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Systems of Innovation[#]

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Abstract: We review the literature on national innovation systems. We first focus on the emergence of the concept of innovation systems, reviewing its historical origins and three main flavours (associated to three "founding fathers" of the concept). After this, we discuss how the notion of innovation systems filled a need for providing a broader basis for innovation policy. We conclude with some perspectives on the future of the innovation systems literature.

Keywords: National innovation systems, innovation policy

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1. Introduction

The particular focus on invention and technical change as central factors behind economic growth and development is, as Joel Mokyr illustrates in Chapter 1, of relatively recent origin (Mokyr, 2010). While early classical economists were well aware of the critical role of technology in economic progress, they would typically consider such technical progress as fully embodied within the notion of capital, a vision which remained dominant up to the late 1950s. At that point it was recognised that “something” (a residual, Solow, 1957), a measure of our ignorance (Abramowitz, 1956) appeared behind most of the economic growth in the twentieth century and the acceleration in the post-war period. Thus, while Adam Smith did observe in his *Wealth of Nations* that improvements in machinery came both from the manufacturers of machines and from “philosophers or men of specialisation, whose trade is not to do anything but to observe everything ...”, he considered such advances of technology as largely due to the inventiveness of people working directly in the production process or immediately associated with it: “... a great part of the machines made use of in those manufactures in which labour is most subdivided, were originally the inventions of common workmen” (Smith, 1776, p. 8).

This view on technological advances led to a strong critique from Friedrich List who, back in 1841, wrote: “Adam Smith has merely taken the word capital in that sense in which it is necessarily taken by rentiers or merchants in their bookkeeping and their balance sheets ... He has forgotten that he himself includes (in his definition of capital) the intellectual and bodily abilities of the producers under this term. He wrongly maintains that the revenues of the nation are dependent only on the sum of its material capital” (p.183). List’s contribution is particularly important in this context because he was one of the first economists to recognise the crucial role of the ‘systemic’ interactions between science, technology and skills in the growth of nations. For classical economists, such as Smith, ‘innovation’ (though they did not use that particular term) was a process fed by experience and mechanical ingenuity, which enabled improvements to be made as a result of direct observation and small-scale experiments. For List, the accumulation of such knowledge became an essential factor for the growth of nations: “The present state of the nations is the result of the accumulation of all discoveries, inventions, improvements, perfections and exertions of all generations which have lived before us: they form the intellectual capital of the present human race, and every separate nation is productive only in the proportion in which it has known how to appropriate those attainments of former generations and to increase them by its own acquirements" (p. 113).

List's recognition of the interdependence of tangible and intangible investments has a decidedly modern ring to it. He was probably the first economist to argue consistently that industry should be linked to the formal institutions of science and education: "There scarcely exits a manufacturing business which has no relation to physics, mechanics, chemistry, mathematics or to the art of design, etc. No progress, no new discoveries and inventions can be made in these sciences by which a hundred industries and processes could not be improved or altered" (p. 162). His book entitled *The National System of Political Economy* might just as well have been called *The National System of Innovation*. List's main concern was with the problem of how Germany could overtake England. For underdeveloped countries (as Germany then appeared relative to England) he advocated not only protection of infant industries but a broad range of policies designed to accelerate or to make possible industrialisation and economic growth. Most of these policies were concerned with learning about new technology and applying it. In this sense List anticipated and argued in accordance with contemporary theories of 'national systems of innovation'.

Table 1 illustrates the characteristic features of the British national system of innovation (NSI) in the eighteenth and early nineteenth century and of the US NSI in the late nineteenth and twentieth century, following List's historical interpretation of NSIs. In this by and large descriptive interpretation of the most striking historical institutional features of a country's science and technology based growth performance, what is most striking is the particular importance given to the state in coordinating such long-term policies for industry and the economy. In fact, the role of the Prussian state in technology catch up in the mid nineteenth century resembled very much that played by the Japanese state a couple of decennia later, the Korean state a century later, or China today. At each time the coordinating role of the state was crucial, as were the emphasis on many features of the national system of innovation which are at the heart of contemporary studies (e.g., education and training institutions, science, universities and technical institutes, user-producer interactive learning and knowledge accumulation).

In short, the *systems of innovation* approach spells out quite explicitly the importance of the 'systemic' interactions between the various components of inventions, research, technical change, learning and innovation; the *national* systems of innovation brings to the forefront the central role of the state as coordinating agent. Its particular attractiveness to policy makers lays in the explicit recognition of the need for complementary policies, drawing attention to weaknesses in the system, while highlighting the national setting of most of those institutions. The concept of 'national systems of innovation' as it was developed in the 1980s by Freeman (1987), Lundvall (1992), and Nelson (1993), owes much to these historical insights. It provided a view on innovation next to the more traditional market failure approaches to research and innovation policy, which are reviewed in the Chapter by Ed Steinmueller (Steinmueller, 2010).

In this Chapter we first describe the various concepts and definitions used in the NSI literature (Section 2). In Section 3, we discuss some of the reasons for the popularity of the NSI with policy makers. As highlighted above, the origins of the NSI are closely linked to the central role industry is playing as engine of productivity growth, continuous technological improvements and innovation and the central role of the state in organising, improving and evaluating the various institutions dealing with science, technology, innovation, higher education, skills and more broadly learning and development. The NSI concept represented for policy makers an alternative to industrial policies, while at the same time providing strong support for the role of public authorities in creating the 'right' institutional conditions for a knowledge-driven economy to flourish. In Section 4 we discuss the limits of the NSI approach: the new patterns of innovation outside of the traditional industrial technology frameworks (innovation without industrial R&D), and the emergence of global value and knowledge chains questioning the national focus of policies in this area. We conclude the Chapter by summarising five main points about the NSI approach and its policy relevance.

2. A galaxical guide to the economics of NSI

The central idea in modern innovation systems theory is the notion that what appears as innovation at the aggregate level is in fact the result of an interactive process that involves many actors at the micro level, and that next to market forces many of these interactions are governed by non-market institutions. Because the efficiency of this process observed at the macro level depends on the behaviour of individual actors, and the institutions that govern their interaction, coordination problems arise. It is mainly through comparative historical analysis that scholars began to adopt such a systemic view of innovation.[1] Not surprisingly, economists in the institutional tradition of innovation studies (e.g., Freeman, 1987, and Lundvall, 1992) and scholars of evolutionary theories (e.g., Nelson and Winter, 1982, and Metcalfe, 1988) became the strongest proponents of the notion of systems of innovation. In these views the system of innovation is a continuous process where institutions (habits and practices), learning and networks play a central role in generating innovation and technological change.

2.1. Definitions

There have been many different definitions of NSIs. Freeman (1987) states that an NSI is "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (p. 1). Lundvall's broad conceptualisation of NSI includes "all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring" (Lundvall, 1992, p. 12). Nelson (1993, p.4) notes that the innovation system is "a set of institutions whose interactions determine the innovative performance of national firms" and the most important institutions are those supporting R&D efforts. Metcalfe (1995) states that the NSI is "that set of institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store, and transfer the knowledge, skills, and artefacts, which define new technologies. The element of nationality follows not only from the domain of technology policy but from elements of shared language and culture which bind the system together, and form the national focus of other policies, laws and regulations which condition the innovative environment". Edquist (1997) takes even a broad view of innovation systems being "all important economic, social, political, organisational, institutional and other factors that influence the development, diffusion and use of innovations" (p. 14).

[1] A scholar most closely associated with 'innovation' is of course Schumpeter (1934). Whilst Schumpeter sees innovation as new combinations and the commercialisation of an invention, processes which are quite separate from the diffusion of innovations, NSI scholars adopt a more integrative view including from the outset diffusion and application in the economy at large in their concept of innovation system.

Although these definitions share a broad sentiment of the importance of institutions and interactions, of the coordinating role of the government in keeping the system running and of the importance of taking history seriously, they do not provide a common point of departure for an innovation systems theory to be developed. In fact, rather than a single framework, innovation systems theory comes in at least three different flavours, corresponding to the modern forerunners in using the concept. To focus the discussion and to arrive later on in this chapter at our own view on systems of innovation, we now briefly describe these three flavours.

2.2. Main players

The concept of a NSI emerged originally in the late 1980s and was coined by Chris Freeman to describe the congruence in Japanese society between various kinds of institutional networks in both "private and public sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987).[2] In line with his earlier work on long waves of economic and technological development (Freeman, Clark and Soete, 1982), Freeman's focus is on the broad interaction between technology, social embedment and economic growth and its feedback loops reinforcing the system. Freeman emphasises four main elements of the (Japanese) NSI.

The first is the role of policy, in particular that of the Ministry of International Trade and Industry (MITI). Consistent with the observations of List discussed in the previous section, Freeman's view is that Japanese policymakers have contributed significantly to the rapid catch-up of the country by making particular choices for strategic industries and thus creating comparative advantages on which the strong growth performance was built. Second, Freeman stressed the specific role of corporate R&D in the Japanese catch-up. The emphasis here is on the way in which R&D was used to assimilate knowledge (that was sourced from abroad) and then used to create a set of own technological advantages directly applicable in Japan.[3] Third, Freeman focuses on the role of human capital and the organisation of work in firms and

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[2] As early as 1982 Freeman made the first written contribution to the concept of NSI in an unpublished paper called *Technological Infrastructure and International Competitiveness,* which was prepared for OECD. The paper was finally published in 2004 in *Industrial and Corporate Change*. By 1985 Lundvall wrote about an 'innovation system' for the first time.

[3] Freeman's view on this coincides largely with Cohen and Levinthal's (1989) idea on the role of R&D in absorptive capacity, which was published two years later.

industries, clearly influenced by his earlier work on long waves. The implementation of large technological systems (or ‘paradigms’) depends on the capabilities of the people that implement them, and therefore technology and organisation develop in close synergy. Freeman saw the novel and innovative forms of work organisation in Japan and the associated work relations of the large companies as crucial elements in the growth process. Finally, Freeman puts strong emphasis on the conglomerate structure of Japanese industry, arguing that because of a lack of competition, large firms were able to internalise externalities that were associated with innovations in supply chains. Internalising vertically is beneficial to provide workers with the right incentives and to prevent hold-up and shirking. It also yields an overview of the entire process of production, which makes implementation of new work modes and innovative production of intermediates easier. This fits the systems approach to production and innovation in which the efficiency of the feedback loops is important. Freeman’s contribution was followed a year later by a book edited by Dosi et al. (1988) which included three chapters on the NSI concept by Freeman, Lundvall and Nelson.

Although recognised ex post by many as the modern pioneering contribution, Freeman’s work went by largely unnoticed. The main breakthrough, both in academic and policy circles, of the notion of NSI came with two edited volumes that brought together a large number of scholars who had been active in the literature on innovation: Lundvall (1992) and Nelson (1993) put together these volumes, each from a rather different perspective.

Lundvall emphasised in a somewhat similar view to Freeman the way in which NSI was encompassing “the elements and relationships which interact in the production, diffusion and of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state” (Lundvall, 1992, p. 12). He clearly shifts the emphasis away from the sector dimension, towards the much broader national institutional framework within which firms and other organisations operate and which appears of crucial importance to the speed, extent and success by which innovations get introduced and diffuse in the economy at large. Lundvall, who is the more theoretically oriented of the major innovation systems scholars, lists a number of theoretical building blocks, here summarised into three major themes.

The first concerns the sources of innovation or the types of activities by actors in the system that induce innovation. Lundvall makes a distinction between, on the one hand, learning, and on the other hand, search and exploration. Learning is associated with routine activities, such as production, distribution, marketing and consumption. These activities provide experience and insights that lead to new knowledge, and innovation. Basically they can be captured in a set of rules that can be transmitted to everyone. This is consistent with the idea of learning-by-doing (Arrow, 1962). Learning is a distinct activity from R&D, which is classified under the second source of innovation, i.e., search and exploration. This includes both corporate R&D (search) and academic R&D (exploration), but also other types of search are included, such as market analysis.

The second theoretical building block is concerned with the nature of innovation, in particular with the distinction between incremental and radical innovations. Lundvall mainly stresses the incremental and cumulative nature of innovation: it mainly consists of small steps that result from the constant learning and searching by firms. The resulting process of incremental innovations is much more of a continuum than suggested by the distinction between invention, innovation and diffusion. An important dimension of this process is also the feedback between different actors, since each incremental innovation is at least partly a reaction to previous innovation by others who are active in the 'system'.

The third and final theoretical building block of Lundvall's NSI concept is the factor of non-market institutions in the system. These take two major forms. The first is user-producer interaction. This is based in Lundvall's earlier work (e.g., Lundvall, 1988), and is concerned with the exchange of information between users and producers. Although there is clearly a market relationship between those actors, the idea here is that the exchange of information on the use and production of the good or service goes beyond the pecuniary market exchange. Detailed user-feedback leads producers to adapt their products (innovation). The second major form of non-market factors is formed by institutions. Institutions are understood as 'regularities of behaviour' that are largely historically determined and also have close linkages to culture (e.g., Johnson, 1992). Such institutions reduce uncertainty and volatility and provide stability to the actors in the system. This is an instance where the emphasis of the NSI literature on non-market relations is crucial.

The Nelson-volume is more empirically focussed and includes a collection of case studies, most of which consist of historical descriptions of the NSI in a single country (Nelson, 1993). Here the particular arrangement of actors, their incentives, and their collaborative patterns, would explain why a particular NSI is competitive (or not). An important element in this 'Nelson-view' is the 'intertwining of science and technology'. The emphasis of this topic is more narrowly focused on institutions that support formal R&D. This is partly based on Rosenberg's work on the history of the R&D system, and the role of universities in this. Nelson and Rosenberg (1993) sketch how 'technology' (i.e., firms as opposed to universities) has often played a leading role in terms of setting the research agenda, also for university researchers and other scientists not working in commercial R&D labs. It follows that the particular ways in which the university system is set up (i.e., the relative contribution of private funds, incentives for promotion, the system of quality control, and so on), play a large role in determining how efficiently this system works. Nelson's narrower view which focuses mainly on organisations that support R&D contrasts with the broader view of Lundvall where those R&D focused organisations are one part of the larger system (Edquist, 1997).

2.3. Insights and Outcomes

Considering the many contributions since those of Freeman, Lundvall and Nelson, the NSI approach has provided a number of particularly useful insights, which can be summarised in five points.[4]

2.3.1. Sources of Innovation

Especially the Lundvall approach to NSI – which stressed the role of non-R&D-based innovation – was useful in broadening the discussion on innovation beyond the by that time already well established economics of R&D.[5] In Lundvall's original contribution, this was mostly limited to user-producer interactions and interactive learning. Viewed in retrospect this

[4] A recent critique on the NSI, based on the United States is provided by Hart (2009).
[5] In this context, it is interesting to note that Griliches, in the introduction to his NBER volume on R&D, Patents and Productivity (Griliches, 1984), the first NBER volume since the early, seminal 1962 contribution edited by Nelson (Nelson, 1962), refers to Freeman and colleagues as the "interesting literature on success and failures on industrial R&D projects" (Griliches, 1984, p.2), part of the innovation studies literature not covered in the book.

emphasis on non-R&D sources of innovation appears a particularly welcome and useful extension of the classical economists' view of technology and innovation. It was already highlighted in Pavitt's (1984) taxonomy on the sources of innovation highlighting, on the basis of one of the first innovation databases at the Science Policy Research Unit of Sussex University[6], the variety in the sector location – upstream or downstream – of innovation. But the innovation system perspective had not been brought so explicitly to the forefront.

Just as in the case of R&D, the systemic approach to innovation received its major impulse with the systematic collection of innovation data by statistical agencies[7]. The latter has led to successive 'waves' of Innovation Surveys being carried out in various countries, most notably the European Community Innovation Surveys (CIS), which are analysed in more detail in the chapter by Jacques Mairesse and Pierre Mohnen (Mairesse and Mohnen, 2010). These successive innovation surveys highlighted the fact that a large part of innovative firms relied more on non-R&D sources (such as buying machinery, training of workers, or design) than on R&D in the strict sense of the term. Subsequent questions which became a central point for econometric research on innovation focussed on the complementarities between various innovation inputs in their relationship to approximated innovation output, and the economic performance of firms. While these questions can of course be analysed outside the innovation systems literature, the innovation systems view provides a natural conceptual framework for studying the systemic interactions and complementarities between the various sources of innovation, both R&D and non-R&D in explaining firms' successes and failures in innovation.

2.3.2. Institutions (and organisations)

Institutions are central to the NSI concept as they provide structure to as well as insights in the way in which actors (including organisations) behave within the system. Institutions in the broad sense are the habits and practices, or routines (as noted by Nelson and Winter, 1982) that shape the way things are done, how agents act and interact, and how innovation comes about and is perceived. For Edquist organisations (which should not be confused with institutions) are the tangible and legally identifiable parts of the system that facilitate the innovation process

[6] See on the SPRU innovation database Pavitt et al. (1987) and on the so-called Yale innovation survey Levin et al. (1984).

[7] For an overview of that literature see Freeman and Soete (2009).

through bringing actors together. Edquist and Johnson (1997, p. 50) present a taxonomy of the different types of institutions that matter for innovation systems. Their taxonomy distinguishes institutions on characteristics such as formal vs. informal (where informal institutions extend to customs, traditions and norms), basic (e.g., laying down basic arrangements on property rights, conflict management rules, etc.) vs. supportive (the specific implementation of basic institutions), hard (binding, and policed) vs. soft (more suggestive), and consciously or unconsciously designed.

2.3.3. Interactive Learning

In Lundvall's words, the innovation system is a "system constituted by elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge" (Lundvall (1992, p.2). Not only knowledge but also everyday learning (learning by interacting) is important for the innovation process. In this view, the sources of knowledge include all those entities introducing knowledge into social and economic change. The dynamic nature of the system requires continuous learning in order to adapt to challenges. As knowledge introduced to the system is fundamental, learning of individuals as well as organisations is now also necessary within the innovation process. Learning process includes new knowledge, new combinations thereof or the introduction of knowledge to a new person. The emphasis put on interactive learning provides a link between systems of innovation theories and concepts and systems of human resource management and the particular role of labour market institutions and in human resource institutions in enhancing learning capacities in firms and the economy at large (e.g., Arundel et al., 2007 and Bercovitz and Feldmann, 2006). Doing so has actually broadened further the concept of innovation into the direction of List's original thinking.

2.3.4. Interaction

A common feature of all innovation systems is the fact that firms rarely if ever innovate alone. As 'innovation scholars' had been at pains to point out for many years, there is a need for a constant interaction and cooperation between the innovating firm and its external environment, which in the 'optimal' case leads to a virtuous circles of a better exploitation of available knowledge. As Nelson (1993, p.10) noted: "to orient R&D fruitfully, one needs detailed knowledge of its strengths and weaknesses and areas where improvements would yield big payoffs and this type of knowledge tends to reside with those who use the technology, generally firms and their customers and suppliers. In addition, over time firms in an industry tend to develop capabilities … largely based on practice.”

It is this interactive nature of innovation, combined with the non-market-based nature of the institutions that govern the interactions that raise the possibility of ‘systemic failure’, or, in other words, a low innovation performance due to a lack of coordination between the parts of the system. As argued below, this is the main ingredient in the concept of NSI that leads to policy prescriptions that are different from a policy approach based on market failure as reviewed in Steinmueller (2010).

2.3.5. Social capital

Not only formal institutions matter for innovation. Social capital stimulates also innovation. In the economic literature social capital has been identified as an important determinant in explaining differences in income. Knack and Keefer (1997) and Zak and Knack (2001) have shown for a cross-section of countries that countries with higher levels of measured trust are richer. Innovation is an important channel by which social capital improves income growth. The idea is that more advanced historical institutions have established a higher stock of social capital. Social capital in turn influences the innovation process because the financing of risky innovative projects requires that researchers and capital providers trust each other. When they do so, more successful projects are carried out, which improves innovation outcomes by means of more patents. Finally, as shown by Grossman and Helpman (1991) and Aghion and Howitt (1992), higher innovation output yields higher income per capita.

Akcomak and ter Weel (2009) integrate social capital in a simple model of production. In their set up the accumulation of capital generates knowledge which benefits society and increases income. Knowledge grows because of research effort and the rate by which new discoveries are made. They amend the accumulation of knowledge by introducing the stock of social capital. The stock of social capital has a positive effect on the accumulation of knowledge, which in turn increases output. The idea is that social capital has a positive effect on the investment in innovation. When researchers live in areas with a larger extent of social networks and have high norms, venture capitalists are more likely to invest in risky projects. The empirical application to 102 regions in the EU-14 (a homogeneous set of countries that have operated under similar judicial and financial-economic regulation for some time now) reveals that social capital is an important determinant of innovation, which explains on average approximately 15 percent of the change in income per capita in the 102 EU regions between 1990 and 2002.

3. National Systems of Innovation and Policy

The notion of innovation systems has caught on in many policy circles. At the national level, the notion of innovation systems has been used amongst others in Sweden, Finland and the Netherlands, as well as in supra-national organisations such as the OECD (1997 and 1999), the European Commission, UNCTAD, and even the World Bank and IMF (Sharif, 2006). In this section, we survey the main principles of an innovation policy based on the systems concept, we explore the relationship between the innovation systems concept and other forms of policy, such as industrial and regional policy, and we ask the question why policymakers have found the notion of innovation systems so attractive.

3.1. Policies based on NSI

The main implication of the national systems of innovation concept from the point of view of policy is that it provides a much broader foundation for policy as compared to the traditional market failure-based policy perspective. In the market-failure-based perspective, every policy measure must be justified both by the identification of some form of market failure, and by an argument that explains how the policy can bring the system closer to its optimal state. Government failure might be more serious than market failure, so not all market failures merit government interventions.

In a systems view of innovation, markets do not play the overarching role of generating an optimal state. Instead, non-market-based institutions are an important ingredient in the ‘macro’ innovation outcome. Due to the variety in such institutions, and due to the multi-dimensional nature of innovation, the innovation systems approach rejects the idea of an optimal state of the system as a target for policy to achieve. Innovation policy is, just like innovation, continuously on the run. This broad, almost philosophical outlook on policy has two major consequences for the foundations of actual policy measures.

The first is that there is a broader justification of the use of policy instruments as compared to market failure-based policies. For example, R&D subsidies are linked in the market failure-based approach to a lack of incentives at the private level (firms). The subsidy instrument has the aim to lower private costs, thus bringing investment up to the level where social costs equal social benefits. In the systems approach, subsidies serve a more general purpose that includes influencing the nature of the knowledge base in firms, and to increase absorption capacity (e.g., Bach and Matt, 2005 and David and Hall, 2000). Similarly, policies aimed at stimulating cooperation, for example between university and industry, would be motivated in the market failure-based approach by internalising externalities, while in a systems approach, such policies could be aimed at influencing the distribution of knowledge, to achieve coordination (not provided by markets), or to increase the cognitive capacity of firms.

The second implication is that the government or policymaking body is part of the system itself with its own aims and goals being endogenous. Therefore, policymakers have to function within the system itself, and this restricts them. As a (mere) actor in the system, policymakers are unable to design the system in a top-down way. In the market failure-based approach, this would be featured as ‘policy failure’, i.e., the impossibility to achieve a first-best welfare solution by solving market failures. From the systems point of view, policies are necessarily adaptive and incremental. They are, in many cases, specific to the system in which they are set, and would be ineffective in other settings. Their potency lies in the indirect effects that they have throughout the system, but such repercussions are hard to predict precisely, and therefore policies must be experimental in nature (Metcalfe, 2005).

The set of instruments for innovation systems policy includes all instruments that are traditionally the domain of science and technology policy, but also education policy. In addition, industrial policies and regional policies are important ingredients in innovation systems policies. We discuss this wider economic policy dimension of the NSI concept in the remainder of this section.

3.2 NSI as a framework for new industrial policies

NSI-approaches have, not surprisingly given their historical origin, a strong *industrial policy* tradition. The erosion of popularity of traditional industrial policy in the seventies had much to do with the bad press such policies were getting both in terms of the many failures of such policies in restructuring successfully heavy industry sectors such as coal mining and steel, which made the policy-designed aid support schemes seem incapable of bringing about improvements, and, second, with the strong resistance by those workers losing their jobs as a direct consequence of the structural industrial adjustment policies put in place. It was also at that time that Ronald Reagan and Margaret Thatcher began their terms in office with a strong emphasis on supply-side economics and less room for the government to intervene.

The political awareness of having to shift industrial policy from its negative, job reducing image towards a more dynamic, sun rise image was of course very much inspired by the success of Japan in rapidly catching up in many industrial sectors from motor vehicles to semiconductors in the 1970s and really 1980s. At the political level, the US-Japanese semiconductor trade agreement, providing breeding space to the US industry, became one of the clearest examples of a new form of strategic industrial/trade policy with major long term implications for the competitiveness of the US semiconductor industry. In Europe too, this strategic nature of industrial policy was used.

What the debate about 'strategic' industry and trade policy in the 1980s brought to the forefront is that, in contrast to previous literature, once the continuous nature of technological change was taken into account, various dynamic increasing returns and cumulative features would take place across sectors (e.g., Dosi, Pavitt and Soete, 1990). In so far as the actual process of production in firms, regions or countries was closely associated with the existence of technological capabilities in such firms, regions or countries, mechanisms leading to specialisation in production did also have a clear and significant dynamic counterpart in that they also would lead to specialisation in technological skills and capabilities. The potential for dynamic technological specialisation would, in other words, be very much different between technologies and sectors. It would ultimately closely depend on the systemic interactions between technologies and sectors along the lines highlighted by Pavitt (1984), and the first sector-based evidence studies on innovation of the late 1970s and early 1980s. The identification and support of 'strategic' technologies or sectors, even though not justified on the basis of static allocative efficiency, could then well be justified from a dynamic, innovation system perspective in terms of long term output and productivity growth.

3.3 Moving beyond sectors: more systemic policy views

At the point in time of its emergence, i.e., the late 1980s and early 1990s, the NSI concept as summarised in Section 2 fitted perfectly with the need for a shift in purely sector-based explanations, either of the technology push or the demand pull kind, for countries' economic growth performance. This development was complemented by the interest in explaining the competitiveness of nations at the side of policy makers and in particular at the level of international organisations such as the OECD. The interest at the OECD was fuelled by the appointments and consulting work of Freeman and Lundvall. Introducing the NSI offered a welcome opportunity to broaden the policy focus to the much broader 'knowledge and innovation system', in which performance would now depend on the way *all* actors would perform and not only on neoclassical economics as emphasised by the US and UK governments.

The fact that the national innovation systems of countries would show marked differences, associated with their individual paths of specialisation in production, also had obvious policy implications. Policy intervention could indeed be desirable or even necessary but had now to be informed by local conditions and based on the study of innovation processes, organisations and institutions and their interactions over relatively extended periods. It became now crucial to identify which elements of the system might be subject to inertia so that particular deficiencies could be addressed. Authors in the NSI-literature tradition started to refer to the 'dynamic co-evolution of knowledge, innovations, organisations and institutions'. From a systemic perspective, the case could be made that it was the weakest chain, which would be the most critical one for economic growth and development, and hence also for policy intervention.

Again, the idea that there is something to learn from institutional arrangements and policies in other, more 'advanced' environments, as exemplified in the subsequent European focus on the knowledge gap with the US, and that systematic comparative studies would be a useful tool in this respect, was of course not new. Alexander Gerschenkron pioneered this kind of comparative country study back in the 1950s. As he pointed out, although the technological gap between the frontier country and the laggard would represent 'a great promise' for the latter (a potential for higher growth through imitating frontier technologies), there were also various problems that would prevent backward countries from reaping the potential benefits to the full. Gerschenkron actually argued that if one country succeeded in embarking on an innovation-driven growth path, others might find it increasingly difficult to catch up. His favourite example was Germany's attempt to catch up with Britain a century ago. When Britain industrialised, technology was relatively labour intensive and small scale. But in the course of time technology became more capital and scale intensive, so when Germany entered the scene, the conditions for entry had changed considerably. Because of this, Gerschenkron argued, Germany had to develop new institutional instruments for overcoming these obstacles, above all in the financial sector, "instruments for which there was little or no counterpart in an established industrial country" (Gerschenkron, 1962). He held these experiences to be valid also for other technologically lagging countries. Another example of the role of institutional factors in the development of knowledge and innovation, although in a different historical context, is the role of intellectual property in industrial development. The catching-up process of Taiwan, Korea and other East Asian tigers took place in a time frame when the international protection of intellectual property was much weaker than it is today (e.g., Fagerberg, Srholec and Verspagen (2010) in this volume).

In this context Moses Abramovitz (1986) introduced the notions of technological congruence and social capability to discuss what he called the 'absorptive capacity' of late-comers and which do have affinity with the system of innovation perspective as subsequently introduced. The concept of technological congruence referred to the degree to which leader and follower country characteristics were congruent in areas such as market size and factor supply. The concept of social capability pointed to the various efforts and capabilities that backward countries possessed in order to catch up, such as improving education, infrastructure and technological capabilities (e.g. R&D facilities). Abramovitz, who could be described, next to List, as another precursor of system of innovation thinking explained the successful catching up of Western Europe vis-à-vis the United States in the post-war period as the result of both increasing technological congruence and improved social capabilities. As an example of the former he mentioned explicitly how European economic integration led to the creation of larger and more homogenous markets in Europe hence facilitating the transfer of scale-intensive technologies initially developed for US conditions. Improved social capabilities on the other hand were reflected in such other factors as the general increase in educational levels, the rise in the share of resources devoted to public and private sector R&D and the success of the financial system in mobilising resources for change. In a similar vein the failure of many developing countries to exploit the same opportunities is commonly accounted for by their lack of technological congruence and missing social capabilities (for example, the lack of a sound financial system, or a too low level, or unequal distribution of education).

The central point here is that concepts such as ‘technological congruence’ and ‘social capability’ are important policy notions which might be helpful in addressing the systemic ‘success’ or ‘failure’ of science, technology and innovation policies. From this perspective four factors appear today essential for the functioning of a national system of innovation. First and foremost, there is the investment of the country in social and human capital: the cement, one may argue, that holds the knowledge and innovation systems together. It will be incorporated in a number of knowledge generating institutions in the public as well as the private sector such as universities, polytechnics and other skills’ training schools. It is the factor most explicitly acknowledged by Nelson. In combination with a low degree of labour mobility, it is also the factor which explains why within a European context of nationally, sometimes regionally, organised education systems, one can still not talk about a European system of innovation (Caracostas and Soete, 1997). With the development of ‘new growth’ models in the economics literature, the role of education and learning in continuously generating, replacing and feeding new technology and innovation has of course received much more emphasis over the last decades. An initial stock of human capital in a previous period is likely to generate innovation growth and productivity effects, downstream as well as upstream with lots of ‘spillovers’ and positive ‘externalities’ (e.g., Lucas, 1988 and the overview by Jones and Romer, 2009). Higher education is itself crucial for the continuous feeding of fundamental and applied research. Many new growth models have tried to build in a more complex fashion such impacts, giving prime importance not just to education itself, but also to its by-products such as research and innovation.

The second central node of a system of innovation is hence not surprisingly the research capacity of a country (or region) and the way it is closely intertwined with the country's higher education system. From a typical 'national' innovation system perspective, such close interaction appears important; from an international perspective the links are likely to have become much looser, with universities and research institutions being capable of attracting talent world wide. In most technology growth models, these first two nodes, higher education and research, form the essential 'dynamo effects' (e.g., Soete and Turner, 1984, and Dosi, 1988) or 'yeast' and 'mushroom' effects (e.g., Harberger, 1998) implicit in the notion of technological change. Accumulated knowledge and human capital act like 'yeast' to increase productivity, while technological breakthrough or discovery suddenly 'mushroom' to increase productivity more dramatically in some firms/sectors than others.

The third 'node' holding knowledge together within the framework of a national system of innovation is, perhaps surprisingly, geographical proximity. The regional clustering of industrial activities based on the close interactions between suppliers and users, involving learning networks of various sorts between firms and between public and private players, represents, as highlighted in Lundvall's approach to national systems of innovation, a more flexible and dynamic organisational set-up than the organisation of such learning activities confined within the contours of individual firms. Local learning networks can allow for much more intensive information flows, mutual learning and economies of scale amongst firms, private and public knowledge institutions, education establishments, etc. In a well-known study Putnam (2000) compares the impact of Silicon Valley and Route 128 in the US. He cites Silicon Valley in California where a group of entrepreneurs, helped by research effort in the local universities, contributed to the development of a world centre of advanced technology. As he puts it: "The success is due largely to the horizontal networks of informal and formal cooperation that developed among fledgling companies in the area" (Putnam, 2000). Today, and despite the advent of Internet, this is still very much the case[8].

In addition to human capital, research and the related phenomenon of local networks, and particularly inter-firm networking, the fourth and last notion essential to any innovation system approach brings one back to Abramovitz 'absorptive capacity' notion and cover the demand factors that influence the take-up of innovations and hence the expected profitability on the part of the innovator. Consumers and more broadly national citizens might be more or less absorptive to new designs, products, ideas, enabling rapid diffusion or very conservative and resistant to change and suspicious of novelty. The demand factors among countries and regions (and even suburbs) vary dramatically, they are likely to influence also the ability of companies to learn and take-up innovations.

The four key elements described above can be thought of as elements of a virtual innovation system. Ideally each one will mutually reinforce the others providing an overall positive impact on a country or region's competitiveness and sustainable growth path. By contrast it is in the interactions between the four constituents that the systemic failures may be most easily identified. To illustrate the point, one may think of the Latin American case. In some of the larger countries, there is excellent tertiary education and research, but the graduates have tended in the past to take secure government lab jobs, which means that industry-public research links are weak. Research rarely flows to the private sector, but instead is targeted more towards the world research community.

In short, the NSI literature broadens the scope and rationale for innovation policy, from specific policy fields and targets such as higher education, research or innovation to the interactions between those fields. Targeting increases in R&D investment – a rather popular policy target: one may think of the European, so-called three percent Barcelona target – while the supply of researchers is not being addressed; or worse, in the case of Europe, is likely to fall due to ageing population trends is e.g. unlikely to yield the expected results. One immediate, possible solution to this problem could be to encourage the immigration of high-educated people (blue card),

[8] Face-to-face contacts and 'meet-ups' are needed to ensure cross-posting. A good example is the movement of social-network firms such as Facebook to Silicon Valley when it became commercial and the Web 2.0 community around San Francisco in general.

which is used in the United States (green cards).

4. Current policy challenges to the NSI concept

The concept of national systems of innovation is itself, however, under erosion from two sides. First of all, there is of course the emergence of various new sorts of knowledge ‘service’ activities, allowing for innovation without the need for particular leaps in science and technology, something that has been referred to as ‘innovation without research’ (Cowan and Van de Paal, 2000, p. 3). While in many ways not new, and reminiscent of Smith’s reference to inventors as “philosophers… whose trade is not to do anything but to observe everything” as quoted above, innovation is now less linked to the typical manufacturing forward and backward linkages, but ‘fuelled’, so to say, by the Internet and broadband, by more open flows of information raising of course many information-search problems as it is now confronted with impediments to accessing the existing stock of information that are created by intellectual property right laws. Second and closely related, the ‘national’ perspective on an innovation system approach appears under pressure given the globalisation trends and the inherent limits of national policy making in an area which is increasingly borderless.

4.1 The service economy: Innovation without (industrial) research

With the rise in service activities, the notion of a primarily industrial research based systems of innovation policy approach, has become increasingly questioned (Freeman and Soete, 2009). Many authors already emphasised the changing nature of the innovation process itself in the 1990s.[9] According to David and Foray (1995), innovation capability had to be seen less in terms of the ability to discover new technological principles, and more in terms of the ability to exploit systematically the effects produced by new combinations and uses of components in the existing stock of knowledge. Not surprisingly the new model appeared more closely associated with the emergence of various new sorts of knowledge ‘service’ activities, implying to some extent, and in contrast to the Frascati R&D focus, a more *routine* use of the technological base, allowing for innovation without the need for particular leaps in science and technology, a feature pre-dating somehow the industrial research lab of the 20th Century and something which

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[9] At the risk of omitting some, one may think of Gibbons (1994), David (1996), Lundvall (1994), Foray (1998) and Edquist (1997).

had of course already been recognized by economic historians (Rosenberg, 1976, 1982). This view brings into the debate the particular importance of science and technology service activities as it now puts a stronger emphasis on access to state-of-the-art technologies. This mode of knowledge generation, based in David and Foray's (1995, p. 32) words "on the recombination and re-use of known practices", does, however, raise much more extensive information-search problems as it is confronted with impediments to accessing the existing stock of information that are created by intellectual property right laws.

Not surprisingly at the organisational level, the shift in the nature of the innovation process also implied a shift in the traditional locus of knowledge production, in particular the professional R&D lab. The old system was based on a relatively simple dichotomy. On the one hand there were the knowledge generation and learning activities taking place in professional R&D laboratories, engineering and design activities, of which only the first part was measured through the *Frascati Manual*'s definition of R&D on the other hand there were the production and distribution activities where basic economic principles would prevail of minimising input costs and maximising sales. This typical sector-based innovation system perspective is still very much dominant in many industrial sectors ranging from chemicals to motor vehicles, semiconductors and electronic consumer goods, where technological improvements at the knowledge-generation end still appear today to proceed along clearly agreed-upon criteria and with a continuous ability to evaluate progress. The largest part of engineering research and development consists of the ability to 'hold in place': i.e., to replicate at a larger industrial scale and to imitate experiments carried out in the research laboratory environment.

The more recent models of technological progress associated with service activities with, for example, the continuous attempts at ICT-based efficiency improvements in financial and insurance sectors, the wholesale and retail sectors, health, education, government services, business management and administration, are much more confronted with the intrinsic difficulties in replication. Learning from previous experiences or from other sectors is difficult, sometimes even misleading. Evaluation is complicated because of changing external environments: over time, among sectors, across locations. It will often be impossible to separate out specific context variables from real causes and effects. Systemic insights appear less directly relevant: technological progress and innovation will be based more on ‘trial and error’ yet often without providing ‘hard’ data that can be scientifically analysed and interpreted. The result is that the outcome of the innovation process is less predictable; more closely associated with entrepreneurial risk-taking and local context conditions.

Some systems of innovation concepts, such as the notion of user-driven innovation, originally developed by innovation scholars such as Lundvall and his group in Aalborg in the late 1970s (Lundvall, 1985), might now take on more importance as in the case of Von Hippel (2004; 2010) whereby the risks of developing an unsuccessful technology is spread across many user-producers who contribute and perhaps implement their own ideas. The notion of innovation becomes here, in other words, even more ‘systemic’, but now rather in terms of networks, consumer user-producer relationship leading to new forms of collaborative innovation.

4.2. From national to international systems of innovation

The second feature which has increasingly challenged the notion of national system of innovation is of course the rapid growth in international research and knowledge flows. Since the 1990s it is probably fair to say that world wide, the largest part of world wide economic growth has been associated with an acceleration in the diffusion of technological change and world wide access to knowledge, as opposed to individual countries’ domestic efforts in research and knowledge accumulation. Most of the growth evidence of the last ten to fifteen years points to the particular importance of the international dimensions of knowledge accumulation in having brought about growth. This may be surprising in view of the particular attention given to European knowledge accumulation in the EU’s Lisbon agenda – and subsequently made explicit in the European Union three percent R&D Barcelona target. Undoubtedly, and as emphasised by David and Foray (2002), the emerging digital technologies: in particular the easy and cheap access to broadband, the world wide spreading of internet and of mobile communication have been instrumental in bringing about a more rapid diffusion of best practice technologies, and in particular more capital and organisational embedded forms of technology transfer such as licences, foreign direct investment and other forms of formal and informal knowledge diffusion.

To what extent is the NSI policy framework still useful within this much more globalised world? In many (small) countries, the globalisation trends described above might well have undermined much of the relevance of national innovation policies, systemic or not. Worse, it might even be argued that national systemic innovation policies have tended to miss emerging international trends, assuming that national weaknesses could only be addressed within the boundaries of national environments. Thus, it could be argued that in Europe, where the policy impact of the NSI literature was greatest, the NSI literature has barely contributed to the debates surrounding the creation of European research and innovation institutions such as the European Research Area, the European Research Council or the European institute on Innovation and Technology. As a result, the European policy debate has been characterised by continuous debates about the 'rationale' for European research and innovation policies next to individual member states' national systems of innovation policies.[10]

In this sense therefore, the globalisation of knowledge flows represents a real challenge for systems of innovation policies, developed primarily within a national context.

5. Conclusions

We sum up the discussion in five main points. The first is that the notion of innovation systems points to a crucial role of history in contemporary economic performance, and the roots it has in innovation performance. Innovation performance of individual actors (firms, but also other organisations) is influenced by a broad set of institutions and patterns of interactions, which are specific to the historical context in which they emerged. Strongly connected to this view is the notion that innovation systems are not usefully assessed by using the traditional notion of equilibrium that implies optimality and welfare maximisation. Differences between innovation systems exist, and are at the root of differences in aggregate and microeconomic performance, but in order to explain such differences, the innovation systems approach argues that historical analysis (in a broad sense) plays a more important role than economic theory.

[10] The notion of a European Research Area as it took form and became probably the most successful 'add-on' to the Lisbon 2000 summit agenda, was based on the argument about scale as the basis of European integration. An argument which had already become gradually eroded by then; the international knowledge diffusion and world-wide mobility of researchers had become the norm in many scientific fields in the 1990s. See the recent Expert Group on Community research policy in the knowledge based economy, EC (2009).

Second, although there is broad agreement in the innovation systems literature about this and other broad issues, there remain important differences in the ways that different scholars are using the notion of an innovation system. We have pointed to three main flavours of innovation systems analysis, connected to three of the most influential early contributions, by Freeman, Lundvall and Nelson, and these flavours still dominate the current literature. Additionally, the distinction between national, regional and sector-based systems also adds to diversity in the literature.

Third, and at a more concrete level than the first conclusion, the innovation systems literature has led to five main insights: the importance of a broader set of innovation inputs than just R&D, the importance of institutions and organisations, the role of interactive learning, leading to a dynamic perspective rather than a static allocative one, the role of interaction between agents, and, finally, the role of social capital. Each one of those specific points opens up links with literatures and approaches that are not so common in (mainstream) economics. In other words, the innovation systems literature is one that is rather multidisciplinary.

Fourth, the national innovation systems literature is one that is primarily aimed at analysing policy, and, correspondingly, it has sought, in many cases successfully, policy influence. As we have argued, the notion of innovations systems opens up possibilities for re-interpreting and re-engaging existing policy alternatives, such as industrial policy and trade policy. What it offers policy makers is a framework, not so much characterised by a different set of policy instruments, but rather by a wider set of justifications for policy, and a wider set of policy goals. Innovation systems offer the policy maker a tool for analysing innovation processes and influencing them, without the strong restriction of innovation policy to market failures that characterises the mainstream approach. This offers opportunities, but also hosts threats. The opportunities are related to the broader set of processes that are embodied in the innovation systems approach, and which enable more channels for influencing innovation performance. The threats are related to a potential misjudgement by policymakers of how innovation systems actually work, and even the possibility that political hobby horses are implemented under the umbrella of a broad innovation systems approach.

Finally, the innovation systems approach has managed to obtain a strong position in the literature and in policy circles, but its future depends on how well its proponents will be able to develop the approach further. Innovation systems has become a phenomenon that is most often analysed in a qualitative way, or using an indicators scoreboard approach. While this has been useful in reaching the conclusions outlined above, it is also clear that this approach has its limitations in terms of being able to reach concrete conclusions and concrete policy advice. It is one thing to reach the conclusion that institutions matter, but it is quite another to be able to suggest a concrete assessment of how institutional arrangements influence innovation performance, and by how much. In order for the innovation systems approach to remain influential, it needs to address these concrete issues. This has, arguably, happened already to some extent in the Nelson tradition of innovation systems, in particular in the literature on university-industry interaction and the role of university patents (e.g., Mowery and Sampat, 2001; Cohen et al., 1998). Such an empirically oriented approach to concrete issues might also be the way forward for the "European traditions" in innovation systems.

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Table 1
Characteristics of British national system of innovation in the 18th and 19th century

• Strong links between scientists and entrepreneurs.
• Science has become a national institution, encouraged by the state and popularised by local clubs.
• Strong local investment by landlords in transport infrastructure (canal and roads, later railways).
• Partnerships of organisations enable inventors to raise capital and collaborate with entrepreneurs
• Profits from trade and services available through national and local capital markets to
• Invest in factory production especially in textiles.
• Economic policy strongly influenced by classical economics and in the interests of industrialisation
• Strong efforts to protect national technology and delay catching up by competitors.
• British productivity per person about twice as high as European average by 1850
• Reduction or elimination of internal and external barriers to trade.
• Dissenters' academes and some universities provide science education. Mechanics trained in new industrial towns on part-time basis.

Characteristics of US national system of innovation, late 19th and 20th century

• No feudal barrier to trade and investment; slavery abolished 1865; capitalist ideology dominant.
• Railway infrastructure permits rapid growth of very large national market from 1860s onwards.
• Shortage of skilled labour induces development of machine intensive and capital intensive techniques (McCormick Singer, Ford).
• Abundant national resources exploited with heavy investment and big scale economies (steel, copper, oil).
• Mass production and flow production as typical US techniques.
• Strong encouragement of technical education and science at federal and state level from 1776 onwards.
• US firms in capital intensive industries grow very large (GM, GE, SO, etc.) and start in-house R&D.
• US productivity twice as high as Europe by 1914.
• Major import of technology and science through immigration from Europe.

Source: Freeman and Soete (1997)

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