Paper no. 2005/02

From theory to practice: the use of systems of innovation approach in innovation policy

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http://www.circle.lu.se/publications
ISSN 1654-3149

WP 2005/02

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Abstract

The main objective of this chapter is to discuss the implications of the adoption of the Systems of Innovation (SI) Approach in innovation policymaking. One of the main criticisms of the SI approach is the difficulty in translating it into real policymaking. This paper proposes a way of dealing with this complex problem. By breaking down the operation of the SI into 'activities,' the role of the government and the interplay between private and public actors can be discussed, and specific recommendations on how and when public actors should intervene can be made. The authors propose ten activities that capture the operation of an innovation system. The role of the public sector in each activity is then discussed, and a new research agenda is proposed.

Keywords: innovation systems, innovation policy

From Theory to Practice: the Use of the Systems of Innovation Approach in Innovation Policy

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and

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1. Introduction

Since the seminal work of Freeman (1987) on the Japanese national innovation system, the number of contributions to the systems of innovation approach at a national, sectoral and regional level has grown (Lundvall 1993; Carlsson & Jacobson, 1993; Cooke, Gomez-Uranga et al., 1997; Edquist, 1997; Edquist & Johnson, 1997; Lundvall, Johnson et al., 2002; Malerba, 2004; Malerba & Orsenigo, 1997; Nelson 1993).

The academic discussion started in the 90's jumped in the political sphere thanks to the Organization of Economic Co-operation and Development (OECD) who played a prominent role in promoting the use of the SI approach in the design and implementation of innovation policy in the OECD countries (Godin, 2004). Among the diverse initiatives that took place in the OECD during the1990s, the 7-year project on National Systems of Innovation (NSIs) (1995-2002) is of special relevance. The OECD had a great influence in the member countries and some of the governments soon adopted the innovation system approach in their innovation policy. However, as argued by (Mytelka & Smith, 2002), the SI approach has not been entirely successful in making the task of designing policy and proposing policy instruments easier.

This paper proposes a way of dealing with such complex reality. By breaking down the operation of the SI into 'activities,' the role of the government and the interplay between private and public actors can be discussed, and specific recommendations on how and when public actors should intervene can be made. The point of departure of this chapter for the discussion of innovation policy is the 'generic' SI approach, as discussed briefly in its second section This section also identifies the main components of the SI approach. Section 3 presents different approaches to classifying the activities in a SI; In section 4 the authors propose ten activities that capture the operation of an innovation system. The role of the public sector in each

activity is then discussed, and a new research agenda is proposed; section 5 draws some conclusions.

2. Systems of innovation [i]

There are almost as many definitions of SIs as authors, but most relate in some way to the definition of a system. According to Ingelstam (2002):

1. a system consists of two kinds of *constituents*: there are firstly, some kinds of *components* and secondly, there are *relations* among them. The components and relations should form a coherent whole (which has properties different from the properties of the constituents);
2. the system has a *function* – that is, it is performing or achieving something;

3. it must be possible to discriminate between the system and the rest of the world; that is, it must be possible to identify the *boundaries* of the system. If we, for example, want to make empirical studies of specific systems, we must, of course, know their extension.[ii]

A systemic approach is the point of departure for the literature on technological systems (Dosi, 1982; Gille, 1978; Hughes, 1983; Rosenberg, 1982), industrial systems (Hirschman, 1958; Porter, 1992), and innovation systems. Within this last group, and according to the level of analysis it is possible to distinguish between (Edquist, 1997):

- National Innovation Systems (Freeman, 1987; Lundvall, 1992; Nelson, 1993);
- Regional Innovation Systems (Camagni, 1991; Cooke et al., 1997; Braczyk et al., 1998; Cooke, 2001; and Asheim & Isaksen, 2002);
- Sectoral and "technological innovation systems" (Breschi & Malerba, 1997; Carlsson, 1995; Carlsson & Stankiewicz, 1991: Malerba, 2004).

For the purpose of the discussion here, we propose that an SI includes "all important economic, social, political, organizational, institutional and other factors that

influence the development, diffusion and use of innovations," (Edquist, 1997).[iii] If all factors that influence innovation processes are not included in a definition, one has to argue which potential factors should be excluded – and why. This is quite difficult, since, at the present state of the art, we do not know the determinants of innovations systematically and in detail.

2.1.. What are the components of an SI?

Organizations and institutions are often considered to be the main components of SIs, although it is not always clear what is meant by these terms. Let us, therefore, specify what organizations and institutions mean here (Edquist, 1997):

Organizations are "formal structures that are consciously created and have an explicit purpose," (Edquist & Johnson, 1997). They are "players or actors."[iv] Some important organizations in SIs are firms (normally considered to be the most important organizations in Sis), universities, venture capital organizations and public agencies responsible for innovation policy, competition policy or drug regulation.

Institutions are "sets of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups and organizations," (Edquist & Johnson, 1997). They are the "rules of the game." Examples of important institutions in SIs are patent laws, as well as rules and norms influencing the relations between universities and firms. Obviously, these definitions are of a Northian character (North, 1990), discriminating between the rules of the game and the players in the game.

Which institutions and organizations are included within the boundaries of the system of innovation is a matter of discussion. Lundvall (1992) distinguishes between a narrow and a broad definition of an SI. The narrow one includes only the organizations

and institutions involved in research activities (searching and exploring). This embraces universities, R&D departments in firms, and technological institutes. The broad definition, on the other hand, refers to 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). This chapter adopts this broader perspective.

2.2. Implications of the SI approach for innovation policy

Innovation policy is public actions that influence innovation processes: that is, the development and diffusion of (product and process) innovations. The objectives of innovation policy are often economic ones, such as economic growth, productivity growth, increased employment and competitiveness. However, they may also be of a non-economic kind, such as cultural, social, environmental, or military. The objectives are determined in a political process, and not by researchers. They must, however, be specific and unambiguously formulated in relation to the current situation in the country and/or in comparison to other countries.

Understanding innovation as a complex interactive learning process has important implications for the design and implementation of any kind of policy to support innovation. It affects the focus of the policy, the instruments, and the rationale for public policy. This chapter will deal mainly with the first two issues, whilst the third will be discussed in detail in Chaminade & Edquist, 2005.

The implications of the SI approach for public policy are better understood when its basic assumptions are compared to those of mainstream economics (Lipsey & Carlaw, 1998; Smith, 2000).

a. Knowledge, learning and innovation in mainstream economics

One of the basic assumptions of neoclassical economic theory is perfect information: that is, all economic agents can maximize their profits because they have perfect information about the different options available to them. Knowledge is equal to information: that is, it is codified, generic, accessible at no cost, and easily adaptable to the firm's specific conditions.

These tacit assumptions about the properties of knowledge are included in the discussion about the process of invention. For Nelson (1959) and Arrow (1962), the knowledge emanating from research has some specific properties: uncertainty, unappropriability and indivisibility (Smith, 2000). 'Uncertainty' refers to the impossibility of knowing a priori the outcomes of the research process and the risk associated to it. 'Unappropriability' refers to firms' being unable fully to appropriate the benefits which derive from the invention. As knowledge is information, freely accessible to all economic agents, this means that there is no incentive for the research activity. Finally, 'indivisibility' implies that there is a minimum scale of knowledge needed before any new knowledge can be created: that is, new knowledge is created on the basis of an existing pool of knowledge (inside or outside the firm). Therefore, it is difficult to separate what constitutes new knowledge from the knowledge that already exists.

For neoclassical economics, the innovation process is narrowed down to research (and invention). How to transform the results of the research activity into products or processes that can be traded in the market is a black box (Rosenberg, 1982; 1994). For the neoclassical theorists, the process of innovation is a fixed sequence of phases, where some research efforts will automatically turn into new products.

These three characteristics of scientific knowledge (uncertainty, unappropriability, and indivisibility) will lead to an underinvestment in R&D activities. This constitutes the main rationale for public intervention in research activities. Policymakers have to intervene because of a *market failure*: private actors in the economies will systematically under-invest in R&D, not reaching the optimal allocation of resources for invention.

As argued by Smith (2000), the neoclassical approach, despite its many shortcomings, can be useful for understanding basic science, but it is very limited when trying to explain innovation activities, especially those with closer links to the market.

The policy implications that emerge from the market failure theory are, from a practical and specific point of view, not very helpful for policymakers. They are too blunt to provide much guidance. They do not indicate how large the subsidies or other interventions should be, or within which specific areas one should intervene. They say almost nothing about how to intervene: that is, which policy instruments that should be used and the process through which they should be implemented. Standard economic theory is not of much help when it comes to formulating and implementing specific R&D and innovation policies. It only provides general policy implications: for example, that basic research should sometimes be subsidized (Edquist, Malerba et al., 2004). The market failure approach is too abstract to be able to guide the design of specific innovation policies.

b. Knowledge, learning and innovation in the SI approach

The general policy implications of the SI approach are different from those of standard economic theory.[v] This has to do with the fact that the characteristics of the two frameworks are very different. The SI approach shifts the focus away from actions at

the level of individual and isolated units within the economy (firms, consumers) towards that of the collective underpinnings of innovation. It addresses the overall system that creates and distributes knowledge, rather than its individual components, and innovations are seen as the outcome of evolutionary processes within these systems.

The SI approach has its roots in evolutionary theory (Nelson & Winter, 1982). Firms are a bundle of different capabilities and resources (Eisenhardt & Martin, 2000; Grant, 1996; Spender, 1996) which they use to maximize their profit. Knowledge is not only information, but also tacit knowledge; it can be both general and specific and it is always costly. Knowledge can be specific to the firm or to the industry (Smith, 2000).

The innovation process is interactive within the firms and among the different actors in the innovation system. At the level of the firm (Kline & Rosenberg, 1986), innovation can take place in any part of the firm. Furthermore, Kline & Rosenberg argue that the process of mission-oriented research will be initiated only if the firm cannot find inside and outside the firm, the technical solution in the existing pools of knowledge (Kline & Rosenberg, 1986: 291). The SI approach emphasises the fact that firms do not innovate in isolation but with continuous interactions with the other actors in the system (at regional, sectoral, national, and supranational level).

The main focus of the SI approach is, therefore, the operation of the system and the complex interactions that take place among the different organizations and institutions in the system. Policymakers need to intervene in those areas where the system is not operating well. The policy rationale is based on systemic failures or problems rather than on market failures.

However, the notion of ‘market failure’ in mainstream economic theory implies a comparison between conditions in the real world and an ideal or optimal economic system. Hence, the notion of failure is associated with the existence of an optimum.

However, innovation processes are path-dependent over time, and it is not clear which path that will be taken. They have evolutionary characteristics. We do not know whether the potentially best or optimal path is being exploited. The system never achieves equilibrium, and the notion of optimality is irrelevant in an innovation context. We cannot specify an ideal or optimal SI. Hence, comparisons between an existing system and an ideal or optimal system are not possible, and the notion of market failure loses its meaning and applicability. Not to lead thoughts in wrong directions, we therefore prefer to talk about systemic problems instead of systemic failures.

Systemic problems mentioned in the literature include (Smith, 2000; Woolthuis, Lankhuizen et al., 2005):

- infrastructure provision and investment, including the physical infrastructure (for example, IT, telecom, transport) and the scientific infrastructure (such as high-quality universities and research laboratories, technical institutes);
- transition problems – the difficulties that might arise when firms and other actors encounter technological problems or face changes in the prevailing technological paradigms that exceed their current capabilities;
- lock-in problems, derived from the socio-technological inertia, that might hamper the emergence and dissemination of more efficient technologies;[vi]
- hard and soft institutional problems, linked to formal rules (regulations, laws) as well as more tacit ones (such as social and political culture);
- network problems, which include problems derived from linkages too weak or too strong (blindness to what happens outside the network) in the SI;
- capability problems, linked to the transition problems, referring to the limited capabilities of firms, specially small and medium size enterprises (SMEs), that might limit their capacity to adopt or produce new technologies over time.

It is obvious that not all these systemic problems can be solved by public intervention. And even in those cases where public intervention is expected, we know very little about how the intervention should take place.

How can we then identify 'problems' that should be subject to innovation policy? As argued earlier, we cannot compare an existing system with an ideal or optimal one (in order to identify a 'systemic problem'). This is contrary to most policy analysis, which basically compares existing situations with imaginary, supposedly optimal or ideal, ones.

What remains are empirical comparisons between different existing systems.[vii] Comparison is a means for understanding what is good or bad, or what is a high or a low value for a variable in an SI. Historically pre-existing systems - national, regional and sectoral - can be compared with currently existing ones. Or different currently existing systems can be compared with each other. These comparisons must be genuinely empirical and very detailed.[viii] If so, they can identify problems that should be subject to policy intervention. Substantial analytical and methodological capabilities are needed to identify these problems.[ix] This is what can be called benchmarking.

In order to be able to design appropriate innovation policy instruments, it is also necessary to know at least the most important causes of the problems identified. Not until they know these can policymakers know whether to influence or change organizations, or institutions, or the interactions between them – or something else. Therefore, an identification of a problem should be supplemented by an analysis of its causes as a part of the analytical basis for the design of an innovation policy.

In sum, understanding innovation as a systemic process has important implications for policy makers. The rationale for public intervention changes as well as the focus of that intervention. Under the SI perspective, policy makers need to address

systemic problems. The design of an appropriate innovation policy based on the SI approach needs to start with a thorough analysis of the operation of the SI in focus. This is easier said than done. Scholars dealing with innovation systems have focused on the composition of the systems, in terms of institutions and organizations, as well as their measurement and comparison (Pavitt & Patel, 1994). But we still know very little about the dynamics of SIs, or the activities within them. Some of the things we know are summarized in the next section.

3. Activities in the system of innovation – review of the literature

One way of analyzing SIs is to focus not only on its constituents but on what actually happens in the systems. At a general level, the main function – also known as 'overall function' – in SIs is to pursue innovation processes: that is, to develop and diffuse innovations. What we, from now on, call 'activities' in SIs are those factors that influence the development and diffusion of innovations.[x]

Although a system is normally considered to have a function, this was not addressed in a systematic manner in the early work on SIs. From the late 1990s, some contributions on functions or activities in innovation systems were published[xi] (Galli & Teubal, 1997; Johnson & Jacobsson, 2003; Liu & White 2001; Rickne, 2000).[xii]

As Table 1 shows, the variety of classifications is the result of the different research objectives and definitions of activities. It this sense, four approaches can be distinguished:

- innovation production process, looking at the different activities needed to turn an idea into a new product or process. Edquist, (2004), Furman, Porter et al., (2002) (and Liu & White, 2001 to a lesser extent) are examples of this approach;

- knowledge production process, focusing on how knowledge is created, transferred and exploited. There is here a strong emphasis on the channels and mechanisms for knowledge distribution. David & Foray 1994 (1995) and Johnson & Jacobsson (2003) follow this criterion. This is close to the Aalborg approach to innovation systems as learning systems and the emphasis placed on learning and knowledge dynamics in firms and networks (Lundvall, Johnson et al., 2002).
- organizational performance, using the organizations as the starting point and identifying the activities of the different organizations that have an impact in the innovation system. Borrás (2004) would be an example of this approach.
- Innovation policy, using innovation policy as a focal point, that is, what activities (and organizations) in the innovation system can be stimulated by public intervention. The OECD and other international organizations follow this approach.
- One point of criticism that can be expressed in relation to the OECD approach is that it considers only those activities that can be directly affected by public intervention. It ignores other activities in the system that are equally important, but whose links to innovation policy instruments are not so obvious.

We believe that a different approach is needed, one that starts with the relevant activities in the system of innovation and discusses, for each of them, what is the division of labor between private and public actors in the performance of each activity. This will provide policymakers with a new perspective on:

a) what role they can play in stimulating different activities in the system of innovation;

b) once the complex division of labor between public and private actors has been unfolded, what could be the appropriate instruments to do this;

c) how to identify future research needs. This discussion will be taken forward in section 4.

TABLE 1. ACTIVITIES IN SYSTEMS OF INNOVATION

Author(s)	Definition of function or activity	Main criteria for classification	Breakdown of functions, activities or building blocks
Borrás, 2004	Activities of the different organizations in the system of innovation affecting innovation performance	Role of institutions in the system of innovation.	1. 5 generic functions are identified: to reduce uncertainty; to manage conflict and cooperation; to provide incentives, to build competences and to define the boundaries of the system. 10 specific functions in the system of innovation are listed: 1. production of knowledge 2. diffusion of knowledge 3. appropriation of knowledge 4. regulation of labour markets 5. financing innovation 6. alignment of actors 7. guidance of innovators 8. reduction of technological diversity 9. reduction of risk 10. control of knowledge use.
David & Foray	Factors affecting the	Knowledge distribution	1. Distribution of knowledge (DoK) among universities,

1994, 1995	knowledge distribution power of an SI	processes organized according to the relationship between organizations	research organizations and industry 2. DoK within a market and between suppliers and users 3. Re-use and recombination of knowledge 4. DoK among decentralized R&D projects 5. Dual technological development of civilian and military technologies
Edquist, 2004	Factors that influence the development and diffusion of innovation	Determinants of the innovation process	1. Knowledge inputs to the innovation process 2. Demand-side factors 3. Provision of constituents in SIs 4. Support services for innovating firms
Furman, Porter et al., 2002	Building blocks required to produce and commercialize a flow of technologies new to the world over the long term	Determinants of national innovative capacity	1. Strong innovation infrastructure 2. Strong innovation environments (incl. input conditions, demand conditions, related and supporting industries and context for firm strategy and rivalry) 3. Linkages between 1 and 2.

Author(s)	Definition of function or activity	Main criteria for classification	Breakdown of functions, activities or building blocks
Galli & Teubal, 1997	Factors affecting the production and diffusion of innovations	Activities according to type of organization (hard or soft)	Hard functions 1. R&D 2. Supply of scientific and technical services to third parties Soft functions 3. Diffusion of information, knowledge and technology to bridging organizations. 4. Policy making by government offices 5. Design and implementation of institutions 6. Diffusion/divulgation of scientific cultures 7. Professional coordination through academies, prof. associations.
Johnson and Jacobsson 2003	Factors that affect the knowledge production processes	Knowledge production processes that can be influenced by public	1. Creating new knowledge 1. Guide for research process 2. Providing resources

		policy	3. Facilitating generation of knowledge economies 4. Dissemination of market information
Liu & White, 2001	Factors that influence the development, diffusion and use of technological innovation	Knowledge production process	1. Research 2. Implementation 3. End-use 4. Linkage 5. Education
OECD 2002a	Core blocks in the system of innovation to be considered in a comprehensive innovation policy approach	Innovation Policy	1. Enhancing firm innovative capacities (capacity building) 2. Exploiting Power of markets 3. Securing Investment in knowledge 4. Promoting the commercialization of publicly funded research 5. Promoting cluster development 6. Promoting internationally open networks

4. Linking innovation activities in the system of innovation with innovation policy

We believe that it is important to study the activities in SIs – or causes/determinants of innovation processes – in a systematic manner. The hypothetical list of activities presented below is based upon the previous literature review and on our prior knowledge about innovation processes and their determinants. This list is provisional and will be subject to revision as our knowledge about determinants of innovation processes increases. On this basis, we argue that the activities listed below can be expected to be important in most SIs. The main activities in the system of innovation relate to the provision of knowledge inputs to the innovation process (1-2), the demand-side factors (3-4), the provision of constituents of SIs (5-7), and the provision of support services for innovating firms (8-10).

I. Provision of knowledge inputs to the innovation process

1. Provision of Research and Development (R&D) creating new knowledge, primarily in engineering, medicine and the natural sciences.
2. Competence-building (provision of education and training, creation of human capital, production and reproduction of skills, individual learning) in the labor force to be used in innovation and R&D activities.

II. Provision of markets – demand-side factors

3. Formation of new product markets.
4. Articulation of quality requirements emanating from the demand side with regard to new products.

III. Provision of constituents for IS

5. Creating and changing organizations needed for the development of new fields of innovation, for example, enhancing entrepreneurship to create new firms and intrapreneurship to diversify existing firms, creating new research organizations, policy agencies, etc.
6. Provision (creation, change, abolition) of institutions – for example, IPR laws, tax laws, environment and safety regulations, R&D investment routines, etc - that influence innovating organizations and innovation processes by providing incentives or obstacles to innovation.
7. Networking through markets and other mechanisms, including interactive learning between different organizations (potentially) involved in the innovation processes. This implies integrating new knowledge elements developed in different spheres of the SI and coming from outside with elements already available in the innovating firms.

IV. Support services for innovation firms

8. Incubating activities, for example, providing access to facilities, administrative support, etc. for new innovating efforts.
9. Financing of innovation processes and other activities that can facilitate commercialization of knowledge and its adoption.
10. Provision of consultancy services of relevance for innovation processes, for example, technology transfer, commercial information and legal advice.

Here we are placing greater emphasis on activities than much of the early work on SIs. Nonetheless, this emphasis does not mean that we can disregard or neglect the components of SIs and the relations among them. Organizations or individuals perform

the activities, institutions provide incentives and obstacles influencing these activities. To understand and explain innovation processes, we need to address the relations between activities and components, as well as among different kinds of components.[xiii]

We believe that understanding the dynamics of each of these activities can be a useful departure point for identifying the role of the government in stimulating the innovation system and the division of labor between public and private actors.

4.1. Provision of knowledge inputs to the innovation process

4.1.1. Provision of R&D

R&D is an important basis for some innovations, particularly radical ones in engineering, medicine and the natural sciences. Such R&D has traditionally been an activity partly financed and carried out by public agencies. This applies to basic R&D, but also to more applied kinds of R&D in some countries. This publicly performed R&D is carried out in universities and in public research organizations. NSIs can differ significantly with regard to the balance between these two kinds of organizations. In Sweden, less than five per cent of all R&D is carried out in public research organizations. In Norway, this figure is more than twenty per cent. Public organizations carrying out R&D are also governed or influenced by different institutional rules in different national systems.

However, a considerable part of the R&D in some countries is financed and carried out by the private sector, primarily firms.[xiv] In 1999, the proportion of all firm-financed R&D in the OECD countries ranged from 21 percent (Portugal) to 72 percent (Japan) (OECD, 2002b). Such data may be a way of distinguishing between different types of NSIs. In most NSIs in the world today, little R&D is carried out and most of this is performed in public organizations. Most of these countries are poor and medium-

income countries. Those few countries that do a lot of R&D are all rich, and much of their R&D is carried out by private organizations. This includes some large countries, such as the United States (US) and Japan, but also some small and medium-sized countries such as Sweden, Switzerland and South Korea. There are also some rich countries that do little R&D, for example, Denmark and Norway.

Because innovation processes are evolutionary and path-dependent, there is the danger of negative lock-ins, that is, trajectories of innovation that lead to inferior technologies resulting in low growth and decreasing employment. Potentially superior innovation trajectories may not take off and the generation of diversity may be reduced or blocked. In such situations, governments may favor experimentation and use R&D subsidies to support possible alternatives to the winning technologies (Edquist, Malerba et al., 2004).[xv]

Therefore, public organizations can influence R&D activity in different ways, from direct investment and performance through public universities and research centres to stimulating alternative technologies via R&D subsidies. However, much research is needed to understand the relationship between R&D, innovation, productivity growth, the role of R&D in innovation in different sectors, and the impact of different instruments in the propensity of the firms to invest in R&D.

4.1.2. Competence building

The concept of competence building is usually linked to the qualification of human resources. However, it involves other processes and activities related to the capacity to create, absorb and exploit knowledge.

Here we follow the definition of Lundvall, Johnson et al., (2002) of competence building that includes: "…formal education and training, the labor market dynamics and

the organization of knowledge creation and learning within firms and in networks (Lundvall, Johnson et al., 2002)

Education and training of importance for innovation processes (and R&D) is primarily provided by public organizations (schools, universities, training institutes) in most countries. However, some competence-building is done in or by firms through learning-by-doing, learning-by-using, or learning-by-interacting. Competence-building leads to creation of human capital accumulated in the heads of people: that is, it is a matter of individual learning, the result of which is controlled by individuals.[xvi]

The organizational and institutional contexts of competence-building vary considerably among NSIs. There are particularly significant differences between the systems in the English-speaking countries and continental Europe. However, scholars and policymakers lack good comparative measures on the scope and structure of such differences. There is little systematic knowledge about the ways in which the organization of education and training influences the development and diffusion of innovations. Since labor, including skilled labor, is the least mobile production factor, domestic systems for competence-building remain among the most enduringly national of elements of NSIs.

Competence-building should not only be limited to human capital. Organizations have competences that exceed those of the employees. Human capital is hired by the company but is always owned by the individual. However, there are ways by which the firm can capture individual knowledge and transform it into organizational knowledge. The organization of the processes of knowledge creation and learning within the firm and in networks are also part of the competence-building activity. Those processes have received attention from the scholars only very recently (Chaminade, 2003; Edvinsson & Malone, 1997; Guthrie & Petty, 2000; Nooteboom, 2004; Sanchez,

Chaminade et al., 2000; Tsekouras & Roussos, 2005) and many questions remained unanswered.

The role of the government in the timely provision of qualified human resources is clear, although the division of labor between private and public actors is still under debate. However, the situation is very different when we come to components of competence-building such as knowledge and learning dynamics. We know very little about knowledge dynamics in firms and in networks. Evidence is based on cases; these can seldom be compared and the evidence is not enough to make generalizations. Little can be said about the role of government supporting these processes, although some attempts have been made (European Commission, 2003; OECD, 1999). It remains an issue to be further developed.

4.2. Formation of new markets and articulation of quality requirements – demand-side factors[xvii]

In the very early stages of the development of new fields of innovation, there is uncertainty whether a market exists or not. An illustrative example was the belief that the total computer market amounted to four or six computers in the 1950s. Eventually markets develop spontaneously.

One example of market creation is in the area of inventions. The creation of intellectual property rights through the institution of a patent law gives a temporary monopoly to the patent owner. This makes selling and buying of technical knowledge easier.[xviii] Public policymakers can also enhance the creation of markets by supporting legal security or the formation of trust.

Another example of public support to market creation is the creation of standards. For example, the Nordic Mobile Telephony Standard (NMT 450) created by the Nordic telecomunication offices (PTTs) in the 1970s and 1980s - when they were state-owned monopolies - was crucial for the development of mobile telephony in the Nordic countries. This made it possible for the private firms to develop mobile systems (Edquist, 2003).

In some cases, the instrument of public innovation procurement has been important for market formation. Public innovation procurement is the public buying of technologies and systems, which did not exist at the time. This has been - and is - an important instrument in the defence material sector in all countries. It has also been important in infrastructure development (telecom, trains, etc) in many countries.[xix]

There may also be public subsidies intended to enhance adoption of innovations. One example is subsidies that exist in many countries for electricity produced by windmills.

The provision of new markets is often linked to the articulation of quality requirements, which may be regarded as another activity of the SI. Articulation of quality requirements emanating from the demand side with regard to new products is important for product development in most SIs. It is an important activity, enhancing innovation and influencing processes of innovation in certain directions. Most of this activity is performed spontaneously by demanding customers in SIs. It is a result of interactive learning between innovating firms and their customers. In investigations of collaboration between organizations in their pursuit of innovation such collaboration is one of the most frequent.

Quality requirements can also be a consequence of public action, for example, regulation in the fields of health, safety, and the environment, or the development of

technical standards. Public innovation procurement normally includes a functional specification of the product or system wanted, and this certainly means demand articulation that influences product development significantly.

But we know very little about the formation of new markets and the articulation of quality requirements. Instruments such as public procurement, regulation, or subsidies can influence these activities, but further discussion is needed on the adequate division of labor between public and private actors.

4.3. Provision of constituents

4.3.1. Creation and change of organizations

As pointed out in section 2.2., organizations are normally considered to be one of the main components in systems of innovation. Entry and exit of organizations, as well as change of incumbent organizations, is therefore naturally an important activity constituting a part of the change of systems of innovation as such.

Creation and change of organizations for the development and diffusion of innovations is partly a matter of spontaneous firm-creation (through entrepreneurship) and diversification of existing firms (through intrapreneurship). However, public action can facilitate such private activities by simplifying the rules of the game and by creating appropriate tax laws. New R&D organizations and innovation policy agencies can also be created through political decisions.

One important role of policy is to enhance the entry and survival of new firms by facilitating and supporting entrepreneurship. As compared to incumbents, new entrants are characterized by different capabilities, and they may be the socio-economic carriers of innovations. They bring new ideas, products, and processes. Hence, governments should create an environment favorable to the entry of new firms and the growth of successful small- and medium-sized firms. Survival and growth of firms often

require continuous (or at least multiple) innovation, particularly in high-tech sectors of production.

Enhancement of entrepreneurship and intrapreneurship is a way of supporting changes in the production structure in the direction of new products. There are actually three mechanisms by which the production structure can change through the addition of new products:

1) existing firms may diversify into new products (examples are Japan and South Korea);
2) new firms in new product areas may grow rapidly (the US is an example);
3) foreign firms may invest in new product areas in the country (Ireland is an example).

To add new products to the existing bundle of products is important, since the demand for new products often grows more rapidly than for old ones – with accompanying job creation and economic growth. New products are also often characterized by high productivity growth.

Governments should therefore create opportunities and incentives for changes in the production structure. Policy issues in this context concern how policymakers can help develop alternative patterns of learning and innovation, and nurture emerging sectoral systems of innovation.

In any system of innovation, it is important, from a policy point of view, to study whether the existing organizations are appropriate for promoting innovation. How should organizations be changed or engineered to induce innovation? This dynamic perspective on organizations is crucial in the SI approach, in both theory and practice. Creation, destruction and change of organizations were very important in the development strategies of the successful Asian economies and they are crucial in the

ongoing transformation of Eastern Europe. Hence, organizational changes seem to be particularly important in situations of rapid structural change which, in turn, is linked to building the capacity to deal with changes.

4.3.2. Interactive learning, networking and knowledge integration

In section 2.1., we pointed out that relations among components are a basic constituent of systems. Interactive learning is a basis for competence-building. The SI approach emphasises interdependence and non-linearity. This is based on the understanding that firms normally do not innovate in isolation but interact with other organizations through complex relations that are often characterized by reciprocity and feedback mechanisms in several loops. Innovation processes are not only influenced by the components of the systems, but also by the relations between them. This captures the non-linear features of innovation processes and is one of the most important characteristics of the SI approach.

The interactive nature of much learning and innovation implies that this interaction should be targeted much more directly than is normally the case in innovation policy today.[xx] Innovation policy should not only focus on the components of the systems, but also – and perhaps primarily – on the relations among them. Relations between organizations may occur through markets but also through other mechanisms. This implies integrating new knowledge elements developed in different spheres of the SI and coming from outside with elements already available in the innovating firms.

Most interaction between organizations involved in innovation processes occurs spontaneously when there is a need. The activity of (re)combining knowledge - from any source – into product and process innovations is largely carried out by private firms. They often collaborate with other firms, but sometimes universities and public research

organizations are also involved. The long-term innovative performance of firms in science-based industries is strongly dependent upon the interactions between firms and universities and research organizations. If they are not spontaneously operating smoothly enough, these interactions should be facilitated by means of policy. Here formal institutions are important, as we will see in sub-section 4.3.3.

The relations between universities and public research organizations on the one hand and firms on the other are coordinated only to a limited degree by markets. This linkage activity is addressed (by policy) in different ways, to different extents in different NSIs, and sometimes not at all. Incubators, technology parks, public venture capital organizations - to be discussed in later subsections - may also be important in similar ways. This means that the public sector may create organizations to facilitate innovation. At the same time, however, it may create the rules and laws that govern these organizations and their relations to private ones – that is, create institutions. (Edquist, Malerba et al., 2004).

4.3.3. Creation and change of institutions

As shown in section 2.3., institutions are normally considered to be the second main component (in addition to organizations) in SIs. The creation, abolition and change of institutions are activities crucial to the maintenance of SIs' dynamism.

Important institutions in systems of innovation are IPR laws, technical standards, tax laws, environment and safety regulations, R&D investment routines, firm-specific rules and norms, etc; these influence innovating organizations and innovation processes by providing incentives or obstacles for organizations and individuals to innovate.

IPR laws are considered to be important as a means of creating incentives to invest in knowledge creation and innovation (and, as we have seen in section 4.2.1.,

they are leading to the creation of markets). Tax laws are also often considered to influence innovation processes. An important question is here which kinds (and levels) of taxes become obstacles or facilitators of innovation (and entrepreneurship).

We have already mentioned the important role of institutions in facilitating the interaction between organizations in the previous subsection. Governments may, for example, support collaborative centers and programs, remove barriers to cooperation and facilitate the mobility of skilled personnel between different kinds of organizations. This might include the creation or change of institutional rules that govern the relations between universities and firms, such as the one in Sweden stating that university professors shall perform a 'third task' in addition to teaching and doing research: that is, interact with the society surrounding the university, including firms (Edquist et al., 2004).

Some kinds of institutions are created by public agencies. They are often formal (codified) ones. Others develop spontaneously over history without public involvement. There are institutions that influence firms and there are institutions that operate inside firms.[xxi]

Those formal institutions that are created by public agencies are policy instruments. Public innovation policy is largely a matter of formulating the rules of the game that will facilitate innovation processes. These rules might have nothing to do with markets, or they might be intended to create markets or make the operation of markets more efficient.

Just as in the case of organizations, it is important, from a policy point of view, to study whether the existing institutions are appropriate for promoting innovation and to ask the same question of how institutions should be changed or engineered to induce innovation. Here, too, the evolution and design of new institutions were very important

in the development strategies of the successful Asian economies as well as in the ongoing transformation of Eastern Europe. Hence, institutional (as well as organizational) changes are particularly important in situations of rapid structural change.

4.4. Support services for innovative firms

4.4.1. Incubation

Incubating activities include such things as provision of access to facilities, and administrative support for new innovating efforts. We know very little about how incubating activities emerge in the SI. Incubating activities have been carried out in science parks to facilitate commercialization of knowledge in recent decades. That this activity has become partly public has to do with the uncertainty characterizing early stages of the development of new products, which means that markets do not operate well in this respect.

However, innovations are also emerging in existing firms through incremental innovation and when they diversify into new product areas. In those cases, the innovating firms normally provide incubation themselves. There is a need to understand better the conditions under which incubation needs to be a public activity and when it should be left to the private initiative.

4.4.2. Financing

Financing of innovation processes is necessary for the commercialization of knowledge into innovations and their diffusion. Financing of innovation is primarily done by private organizations within innovating firms, through stock exchanges, by venture capital organizations, or through individuals (business angels). Again, however,

financing is sometimes - for example in the form of seed capital - provided by public organizations in many countries, including the US.

As in all public interventions, financing should only be provided publicly when firms and markets do not spontaneously perform this activity (for example when uncertainty is too large). But the question is not just when the public sector should finance innovation activities but also how: that is, what should be the instruments and what should be the appropriate balance between public and private funding in a particular SI.

4.4.3. Provision of consultancy services

Consultancy services are very often of importance for innovation processes. Those of relevance for innovation processes are, for example, technology transfer, commercial information and legal advice. They are primarily carried out by private organizations. If they are large and rich in competence in various fields, the innovating firms themselves may do this in cases where the innovations are created by diversification processes. They may also be provided by specialized consultancy firms both in such cases and in cases where a new firm is established around the innovation.

Specialized consultancy firms are normally classified as Knowledge Intensive Business Services (KIBS), a service sector that is growing rapidly. KIBS firms provide services in the field of computer hardware and software, other technical services, management, marketing, patenting, legal advice, accounting, etc.

But there are certain cases (groups of SMEs, mature sectors) where these services are also provided by public authorities, either directly or by their acting as broker between firms and service providers. Examples of these can be found in regional public agencies.

Once again, the discussion of the division of labor between public and private actors needs to be supported by more evidence of the systemic problems that give reason for public intervention.

5. Conclusions and future research agenda

This chapter has placed a great emphasis on activities that operate in SIs. However, this emphasis does not mean that we can neglect the components of SIs and the relations among them. *Organizations* or individuals perform the activities and *Institutions* provide incentives and obstacles. We believe that the analysis of innovation systems proposed here can fruitfully be used for innovation policy purposes, and that the activities that influence innovation processes in the systems are a useful point of entry in the policy analysis. Thereafter, one can identify the organizations performing the activities and see that there is not a one-to-one relation between them, but that a certain kind of organization can perform more than one activity and that many activities can be carried out by more than one category of organization.

A similar exercise can be carried out for innovation policy: we can analyze the division of labor between private and public organizations with regard to the performance of each of the activities in innovation systems, investigate whether these activities are performed by private or public organizations, and whether this division of labour is motivated or not.

The policy discussion at each point is focussed upon changes in the division of labor between the private and the public spheres or upon changes in those activities already carried out by the public agencies. This includes adding new public policy activities as well as terminating others. Terminating activities carried out by public organizations are not the least important!

However, the discussion of the division of labor between private and public organizations is burdened by our lack of knowledge on several issues that should be part of our future research agenda in innovation policy and systems of innovation:

a) How is each of the activities related to the propensity to innovate in the system of innovation?
b) Which institutional rules are governing each activity?
c) What is the role of private and public actors for each activity; and how has it evolved over time?
d) What are the differences between countries in these respects?

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Notes

[i] This section is partly based on Edquist 2004.

[ii] Only in exceptional cases is the system closed in the sense that it has nothing to do with the rest of the world (or because it encompasses the whole world).

[iii] A more detailed discussion of the different definitions of national systems of innovations can be found in Edquist (2004).

[iv] Although there are kinds of actors other than organizations – for example individuals – the terms 'organizations' and 'actors' are used interchangeably in this chapter.

[v] The rest of this subsection is based upon Edquist (2001) and Edquist et al. (2004).

[vi] One clear example of lock-in is fossil energy (Smith, 2000). The productive system is so dependent on fossil energy that it is preventing the expansion of new forms of energy (such as solar, eolic, etc).

[vii] One may also compare existing systems with 'target systems,' that is, systems that have characteristics that are wanted by someone. Such target systems must not, however, be confused with ideal or optimal systems.

[viii] To carry out such comparisons is one of the objectives in a current project, which compares the national systems of innovation in Norway, Sweden, Finland, Denmark, the Netherlands, Ireland, Singapore, Hong Kong, Taiwan and South Korea. It will be published as Edquist & Hommen (2006).

[ix] Such capabilities are also needed to design policies that can mitigate the problems.

[x] Examples of activities are R&D as a means of the development of economically relevant knowledge that can provide a basis for innovations, or the financing of the commercialization of such knowledge, that is, its transformation into innovations. The activities in SIs are the same as the determinants of the main function. An alternative term to 'activities' could have been 'sub-functions.' We chose 'activities' in order to avoid the connotation of 'functionalism' or 'functional analysis' as practiced in

sociology, which focuses on the consequences of a phenomenon rather than on its causes, which are in focus here (Edquist, 2004).

[xi] We have broadened our analysis to include not only those contributions specifically dealing with activities in the NSI but also those that discuss the determinants of the innovation capacity or learning competences of a national system of innovation as both are relevant for the discussion on policy issues.

[xii] This work is summarized in Edquist (2004).

[xiii] These relations are addressed in Edquist (2004).

[xiv] There are also public financial support schemes to stimulate firms to perform R&D. One example is tax credits for R&D.

[xv] Another policy instrument that can be used for the same purpose is public innovation procurement.

[xvi] There is also organizational learning, the result of which is controlled or owned by firms and other organizations. Organizational learning leads to the accumulation of 'structural capital,' a knowledge-related asset controlled by firms (as distinct from 'human capital'). An example is patents. Organizations can also accumulate knowledge thanks to their ability to combine knowledge bases of individuals. Organizations have an interest in transforming individual knowledge into organizational knowledge.

[xvii] In the discussion here, we have chosen to discuss the two activities related to the demand side that were mentioned in the beginning of section 4 in one subsection. They could as well have been discussed in separate subsections.

[xviii] Paradoxically, then, a monopoly is created by law, in order to create a market for knowledge: that is, to make it possible to trade in knowledge. This has to do with the peculiar characteristics of knowledge as a product or commodity. It is hard for a buyer

to know the price of knowledge, since you do not know what it is before the transaction. (If you know what it is, you do not want to pay for it.) In addition, knowledge is not worn out when used – unlike other products.

[xix] Public innovation procurement is analysed in Edquist, Hommen & Tsipouri (2000).

[xx] Interactive learning has been studied empirically by Lundvall (1992) and Meeus & Oerlemans (2001).

[xxi] For taxonomies of institutions see Edquist & Johnson 1997.

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