systems and in their configurations (Smith, 2000; Klein Woolthuis *et al.*, 2005): (i) capability failures if actors lack the appropriate skills and resources, (ii) coordination failures in the case of interactions lacking between actors, and (iii) institutional failures in cases where context conditions hinder the further development of innovations or when actors are unable to influence institutional structures in a way to support innovation (e.g. in the form of industry standards, lacking legitimacy of designs, or lacking support policies). All these deficiencies emphasize that misaligned constellations of factors may be equally limiting for innovation success as the absence of individual critical factors. As a consequence, IS frameworks are able to explain why 'best practice' approaches are often difficult to replicate in other contexts because preconditions and constellations vary. More recently,

the rather static concept of system failures has been expanded by proposing also transformational system failures as rationales to justify policy interventions in matters of the direction of innovation—an issue that has acquired growing importance in the context of the debate about new mission-oriented innovation policy (Weber and Rohracher, 2012).

V. Outlook on a renewed research and policy agenda

The focus on constellations and dynamic interactions provides the starting point for a more explanatory ambition of IS frameworks that enables us to distinguish successful innovation modes from failing ones. However, one of the core problems of a constellation-based explanatory framework is that, in general, a myriad of constellations of system elements could lead to similar levels of innovation success, while similar constellations could lead to widely varying outcomes depending on the context conditions. IS approaches which focus on the analysis of structures only, i.e. the constellation of actors, their networks, and institutional arrangements, may quickly degenerate into extensive listings of all potentially relevant elements. Furthermore, as innovation structures are getting increasingly fluid due to the challenges of digitalization and globalization, a static, structural approach may quickly prove to become unmanageable.

One way that IS researchers have tried to cope with this problem was to elaborate a more 'process' focused view, i.e. to analyse the way in which system elements are recombined over time and how they reinforce each other. A process view tends to provide a much more stable characterization of emerging system resources even under conditions of rapidly changing actors, networks, and institutional arrangements. Scholars identified lists of core processes that were accounted for in earlier (structural) IS analyses and which seemed to be good indicators for successful innovation development. Several alternative lists of these core processes have been proposed in the literature, but all gravitate around the following six: (i) knowledge generation and diffusion, (ii) entrepreneurial experimentation, (iii) guidance of the search, (iv) resource mobilization, (v) market formation, and (vi) legitimation (Hekkert *et al.*, 2007; Bergek *et al.*, 2008). According to the process-focused view, successful innovation can be understood as resulting from the balanced interplay among these six key processes that are a consequence of activities of all sorts of actors being embedded in specific institutional contexts. Over time, research showed that different constellations of functions prevail in different industry maturation phases (Suurs and Hekkert, 2012). Explanation of successful industry formation processes can therefore be derived from benchmarking supportive constellations of core processes with those that provide bottlenecks and barriers to development.

In our view, process-based analyses would potentially open new inroads for a more dynamic account of IS. This would need a reconsideration of some of the core elements when applying an IS perspective. First, we propose that IS approaches should deal more mindfully with the specific strengths that all IS perspectives share: identifying emergent properties and shared resources for explaining the success of innovations in technologies and products. This implies the attention to a broad range of actors, their manifold patterns of interaction, and the way they are embedded in existing institutional contexts as well as how they develop institutions to promote and mature innovations.

As one of the most decisive methodological points, system boundaries should be chosen in a way that best fits the phenomenon to be analysed. Territorial boundaries should be justified by the existence of systemic interactions in the innovation field considered (Carlsson and Stankiewicz, 1991; Coenen *et al.*, 2012). This is in particular true under conditions of increasing globalization of innovation (Truffer *et al.*, 2015). When boundaries are chosen, an explicit analysis of which sort of forces and factors are relegated to the 'context' of the system would equally be important (Oinas and Malecki, 2002; Fromhold-Eisebith, 2007; Bergek *et al.*, 2015). This means that even if the target group of IS research is regional and national policy-makers, considering IS structures that transcend the territorial boundaries of their regions or countries may be necessary because they impact the very conditions for carrying out successful innovation in a specific region (Binz *et al.*, 2014; Boschma *et al.*, 2017). Depending on whether the problem addressed has more to do with how an innovation can be embedded in an institutional context, or whether it is dependent on the development of internal institutions, or whether agency plays a predominant role, different insights from sub-variants of the IS family may provide deeper insights on how to tackle them. However, conceptual development should overcome the currently largely separated understanding of different IS variants and aim for a more integrative approach.

For that purpose, the different elements of an IS may have to be revisited. Actors have always been a starting point for the analysis of IS dynamics. However, an explicit conceptualization of agency in system contexts is still missing. Recent theorizing in the field of corporate IS or innovation ecosystems holds promise here. However, these attempts have not yet provided an encompassing framework (Oh *et al.*, 2016). Some more elaborate inroads have furthermore been provided in recent TIS research, where attempts at providing a micro-foundation for TIS have been proposed (Farla *et al.*, 2012), or the role of incumbents has gained more attention (Smink *et al.*, 2015; Wesseling *et al.*, 2015).

Regarding the role of institutions, we identified a need to 'internalize' the dynamics of institutions into the IS framework. The object of analysis in IS research should preferably consist of socio-technical constellations instead of mere technologies and products. As a consequence, institutions have to be considered as co-evolutionary elements in the overall analysis and not merely as independent variables. For that purpose, IS studies could profit from insights developed in the field of neo-institutional sociology (Fuenfschilling and Truffer, 2014), or institutional entrepreneurship and institutional work (Fuenfschilling and Truffer, 2016). Networks can be seen as an intermediary form of coordination between actor strategies and institutional arrangements. Besides formalized networks, increasingly also weak ties, informal networks, and temporal networks should be taken into account (Musiolik *et al.*, 2012). Methodologically, innovation system accounts have so far not taken full advantage of methods of social network analysis. In the case of national and regional IS, a shift of emphasis towards institutional dynamics will enable us to analyse adaptation strategies for local institutional structures under rapidly changing context conditions. An example of this required shift is provided by the recent economic geography literature with its emphasis on regions' ability to create new industrial paths and to remain competitive in quickly changing industrial development paths (Boschma *et al.*, 2017)

Finally, as more emphasis is put on institutional dynamics new forms of innovation will also come into the focus. A case in point is provided by the increasing relevance

of innovation in new business models and broader valuation strategies (Jeannerat and Crevoisier, 2016) compared to conventional technology-oriented innovation. This also requires a heightened attention towards user processes, the roles of NGOs and civil society organizations, which may play a decisive role in the generation of new technologies, products, or institutional arrangements. The growing prominence of service innovation (Gallouj *et al.*, 2013), social innovation (Howaldt and Jacobsson, 2012), demand-led innovation (policy) (Aho *et al.*, 2006), and other newly emerging practices of open research and innovation (Leitner *et al.*, 2012; Weber *et al.*, 2016) calls for an adjustment of what should be core to the IS approach, namely the innovation process itself. IS literature has so far not given much response to these novel developments, neither has it absorbed these developments in its conceptual framing. This will be all the more important as we move away from narrow competitiveness concerns towards the ambition to tackle grand challenges.

VI. Conclusion

We conclude that in spite of recent criticism of the IS concept, it is not outdated for tackling today's scientific and policy challenges, but may be in need of renewal. The core features of innovation systems, i.e. in particular the emphasis put on the interplay between heterogeneous elements (actors, technologies, and institutions), the systemic understanding that the interaction of a diverse set of elements with a confined realm creates higher-order properties and resources, and the importance assigned to the specific configurations of system elements, are still crucial for explaining innovation phenomena and for guiding innovation policy.

The quest for renewal is driven by new patterns and practices of innovation as well as by changing requirements on the policy side. A research agenda to guide this renewal would have to address first of all matters of delimitation and focus of IS analysis. Choosing boundaries appropriately escapes standardized approaches, but requires arguing carefully what is inside and what is outside. This is even more important in the view of increasingly internationalized research and innovation patterns. Second, while much progress has been made in better understanding the process dynamics of innovation systems, there is still ample room for advancing that understanding. Third, and related to the previous point, the already ongoing relaxation of centring on technology as the main force behind innovation, an opening up of the notion of innovation as such is needed, thus giving full justice to the social and economic forces on the demand side. Fourth, we are increasingly confronted with transformative change, driven either by disruptive innovations or by long-term and wicked challenges.

Such a conceptually reframed understanding of IS approaches helps to specify in what regards IS studies can provide an added value to the understanding of innovation processes as compared to other perspectives on innovation. And, more importantly, it allows the demarcation of the productive realm of the application for IS approaches. They probably provide more potent explanatory frameworks in situations where innovations are interacting in a complex way with their manifold environments. For instance, when innovation trajectories have to be combined with national or regional investments in competencies and institutional structures, an IS perspective still helps

to emphasize synergistic effects. The same applies to cases where technologies are still very immature, and where actor roles, product profiles, market segments, and regulatory frameworks are not yet well established, i.e. it applies to early industry formation processes or innovations with a strong public policy component, such as sustainability related innovations. In other more conventional contexts (e.g. the incremental improvement of product designs in an established industry), IS approaches may probably have much less to add, and simpler, analytically more parsimonious approaches might be better suited to the task.

This brings us to the question of what difference this reframed understanding of innovation systems makes from a policy perspective. First of all, matters related to the direction of innovation have acquired growing importance in the context of policy debates, in particular in relation to major societal challenges. This turn in innovation policy brings into question one of the prevailing credos of established innovation systems research, namely that innovation is something positive and desirable *per se*, and calls for an explicit consideration of directionality in the IS framework. With the proposed re-framing, matters of directionality move into the focus and are addressed explicitly by relating innovation policy to the goals and missions defined in different sectoral policies, and by opening up the process of defining the directions of innovation through negotiation processes among a broadened range of stakeholders. In this regard, adjacent approaches, such as socio-technical transitions, have provided important inspirations for the re-framing of the IS framework (Weber and Rohracher, 2012; Bergek *et al.*, 2015), even if a full integration of these aspects still remains on the research agenda.

Second, with many policy issues requiring a coordinated response at different levels and by different actors and policy fields over extended periods of time, a more differentiated consideration of policy coordination is needed, transgressing the boundaries of traditional science, technology and innovation (STI) policy and entering the terrain of sectoral and thematic policies. The re-framing of the IS approach suggest a broadening of the boundaries of innovation systems and stresses the importance of constellations of factors and processes at different levels and realms. This puts fundamental governance principles into the foreground of policy attention, as well as the composition of policy mixes for addressing complex problems, including the consideration of new (system) innovation-oriented policy instruments (Flanagan *et al.*, 2011; Wieczorek and Hekkert, 2012; OECD, 2015).

Third, by suggesting an examination of the interplay between institutional dynamics on the one hand and innovation dynamics on the other, the re-framed IS approach offers sufficient flexibility to address also changes in the practices of research and innovation, which cannot be addressed without looking simultaneously at their embedding in organizational and institutional dynamics. New research and innovation practices, such as new open and trans-disciplinary forms of research and innovation, will only be taken up widely if either existing institutional settings evolve or new ones are created. From a policy perspective, this has major implications for the design of funding programmes, which need to be more open to non-conventional research and innovation practices, but also for incentive structures for scientific careers, which are still predominantly tied to traditional performance indicators.

Finally, innovation is at the origin of disruptive changes in economy and society, but it is also an important response to such disruptions. Devising policies for addressing

disruptive change is going to be one of the challenges to be addressed by further advancements of the innovation systems framework (Perez, 2016). Also in this regard, the broadening of the innovation system boundaries promises to be a productive step forward, because it allows the exploration of broader systemic responses to disruptive developments. This seems reasonable because the consequences of disruptive developments—just think of some of the recent digital examples—not only affect innovation in a narrow sense, but are likely to transform the entire value chain from research and innovation to production and consumption.

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