

Edquist, Charles; Chaminade, Cristina

**Article**

## Industrial policy from a systems-of-innovation perspective

EIB Papers

**Provided in Cooperation with:**

European Investment Bank (EIB), Luxembourg

*Suggested Citation:* Edquist, Charles; Chaminade, Cristina (2006) : Industrial policy from a systems-of-innovation perspective, EIB Papers, ISSN 0257-7755, European Investment Bank (EIB), Luxembourg, Vol. 11, Iss. 1, pp. 108-132

This Version is available at:

<https://hdl.handle.net/10419/44862>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

## ABSTRACT

*This paper focuses on the systems-of-innovation (SI) approach and its policy implications. It introduces the topic by briefly reviewing the emergence, development, and diffusion of this approach and, then, spells out the constituents, activities, and boundaries of the SI approach. On this basis, the paper discusses the reasons for public policy intervention in the innovation process and the division of labour between private and public actors in carrying out SI activities. In this context, the paper argues that the notion of optimality is irrelevant in an innovation system context and it discusses the importance of uncertainty for innovation policy and the inevitable selectivity of such policy. A brief survey of the strengths and weaknesses of the SI approach rounds off the paper and points to avenues for future research.*

**Charles Edquist** is Professor of Innovation Studies and Director of the Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE) at Lund University. **Cristina Chaminade** is Assistant Professor of Innovation Studies at CIRCLE.



# Industrial policy from a systems-of-innovation perspective

## 1. Introduction<sup>1</sup>

The innovation concept used in this paper is wide and includes product and process innovations. Product innovations are new - or better – material goods and new intangible services. Process innovations are new ways of producing goods and services. They may be technological or organisational (Edquist *et al.* 2001).

Firms do not innovate in isolation but in continuous interaction with their environment, including the users but also other actors such as universities, suppliers, or other firms. The main focus of the systems-of-innovation (SI) approach is, therefore, the operation of the system and the complex interactions that take place among the different organisations and institutions in the system (at regional, sectoral, national, and supranational level).

The term ‘national system of innovation’ (NSI) was, in published form, first used by Freeman (1987). He defined it as “the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies” (Freeman 1987, p.1). Two major books on national systems of innovation are Lundvall (1992) and Nelson (1993), which use different approaches to the study of NSIs. Nelson (1993) emphasises empirical case studies more than theory development<sup>2</sup>, and some of the studies focus narrowly on nations’ research and development (R&D) systems. By contrast, Lundvall (1992) is more theoretically oriented and seeks to develop an alternative to the neoclassical economics tradition by placing interactive learning, user-producer interaction, and innovation at the centre of the analysis.

Lundvall argues that “the structure of production” and “the institutional set-up” are the two most important dimensions that “jointly define a system of innovation” (Lundvall 1992, p.10). In a similar way, Nelson and Rosenberg (1993) single out organisations supporting R&D, i.e., they emphasise those organisations that promote the creation and dissemination of knowledge as the main sources of innovation. Organisations disseminating knowledge include firms, industrial research laboratories, research universities, and government laboratories. Lundvall’s broader approach recognises that these narrow organisations are “embedded in a much wider socio-economic system in which political and cultural influences as well as economic policies help to determine the scale, direction and relative success of all innovative activities.” (Freeman 2002, p.195).

Both Nelson and Lundvall define national systems of innovation in terms of determinants of, or factors influencing, innovation processes.<sup>3</sup> However, they single out different determinants in their definitions of the concept, presumably reflecting their judgment about the most important



**Charles Edquist**



**Cristina Chaminade**

1 The paper builds partly on our own earlier work, particularly Edquist (2005), Chaminade and Edquist (2006a and 2006b), Edquist (2001), and Edquist (1994).

2 This emphasis is crystal clear from Nelson and Rosenberg (1993, p.4): “...the orientation of this project has been to carefully describe and compare, and try to understand, rather than to theorise first and then attempt to prove or calibrate the theory”.

3 Their definitions of NSIs do not include, for example, consequences of innovation. This does not mean that innovations emerging in innovation systems do not have tremendously important consequences for socio-economic variables such as productivity growth and employment – on the contrary. And then, distinguishing between determinants and consequences does not, of course, exclude feedback mechanisms between them.

determinants of innovation. Hence, they propose different definitions of the concept, but use the same term. This reflects the lack of a generally accepted definition of a national system of innovation.

A more general definition of (national) systems of innovation includes “all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations” (Edquist 1997, p.14). If a NSI definition does not include all factors that influence innovation processes, 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 innovation systematically and in detail. But obviously one could miss a great deal by excluding some determinants since they might prove to be very important once the state of the art has advanced. For example, 25 years ago, it would have been natural to exclude the interactions between organisations as a determinant of innovation processes. Included in this general definition are the relationships among the factors listed and the actions of both firms and governments.

There are other systems of innovation than national ones – such as sectoral, technological or regional systems. Carlsson (1995) focuses on technological systems, arguing that these are unique to technology fields. The sectoral approach of Breschi and Malerba (1997) similarly focuses on a group of firms that develops and manufactures the products of a specific sector and generates and uses the technologies of this sector. The concept of regional innovation system has been developed and used by Cooke *et al.* (1997) and Braczyk *et al.* (1998), Cooke (2001), Asheim and Isaksen (2002), and Asheim and Coenen (2005) to emphasise the interactions embedded in a certain region. Asheim and Coenen (2005), for instance, define regional innovation systems as a “constellation of industrial clusters surrounded by innovation supporting organizations”.

**National, sectoral, technological, and regional systems of innovation may all be considered variants of a single generic systems-of-innovation approach.**

The three perspectives – national, sectoral and regional - may be considered variants of a single generic systems-of-innovation approach (Edquist 1997). Much of the discussion in this paper is relevant for the generic approach, and is based on the premise that the different SI variants coexist and complement each other. Whether the most appropriate SI concept, in a certain context, should be national, sectoral, or regional depends to a large extent on the questions one wants to ask.<sup>4</sup>

The diffusion of the SI approach has been surprisingly rapid, and it is now widely used in academic circles. The approach also finds broad applications in policy contexts – by regional authorities and national governments, as well as by international organisations such as the OECD, the European Union, UNCTAD and UNIDO<sup>5</sup>. In Sweden, a public agency has even been named after the approach, i.e., the Swedish Agency for Innovation Systems (VINNOVA). The practice of VINNOVA is strongly influenced by the SI approach, an approach that appears to be especially attractive to policy makers who seek to understand differences among economies’ innovative performance, and develop ways to support technological and other kinds of innovation. In addition, managers of firms rely increasingly on the SI approach with a view to placing their companies in their context.

<sup>4</sup> It should also be mentioned that the publications cited in this section by no means exhaust the stock of literature addressing or using the SI approach. Edquist and McKelvey (2000) is a reference collection containing 42 articles on SIs.

<sup>5</sup> For a detailed discussion of the adoption of the SI approach by policy makers see Mylteka and Smith (2002)

Having introduced the gist of the systems-of-innovation approach and its diffusion, the remainder of this paper is structured as follows. The next section describes in greater detail the constituents, function, and boundaries of the SI approach and it previews the activities carried out in systems of innovations. Before turning to an in-depth presentation of such activities in Section 4, we motivate in Section 3 the role of public policy in the innovation process. We consider such innovation policy – i.e., public policy that influences innovation processes – to be the most important part of a future-oriented industrial policy. Section 5 critically assesses the strengths and weaknesses of the SI approach, and Section 6 concludes.

## **2. Constituents, function, boundaries, and activities of systems of innovation**

### **2.1 What is a system?**

In an effort to develop the SI approach, it might be useful to relate it explicitly to ‘general systems theory’, which has been used much more in natural sciences than in social sciences. In everyday language and in large parts of the scientific literature, the term ‘system’ is used generously and with limited demands for a precise definition. This being said, to the question ‘What is a system?’ everyday language and the literature give common answer, focussing on three features (Ingelstam 2002). To begin with, a system consists of two types of constituents: components and relations among them. The components and relations should form a coherent whole, which has properties different from the properties of the constituents. Second, the system has a function, i.e., it is performing or achieving something. Third, 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.<sup>6</sup> Obviously, for empirical studies of specific systems, one must know their extension.

*To develop the SI approach, it might be useful to relate it explicitly to general systems theory.*

Making the SI approach more theory-like does not require specifying all components and all relations among them. This would be too ambitious and unrealistic. At present, it is not a matter of transforming the SI approach into a general theory of innovation, but rather to make it clearer and more consistent so that it can better serve as a basis for generating hypotheses about relations between specific variables within SIs (which might be rejected or supported through empirical work). Even the much more modest objective of specifying the main (rather than all) functions of SIs, their activities and components, and the key relations among the latter would represent a considerable advance in the field of innovation studies. Used in this way, the SI approach can be helpful for developing theories about the relations between specific variables within systems of innovation. To further develop ideas, we now take a closer look at the main components of such systems.

### **2.2 Main components of SIs**

Organisations and institutions are often considered the main components of SIs, although it is not always clear what these terms mean<sup>7</sup>. For the purpose of our analysis, we define organisations as formal structures that are consciously created, have an explicit purpose, and act in the systems

<sup>6</sup> 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). Like the SI approach, general systems theory might be considered an approach rather than a theory.

<sup>7</sup> We will get back to this issue when discussing the weaknesses of the SI approach in Section 5.2.

of innovation (Edquist and Johnson 1997). Some of the important organisations in SIs are firms, universities, venture capital funds, and public agencies responsible for innovation policy, competition policy, regulation (of drugs, for instance), and so on.<sup>8</sup> And then, we define institutions as sets of common habits, norms, routines, established practices, rules, and laws that regulate the relations and interactions between individuals, groups, and organisations (Edquist and Johnson 1997). In essence, institutions defined in this way reflect the rules of the game. Examples of key institutions in SIs are patent laws and the rules and norms influencing the relations between universities and firms. Obviously, our definition of institutions and organisations is 'Northian' in character (North 1990), discriminating between the rules of the game and the players in the game.

***Organisations and institutions are likely to differ across real-world systems of innovations.***

Organisations and institutions are likely to differ across real-world SIs. To illustrate this, first, for organisations: in one country (e.g., Japan), research institutes and company-based research departments might be important players in carrying out R&D, whereas research universities might largely play this role in another country (e.g., the United States). Likewise, in some countries, such as Sweden, most research is carried out in universities, while the independent public research institutes are weak; by contrast, in Germany, for instance, the latter are much more important. That the organisational set-up varies considerably among national systems of innovation is shown in profiles of the national systems in Austria, Belgium, Finland, Germany, Spain, Sweden, Switzerland, and the United Kingdom, presented in OECD (1999a).

Turning to institutions, they also differ considerably among national systems. For example, patent laws are different across countries. In the United States, for instance, an inventor can publish before patenting, whereas this is not possible according to European laws. And then, in Sweden, university teachers own their patents outright, thanks to the so-called 'university teachers privilege'. However, this is not the case in the United States. In Denmark and Germany, new laws have recently transferred patent ownership from teachers to the universities where they work, while in Italy and Australia a transfer in the opposite direction has occurred. Many OECD governments are currently experimenting with changes in the ownership of knowledge created in universities, hoping that such changes will influence the propensity to patent and accelerate the commercialisation of economically useful knowledge.

In summary, there seems to be general agreement that the main components in SIs are institutions and organisations – among which firms are often considered to be the most important organisations. However, the specific set-ups of institutions and organisations vary among systems.

### **2.3 Activities in SIs that influence the innovation processes**

One way of analysing SIs is to focus not only on its constituents, but also 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 here on, call 'activities' in SIs are those factors that influence the development and diffusion of innovations. In this sense, we use the term activities as equivalent to determinants of the innovation process. Although a system is normally considered to have a function, this function and the activities

---

<sup>8</sup> Although there are actors other than organisations – e.g., individuals – the terms organisations and actors (or players) are used interchangeably in this paper.

influencing it were not addressed in a systematic manner in the early work on SIs. From the late 1990s, some contributions addressed these issues (Galli and Teubal 1997, Johnson and Jacobsson 2003, Liu and White 2001, Rickne 2000). As we have argued elsewhere (Chaminade and Edquist 2006a), one can broadly distinguish four approaches that researchers have taken in analysing activities in SIs.

To start with, Edquist 2005, Furman *et al.* (2002) and – though to a lesser extent – Liu and White (2001) focus on activities linked to the innovation process as such, that is, activities needed to turn an idea into a new product or process. The second line of research, represented by the work of David and Foray (1995) and Johnson and Jacobsson (2003) concentrates on activities linked to the knowledge production process, that is, the way knowledge is created, transferred, and exploited. Here there is a strong emphasis on the channels and mechanisms for knowledge distribution. Third, some researchers (Borrás 2004, for example) try to identify the activities of different organisations that have an impact in the innovation system. Finally, for another line of research, innovation policy is the focal point. The main question pursued is which activities (and organisations) in the innovation system can be stimulated by public intervention. The OECD (2002a) and other international organisations follow this approach.

Clearly, there is no consensus as to which activities should be included in a system of innovation and this provides abundant opportunities for further research. We believe that it is important to study the activities of SIs in a systematic manner. Box 1 presents a list of ten priority activities worth studying. The list of activities – structured along four themes – is based on the literature (reflecting the research approaches mentioned above) and on our own knowledge about innovation processes and their determinants: (i) the provision of knowledge inputs to the innovation process, (ii) demand-side activities, the (iii) provision of constituents of SIs, and (iv) support services for innovating firms.

This list is provisional and will be subject to revision as our knowledge about determinants of innovation processes increases. In addition to a set of activities that is likely to be important in most SIs, there are activities that are very important in some types of SIs and less important in others. For example, the creation of technical standards is critically important in some (sectoral) systems, such as mobile telecommunications.<sup>9</sup>

The systematic approach to SIs suggested here does not imply that they are or can be consciously designed or planned. On the contrary, just as innovation processes are evolutionary, SIs evolve over time in a largely unplanned manner. Even if we knew all the determinants of innovations processes in detail (which we certainly do not now, and perhaps never will), we would not be able to control them and design or ‘build’ SIs on the basis of this knowledge. Centralised control over SIs is impossible and innovation policy can only influence the spontaneous development of SIs to a limited extent.

***Systems of innovation cannot be consciously designed or planned but are evolutionary, evolving over time in a largely unplanned manner.***

In Section 4, we will take a much closer look at the activities set out in Box 1, notably the government’s role in different activities in the system of innovation. But let us first see how to motivate government intervention in a systems-of-innovation approach.

---

<sup>9</sup> The activities in this sectoral system are discussed in Edquist (2003).

## **Box 1. Key activities in systems of innovation**

### **I. Provision of knowledge inputs to the innovation process**

1. Provision of R&D and, thus, creating new knowledge, primarily in engineering, medicine and natural sciences.
2. Competence building: educating and training the labour force for innovation and R&D activities.

### **II. Demand-side activities**

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 SI's**

5. Creating and changing organisations needed for developing new fields of innovation. Examples include enhancing entrepreneurship to create new firms and intrapreneurship to diversify existing firms; and creating new research organisations, policy agencies, and so on.
6. Networking through markets and other mechanisms, including interactive learning between different organisations (potentially) involved in 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.
7. Creating and changing institutions – e.g., patent laws, tax laws, environment and safety regulations, R&D investment routines, etc. – that influence innovating organisations and innovation processes by providing incentives for and removing obstacles to innovation.

### **IV. Support services for innovating firms**

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

Source: Edquist (2005)



### 3. Public policy intervention in the innovation process

#### 3.1 A framework for analysis: the importance of systemic failures and the irrelevance of the market-failure benchmark

The main focus of the SI approach is the complex interactions that take place among the different organisations and institutions in the system. Policy makers need to intervene in those areas where the system is not functioning well. Policy rationale is based on ‘systemic’ failures or problems rather than on ‘market’ failure (Chaminade and Edquist 2006b).

Market failure in mainstream economic theory implies a comparison between conditions in the real world and an ideal or optimal economic system. However, innovation processes are path dependent over time, and it is not clear which path will be taken as they have evolutionary characteristics. We do not know whether the potentially optimal path is being exploited. What is more, the system never achieves equilibrium, and the notion of optimality is irrelevant in an innovation context. It follows that we cannot specify an ideal or optimal system of innovation and, therefore, comparisons between an existing system and an optimal system are not possible; as a corollary, it is not meaningful to talk about optimal policies. Thereby, the notion of market failure loses its meaning and applicability. Instead we talk about systemic problems.<sup>10</sup> Systemic problems mentioned in the literature include (Smith 2000 and Woolthuis *et al.* 2005):

***One cannot specify an ideal or optimal system of innovation and, therefore, comparisons between an existing system and an optimal system are not possible.***

- Infrastructure problems, including the physical infrastructure (for example, telecoms and transport) and the scientific infrastructure (such as high-quality universities and research laboratories, technical institutes, and so on);
- 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;
- Capability problems (which are linked to transition problems), i.e., limited capabilities of firms (especially small and medium-sized enterprises), which might limit their capacity to adopt or produce new technologies over time;
- Lock-in problems, derived from the socio-technological inertia, that might hamper the emergence and dissemination of more efficient technologies;<sup>11</sup>
- Hard and soft institutional problems, linked to formal rules (regulations and laws, for example) and more tacit ones (such as social and political culture);
- Network problems, which include problems derived from linkages being too weak or too strong (blindness to what happens outside the network) in the SI.

One way of approaching the criteria for innovation policy intervention is the following. In a modern society, capitalist firms and the market mechanism best fulfil many economic tasks. The market mechanism evaluates and coordinates the behaviour of private and public actors – often in a

<sup>10</sup> This means that we decrease the degree of rigour and formality. We speak about a ‘problem’ on an empirical basis and in a pragmatic way – not referring to a formal model.

<sup>11</sup> 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, wind energy, etc).

smooth and flexible manner. This concerns the production of most goods and services. However, sometimes there are reasons for public intervention to complement markets and private firms. This is true in the areas of law, education, environment, infrastructure, social security, income distribution, research, radical innovations, and so on. In some of these areas, there is no market mechanism operating at all, and the activities are fulfilled through other mechanisms, regulation by institutions, for instance. In others, the market mechanism does not lead to the fulfilment of the objectives established by the government.

**There are two main conditions for public policy intervention in the innovation process of a market economy: policy opportunity and policy competence.**

The key question is thus: which tasks should be performed by the state or the public sector? This question can – and should – be discussed in an analytical way, although ideological judgement will obviously play a role too. Taking an analytical approach, there are two main conditions for public policy intervention in the innovation process of a market economy. One is that capitalist firms and the market mechanism must fail in achieving the objectives formulated. In other words, a problem not spontaneously solved by private actors and market forces must exist (we call this policy opportunity). The second condition is that the state (national, regional, local) and its public agencies must have, or be able to build up, an ability to solve or mitigate the problem (we call this policy competences).

Provided that there is a policy opportunity and the state has the policy competence, there are two main categories of policies to solve or mitigate problems.

First, the state may use non-market mechanisms, which is mainly a matter of using regulation instead of the market mechanisms of supply and demand. One example is a subsidy to a poor region. The state might also provide educational services free of charge or at a subsidised cost. Other kinds of regulation – particularly related to innovation activities – are the creation of technical standards, subsidies in support of private firms' R&D, or tax incentives to R&D and other innovation activities.

Second, through various public actions, the operation of markets can be improved or the state might create markets. Improving the operation of markets is the objective of competition law and competition (anti-trust) policies. It is often a matter of increasing the degree of competition in a market. This might sometimes be achieved through deregulation, i.e., getting rid of old or obsolete regulations. Policy makers can also enhance the creation of markets by supporting legal security or the formation of trust. Another example is innovation support through public procurement. This is when a public agency places an order for a product or a system that does not yet exist and, thus, an element of innovation is required to deliver it.

One difficulty in this context is, of course, that it is not possible to know for sure *ex ante* if public intervention can solve the problem.<sup>12</sup> The decision to intervene or not must then depend on how likely intervention is to mitigate the problem. Hence, the decision must be taken in a situation of uncertainty. Then one can afterwards – *ex post* – evaluate whether the problem was solved or mitigated. If this was not the case, we are talking about a policy failure or a failed policy. In other words, policy failures can never be completely avoided because of the uncertainty mentioned. We must accept mistakes in public activity – as we do in private activities. Moreover, to determine the success or failure of a given policy intervention, it is crucial that the policy objectives were clearly formulated *ex ante*.

---

<sup>12</sup> This is especially the case with innovation. Here, by definition, it is highly unlikely that there will be any clear-cut precedents for the problem to be solved.

There may be two reasons why public intervention cannot solve or mitigate a problem. One is that the problem cannot be solved at all – neither by the market mechanism and private actors nor by public intervention and, thus, all types of intervention would be in vain. The other reason is that the state might first need to develop its ability to solve the problem. A detailed analysis of the underlying problem and its causes, involving a detailed empirical comparison for instance, might be a necessary means of acquiring this ability. Moreover, the creation of new organisations and institutions to carry out the intervention might be necessary, for instance a new research organisation or a patent office, the latter possibly operating on the basis of reformed patent laws. In addition, in analysing the problem at hand, it might turn out that new policy instruments are needed, such as tax breaks for R&D spending.

It is important to note that problems motivating public intervention might concern the future. In fact, the ‘problem’ might not yet have emerged, and a policy addressing this type of situation might be called an opportunity-creating or anticipatory policy. To illustrate, uncertainty might stifle firms’ incentives and thus prevent new technologies from emerging. In these circumstances, public funding of basic R&D, for example, might be helping the search for such technologies. Another example is that training people and stimulating research in public organisations in a certain field could create new opportunities that would not be realised without policy.

***Problems motivating public intervention might concern the future, and a policy addressing this type of situation might be called an anticipatory policy.***

All in all, the discussion of policy intervention raises two issues that are worth pursuing in greater detail. For one thing, policy intervention is especially needed when uncertainty and risk are very high and private actors have insufficient incentives to invest in high-risk products and processes. For another, policy intervention needs to be selective, focusing on specific products, processes, or technologies that better fulfil the objectives (economic, social, environmental, etc.) of the government. These issues of uncertainty and selectivity will be discussed next.

### **3.2 Uncertainty**

When uncertainty and risk are high, the danger that markets underperform relative to government objectives is particularly big. For example, private actors might underinvest in basic R&D (Arrow 1962) or they might not invest at all in activities of great social return but low individual return (e.g., some drugs). High uncertainty might also prevent the emergence of innovations. In the very early stages of developing new fields of innovation there is uncertainty about whether there will be a market for the new product. In these circumstances, public organisations have sometimes been instrumental in market creation, directly – through public technology procurement for instance – or indirectly. In recent decades, government support has also come in the form of ‘incubating activities’ carried out by public or semi-public science parks to facilitate commercialisation of knowledge.

In fact, uncertainty plagues innovation as such, and it is of particular concern for innovation in new fields of production. Historically we have also seen that a minor public intervention in an early stage of an innovation process may have a very large impact. The public support to the development of the Nordic Mobile Telephony Standard (NMT 450) is an example, with the support amounting to a few hundred man-years. But there are also examples of major public efforts in a mature stage of product development having only a small impact. A case in point is the massive support to the Swedish shipyard industry in the 1970-80s, which did not show any long-term impact although it amounted to around ½ percent of GDP over a period of ten years.

Empirical evidence also suggests that large-scale and radical technological shifts rarely take place without public intervention (as opposed to incremental innovations in established sectors).

Carlsson and Jacobsson (1997) have shown this for technological breakthroughs in electronics, semiconductors, and genetic engineering in the United States and Sweden. Mowery (2005) has shown that publicly funded R&D in combination with public technology procurement has played a crucial role in developing new high-tech sectoral systems of innovation in the United States (and thereby in the world). Examples include the early phases of developing numerically-controlled machine tools, commercial aircraft, semiconductors, computer hardware and software, and the internet. Overall, Mowery concludes that government innovation support to new products and sectors has been very strong in the United States.

Before moving on, it is useful to point out that the general conclusion is that innovation involves a high degree of uncertainty and risk. And the higher the uncertainty, the lower are private actors' incentives to invest in certain new activities and the stronger is the motivation for public intervention. This raises a crucial question, hotly debated among scholars and policy makers: are governments better than firms at determining which new activities should be funded? This takes us to the issue of selectivity in innovation policy.

### 3.3 Selectivity

***As innovation policies address certain systemic problems, they cannot be neutral but are necessarily selective.***

We have argued that innovation policies should focus on solving or mitigating certain systemic problems. Obviously, to solve a problem, policies have to target exactly this problem, implying that policies cannot be neutral but are necessarily selective. An example indicating the selectivity of innovation policy is public R&D spending. Impartial analysis might suggest that spending should be reallocated from, say, R&D in information technologies to R&D in biotechnology. As innocuous as it may appear at first sight, re-prioritising public R&D spending is selective since it favours one sector (or firm) at the expense of others. And then, the analysis might show that, say, pharmaceutical firms spend too little on developing drugs with a potentially large positive social impact (e.g., a drug to cure malaria) but invest heavily in privately more profitable drugs – Viagra for instance. The government might decide to allocate funds to research in socially more valuable drugs, but in doing this its innovation policy is clearly selective.

Nevertheless, the design of innovation policy, notably its objective (where to intervene and with which purpose) and instruments (how to intervene), should rest on impartial, professional analyses. In practice, however, policies are not shaped by such analyses alone but also by ideology, the influence of lobbying groups, or simply the imitation of existing policy models. Imitation refers to the tendency to copy policies that have been successful elsewhere without proper adaptation to the circumstances in the new environment. Lobbyism refers to the pressure exerted by special interests groups in the design of innovation policy, trying to favour specific firms or sectors, the car, shipbuilding, and information and communication industries – to name just a few potential recipients of support.

We argue that the selection of objectives and instruments has to be the result of an analysis of the system, its activities and the division of labour between private and public actors. Irrespective of whether innovation policy largely reflects lobbyism (which is common) or analysis of the kind proposed by us (which is rare), the resulting policy is selective rather than neutral. There are reasons to limit the degree of selectivity – and maybe accept it only for sectors and products in very early stages of their development. However, this must be analysed in more depth. Then a distinction needs to be made between selectivity with regard to sectors, products, activities, and firms. In the next section, we will discuss the government's role in different activities of the system of innovation.

In general, we will argue that government support is most needed when uncertainty and risk are high and the likelihood is thus great that the private sector will not act, thereby neglecting socially valuable innovation opportunities. Whether this support to new activities and products should be limited to new sectors or the radical transformation of more traditional sectors (such as helping the car industry to develop engines running on renewable fuels) is still subject to a hot debate among scholars – including the authors of this paper.

#### **4. Activities in SIs from a policy perspective**

In this contribution 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. Organisations 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. However, we believe that understanding the dynamics of each of these activities and the division of labour between public and private actors in performing them can be a useful departure point for discussing the role of the government in stimulating innovation processes. We will therefore now discuss the ten activities introduced in Box 1 from a policy point of view, pointing out the role of public agencies influencing or directly carrying out these activities.

##### **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 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 – in some countries – also to more applied kinds of R&D. This publicly performed R&D is carried out in universities and other public research organisations. NSIs can differ significantly with regard to the balance between these two kinds of organisations in the provision of R&D. In Sweden, less than 5 percent of all R&D is carried out in public research organisations. In Norway, this figure is more than 20 percent. In 1999, the proportion of all firm-financed R&D in the OECD countries ranged from 21 percent in Portugal to 72 percent in Japan (OECD 2002b).

Such data may be a way of distinguishing 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 organisations. Most of these countries are poor or medium-income countries. The few countries that spend a lot on R&D are rich, and much of their R&D is carried out by private organisations. This includes some large countries such as the United States and Japan, but also some small and medium-sized countries such as Sweden, Switzerland, and South Korea.

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 materialise and the generation of diversity may be reduced or blocked. In such situations, governments may favour experimentation and use R&D subsidies and public innovation procurement, for instance, to support possible alternatives to the winning technologies (Edquist *et al.* 2004).

***Path-breaking innovations result from R&D activity often partly financed and carried out by public agencies.***

In sum, public organisations can influence R&D activity in different ways, ranging from allocating funds for specific research activities in 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 for individuals and organisations. Here we follow the definition of Lundvall *et al.* (2002, p. 224) 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".

***In most countries, the education and training that is important for innovation processes is primarily provided by public organisations.***

In most countries, the education and training that is important for innovation processes (and R&D) is primarily provided by public organisations – schools, universities, training institutes, and so on. However, some competence building is done by firms through learning-by-doing, learning-by-using, and learning-by-interacting. Competence building increases the human capital of individuals: that is, it is a matter of individual learning, the result of which is controlled by individuals.<sup>13</sup>

The organisational 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 policy makers lack good comparative measures on the scope and structure of such differences. There is little systematic knowledge about the ways in which the organisation of education and training influences the development and diffusion of innovations. Since labour, including skilled labour, is the least mobile production factor, domestic systems for competence building remain among the most enduringly national elements of NSIs.

Competence building should not be limited to human capital. Organisations have competences that exceed those of the employees. Human capital is hired by the company but is always owned by individuals. However, there are ways by which the firm can capture individual knowledge and transform it into organisational knowledge. Organising the processes of knowledge creation and learning within the firm and in networks is part of the competence-building activity. Scholars have started only very recently to analyse such processes, and many questions remain unanswered (Chaminade 2003, Edvinsson and Malone 1997, Guthrie and Petty 2000, Nooteboom 2004, Sanchez *et al.* 2000).

The role of the government in the timely provision of qualified human resources is clear, although the proper division of labour between private and public actors continues to be debated. However, the situation is very different with regard to components of competence building such as knowledge and learning dynamics. We know very little about knowledge dynamics in firms and networks. Evidence is based on cases, but they can seldom be compared and, thus, the evidence cannot

<sup>13</sup> There is also organisational learning, the result of which is controlled or owned by firms and other organisations. Organisational learning leads to the accumulation of 'structural capital', a knowledge-related asset controlled by firms (as distinct from 'human capital'). An example is a patent. Organisations can also accumulate knowledge thanks to their ability to combine knowledge of individuals. Organisations have an interest in transforming individual knowledge into organisational knowledge.

be generalised. Little can be said about the role of government in supporting these processes, although some attempts have been made (European Commission 2003, OECD 1999). It remains an issue to be further developed.

## **4.2 Demand-side activities**

### **4.2.1 Formation of new product markets**

The government might need to intervene in the market for two main reasons: a market for certain goods and services might not exist yet or the users of goods and services might not be sophisticated enough to provide the required feedback to the producers with regard to new needs.

In the very early stages of the development of new fields of innovation there is uncertainty whether a market exists. A telling example was the belief in the 1950s that the total computer market amounted to four or six computers. Eventually markets develop spontaneously.

One example of market creation is in the area of inventions. The creation of intellectual property rights through patents gives a temporary monopoly to the patent owner. This makes selling and buying of technical knowledge easier.<sup>14</sup> Policy makers 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 NMT 450 mobile telecom standard created by the Nordic telecommunication offices 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.<sup>15</sup> In other words, a market emerged because the public sector demanded products and systems that did not exist before the public innovation procurement. This has been – and still is – an important instrument in the defence sector in all countries. It has also been important in infrastructure development (telecoms, trains, etc.) in many countries. Public policy may also influence demand – and thereby diffusion of innovations – when public agencies require a certain product mix, such as a minimum share of electricity based on renewable resources or of cars powered by fuel cells.

### **4.2.2 Articulation of quality requirements**

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, enhancing innovation and steering 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. However, 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

***Examples of public support to market creation include the establishment of technical standards and public innovation procurement.***

<sup>14</sup> Paradoxically, then, a monopoly is created by law in order to create a market for knowledge: that is, to make trade in knowledge possible.

<sup>15</sup> Edquist and Hommen (2000) analyse public innovation procurement in more detail.

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 labour between public and private actors.

#### 4.3.1 Creation and change of organisations

As pointed out above, organisations are considered key components in systems of innovation. Entry and exit of organisations, as well as change of incumbent organisations, are therefore important activities contributing to the change of systems of innovation as such. Organisations include not only firms, but also universities, business services, research institutes, financing bodies, and so on. But since firms are ultimately responsible for commercialising new products, and as there is only so much one can say in one paper, we will focus here on the creation and change of firms.

Creation and change of organisations 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 organisations and innovation policy agencies can also be created through political decisions.

***An important role of policy is to enhance the entry and survival of new firms by facilitating and supporting entrepreneurship.***

One important role of policy is to enhance the entry and survival of new firms by facilitating and supporting entrepreneurship. Compared to incumbents, new entrants are characterised 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 favourable 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.

Enhancing entrepreneurship and intrapreneurship is a way of supporting changes in the production structure in the direction of new products. There are three mechanisms by which the production structure can change through the addition of new products: existing firms might diversify into new products (as has happened often in Japan and South Korea, for example); new firms in innovative product areas might grow rapidly (as many have in the United States, for example); foreign firms might invest in new product areas in a country (Ireland, for example).

Adding new products to an 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 characterised by high productivity growth. Governments should therefore create opportunities and incentives for changes in the production structure. Policy issues in this context are how policy makers can help develop alternative patterns of learning and innovation and nurture emerging sectoral systems of innovation.

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



ongoing transformation of Central and Eastern Europe. Hence, organisational 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

As we have pointed out, relations among SI components (i.e., organisations like firms, universities, public agencies and institutions such as established practices, rules, and laws) are a basic component (constituent) of systems of innovation. Relations facilitate interactive learning which in turn is the basis for innovation. 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 organisations through complex relations that are often characterised 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 learning and innovation implies that this interaction should be targeted much more directly than is normally the case in innovation policy today.<sup>16</sup> Innovation policy should not only focus on the organisations of the systems, but also – and perhaps primarily – on the relations among them. Relations between organisations might occur through markets but also through other mechanisms. This implies integrating new knowledge developed in different spheres of the SI and coming from outside with knowledge already available in the innovating firms.

***The interactive nature of learning and innovation implies that this interaction should be targeted much more directly than is normally the case in innovation policy today.***

Most interaction between organisations 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 organisations are also involved. The long-term innovative performance of firms in science-based industries strongly depends on interactions between firms, universities, and research facilities. If they are not spontaneously operating smoothly enough, these interactions should be facilitated through policy. Here formal institutions are important, as we will see in the next sub-section.

The relations between universities and public research institutes, on the one hand, and firms on the other are coordinated only to a limited degree by markets. Policies help coordinate relations in different ways and to different degrees, reflecting differences across NSIs – but sometimes they are not coordinated at all. Incubators, technology parks, and public venture capital funds (discussed in sub-section 4.4) might also help in similar ways. This means that the public sector might create organisations to facilitate innovation. At the same time, however, it might create the rules and laws that govern these organisations and their relations to private ones – that is, create institutions (Edquist *et al.* 2004).

#### 4.3.3 Creation and change of institutions

Institutions are normally considered the second main component (in addition to organisations) in SIs. Creating, demolishing, and changing institutions are activities crucial to the maintenance of SIs' dynamism. Important institutions in systems of innovation are intellectual-property-rights (IPR) laws, technical standards, tax laws, environment and safety regulations, R&D investment

<sup>16</sup> Interactive learning has been studied empirically by Lundvall (1992) and Meeus and Oerlemans (2001).

routines, firm-specific rules and norms, and many more. They influence innovating organisations and innovation processes by providing incentives or obstacles for organisations and individuals to innovate. Many institutions are publicly created (such as laws and regulations) and therefore easy to modify by governments. However, others are created by private organisations, such as firm routines, and they are much more difficult to influence by government intervention.

IPR laws are considered important as a means of creating incentives to invest in knowledge creation and innovation (and, as argued above, they create markets). Tax laws are also often considered to influence innovation processes. An important question here is which kinds (and levels) of taxes hinder or facilitate innovation and entrepreneurship.

We have already mentioned the important role of institutions in facilitating the interaction between organisations in the previous sub-section. Governments may, for example, support collaborative centres and programmes, remove barriers to cooperation, and facilitate the mobility of skilled personnel between different organisations. 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). There are also institutions that influence firms and others that operate inside firms (for taxonomies of institutions see Edquist and Johnson 1997).

**Key policy questions are whether existing institutions are appropriate for promoting innovation and how institutions should be changed or engineered to induce innovation.**

Some institutions are created by public agencies. They are often codified and constitute policy instruments (such as the aforementioned IPR laws). 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. But not all institutions are created by public agencies. Other institutions develop spontaneously over history without public involvement, such as culture, norms, routines, and so on.

As in the case of organisations, it is important 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 and in the ongoing transformation of Central and Eastern Europe. Hence, institutional (as well as organisational) changes are particularly important in situations of rapid structural change.

## **4.4 Support services for innovating firms**

### **4.4.1 Incubation**

Incubating activities include the provision of access to facilities and administrative support for new innovating efforts. In recent decades, incubating activities have been carried out in science parks to facilitate commercialisation of knowledge. That this activity has become partly public has to do with the uncertainty characterising early stages of product development, which means that markets do not operate well in this respect. Also very recently, universities have started their own incubating activities to commercialise the results of their research activities.

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 crucial for turning knowledge into commercially successful innovations and to facilitate their diffusion. Finance comes primarily from private actors within innovating firms, stock exchanges, venture capital funds, or individuals ('business angels'). However, in many countries – including the United States – public agencies provide finance, for instance in the form of seed capital in support of innovation activities.

***Financing of innovation processes is crucial for turning knowledge into commercially successful innovations and to facilitate their diffusion.***

As with public intervention in general, public funds should only come forward 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 Consultancy services

We finally arrive at the tenth SI activity included in the list of Box 1, that is, the provision of consultancy services for innovation processes. Worth mentioning here are consultancy services related to the transfer of technology, commercial information, and legal questions. They are primarily offered by private organisations (such as specialised consultancy firms or entrepreneurial associations), and they can be instrumental when innovations result from diversification processes and when new firms are established around innovations.

But there are cases (certain SMEs and mature sectors, for example) where public authorities also provide consultancy services, either directly or by acting as brokers between firms and service providers. As an example one may mention regional public agencies, which provide, among other things, information to local SMEs on market opportunities, new technology developments, and partnership opportunities.

### 5. Strengths and weaknesses of the SI approach to innovation policy

#### 5.1 Strengths of the SI approach

**The SI approach focuses on innovation and learning processes.** The emphasis on learning acknowledges that innovation is a matter of producing new knowledge or combining existing (and sometimes new) elements of knowledge in new ways. This focus distinguishes the SI approach from other approaches that regard technological change and other innovations as exogenous.

**The SI approach adopts a holistic and interdisciplinary perspective.** It is holistic in the sense that it tries to encompass a wide array – or all – of the important determinants of innovation, and allows for the inclusion of organisational, social, and political factors, as well as economic ones. It is interdisciplinary in the sense that it absorbs perspectives from different (social science) disciplines, including economic history, economics, sociology, regional studies, and other fields.

**The SI approach employs historical and evolutionary perspectives,** which makes the notion of optimality irrelevant. Processes of innovation develop over time and involve the influence of

many factors and feedback processes, and they can be characterised as evolutionary. Therefore, an optimal or ideal system of innovation cannot be specified.<sup>17</sup> Comparisons can be made between different real systems (over time and space), and between real systems and target systems, but not between real systems and optimal ones. Although this is a complex view of the innovation process, it is far richer and more realistic than its alternatives.

***The strength of the SI approach is its emphasis on innovation and learning processes, interdisciplinary and evolutionary perspectives, interdependence and non-linearity, product and process innovations, and on the role of institutions.***

**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 organisations through complex relations that are often characterised 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 SI approach can encompass product and process innovations** as well as sub-categories of these types of innovation. Traditionally, innovation studies have, to a large extent, focused on technological process innovations and to some extent on product innovations, but less on non-technological and intangible ones, i.e., service product innovations and organisational process innovations. There are good reasons to use a comprehensive innovation concept, and the systems-of-innovation approach is well suited to this comprehensive perspective since all categories of innovations specified in this paper can be analysed within this concept. That non-technological forms of innovation deserve more attention is also argued in OECD (2002a).

**The SI approach emphasises the role of institutions.** Practically all specifications of the SI concept highlight the role of institutions rather than ignoring them as determinants of innovation. This is important since institutions strongly influence innovation processes. There is, however, no agreement about what the term 'institutions' means (see section 2.3).

These six characteristics are often considered to be strengths of the SI approach by academic analysts, policy makers, and – increasingly – by firm strategists, and partly explain its rapid diffusion. However, the SI approach also has weaknesses, which represent challenges for future research on systems of innovation.

## **5.2 Weaknesses of the SI approach**

The SI approach is still associated with conceptual diffuseness. One example is the term 'institution', which is used in different senses by different authors. It is sometimes used to refer to organisational actors and institutional rules. Sometimes the term means different kinds of organisations or 'players' (according to the definitions in section 2.2). At other times, the term means laws, rules, routines, and other 'rules of the game'. For Nelson and Rosenberg (1993), institutions mean basically different kinds of organisations, and for Lundvall (1992) it means primarily the rules of the game.

Another example of conceptual diffuseness is that the originators of the SI approach did not indicate what exactly should be included in a (national) system of innovation; they did not specify the boundaries of the systems (Edquist 1997). Nelson and Rosenberg (1993) provided no sharp guide to just what should be included in the innovation system, and what can be left out. Lundvall insisted that "a definition of the system of innovation must be kept open and flexible" (Lundvall 1992, p.13).

<sup>17</sup> Since we cannot describe an optimal system, it is also more relevant to talk about 'good practice' or 'relatively good practice' than about 'best practice'.

The SI approach has also been criticised for not being able to establish clear linkages with the microeconomic level. Although the SI approach acknowledges the role of the different organisations in the system, the focus of the approach is the system itself and the interactions between the different actors in the production, use, and diffusion of innovations.

With regard to the status of the SI approach, it is certainly not a formal theory in the sense of providing specific propositions regarding causal relations among variables. It can be used to formulate conjectures for empirical testing, but this has been done only to a limited degree. Because of the relative absence of well-established empirical regularities, 'systems of innovations' should be labelled an approach or a conceptual framework rather than a theory (Edquist 1997).

***Weaknesses of the SI approach include conceptual diffuseness and relative absence of well-established empirical regularities.***

Scholars disagree on the seriousness of these weaknesses of the SI approach and on how they should be addressed. According to some, the approach should not be made too rigorous; the concept should not be 'over-theorised' and it should remain an inductive one.<sup>18</sup> Another position argues that the SI approach is 'under-theorised', that conceptual clarity should be increased and that the approach should be made more 'theory-like'. Such a view has, for example, been expressed by the OECD: "There are still concerns in the policy making community that the NIS approach has too little operational value and is difficult to implement" (OECD 2002a). Fischer (2001) expresses similar concerns.

All told, scholars of systems of innovation continue to debate the importance of the weaknesses of the SI approach. One of the goals of this paper has been to increase the rigor and specificity of the SI approach by unfolding the role of public and private organisations in different activities of the system of innovation.

## **6. Conclusions**

This paper has placed great emphasis on the rationales for public policy intervention in the innovation process and the activities in systems of innovation, and we have elaborated on ten such activities. However, this emphasis does not mean that we can neglect the components of SIs and the relations among them. Organisations 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 organisations performing the activities and see that there is not a one-to-one relation between them, but that a certain kind of organisation can perform more than one activity and that many activities can be carried out by more than one category of organisation.

A similar exercise can be carried out for innovation policy: we can analyse the division of labour between private and public organisations with regard to the performance of each of the activities in innovation systems and whether this division of labour is justified or not. The criteria for policy intervention proposed here are, first, that a systemic problem not spontaneously solved by private actors and market forces exists (i.e., firms and markets fail to achieve the public policy objectives) and, second, that the public agencies must have the ability to solve or mitigate the problem.

---

18 See Lundvall *et al.* (2002) and Lundvall (2003), where it is argued that the pragmatic and flexible character of the concept might be a great advantage. However, Lundvall *et al.* (2002) also argue that efforts should be made to give the concept a stronger theoretical foundation.

The policy discussion at each point should focus on changes in the division of labour between the private and the public spheres and on 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 organisations are not the least important!

In addition to these general conclusions, some specific conclusions follow from our discussion. To start with, an optimal or ideal system of innovation cannot be specified and, therefore, the notion of optimality is irrelevant in the context of the systems of innovation approach. This implies that the notion of 'market failure' loses its meaning and applicability and that an awareness and identification of 'systemic problems' provide a much more meaningful orientation for policy making. Along similar lines, we argued that comparisons cannot be made between real and optimal systems, but only among different real systems (over time and space). Another key insight is that innovation policy normally is and should be selective. The selection should be made on the basis of a rigorous analysis of the system of innovation and not as a result of pure lobbyism. We have argued in favour of prioritising those areas where there is a greater degree of uncertainty and risk (which includes the emergence of new sectors and new products but also new innovations in established sectors) or where the collective returns might be very large.

## References

- Arrow, K. (1962). "Economic welfare and the allocation of resources for invention", in R. Nelson (ed.), *The rate and direction of inventive activity*. Princeton University Press, Princeton, New Jersey, USA.
- Asheim, B. and L. Coenen (2005). "Knowledge bases and regional innovation systems: Comparing Nordic clusters". *Research Policy*, 34(8), 1173-1190.
- Asheim, B. and Isaksen, A. (2002). "Regional innovation systems: The integration of local 'sticky' and global 'ubiquitous' knowledge". *Journal of Technology Transfer*, (27), pp. 77-86.
- Braczyk, H-J., Cooke, P., and Heidenreich, M. (1998). *Regional innovation systems: the role of governance in a globalised world*. UCL, London and Pennsylvania.
- Borrás, S. (2004). "System of innovation: Theory and the European Union". *Science and Public Policy*, (31:6), pp. 425-43.
- Breschi, S. and Malerba, F. (1997). "Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries", in Edquist, C. (ed.), *Systems of innovation: Technologies, institutions and organizations*, Pinter/Cassell Academic, London and Washington.
- Carlsson, B. (1995). *Technological systems and economic performance: The case of factory automation*, Kluwer, Dordrecht, Netherlands.
- Carlsson, B. and Jacobsson, S. (1997). "Diversity creation and technological systems: A technology policy perspective", in Edquist, C. (ed.), *Systems of innovation: Technologies, institutions and organizations*, Pinter/Cassell Academic, London and Washington.
- Chaminade, C. (2003). "How IC management can make your company more innovative", in *How to develop and monitor you company's intellectual capital*, Nordic Industrial Fund, Oslo, Norway.
- Chaminade, C. and Edquist, C. (2006a, forthcoming). "From theory to practice. The use of the systems of innovation approach in innovation policy". CIRCLE Discussion Paper Series. (Forthcoming in *Innovation, learning and institutions*, Oxford University Press, Oxford, UK).
- Chaminade, C. and Edquist, C. (2006b). "Rationales for public policy intervention in the innovation process: a system of innovation approach". Paper presented in the International Conference 'Innovation pressure. Rethinking competitiveness, policy and the society in a globalized world'. Tampere, Finland. March 2006.
- Cooke, P., Gomez Uranga, M., and Etxebarria, G. (1997). "Regional systems of innovation: Institutional and organisational dimensions". *Research Policy*, (26), pp. 475-491.
- Cooke, P. (2001). "Regional innovation systems, clusters, and the knowledge economy". *Industrial and Corporate Change*, (10:4), pp. 945-974.
- David, P. and Foray, D. (1995). Interactions in knowledge systems: Foundations, policy implications and empirical methods. *STI Review*, (16), pp. 14-68.

- Edquist, C. (1994). Technology policy: The interaction between governments and markets, in Aichholzer, G. and Schienstock, G. (eds.), *Technology Policy: Towards an integration of social and ecological concerns*, Walter de Gruiter, New York, USA.
- Edquist, C. (1997). "Systems of innovation approaches - Their emergence and characteristics", in Edquist, C. (ed.), *Systems of innovation - Technologies, institutions and organizations*, Pinter Publishers/Cassell Academic, London, UK. (The book is out of print, but this chapter has been republished in Edquist, C. and McKelvey, M. 2000.)
- Edquist, C. (2001). "Innovation policy – A systemic approach", in Lundvall, B-Å. and Archibugi, D. (eds.), *Major socio-economic trends and European innovation policy*, Oxford University Press, Oxford, UK.
- Edquist, C. (2003). "The fixed internet and mobile telecommunications sectoral system of innovation: Equipment, access and content", in Edquist, C. (ed.), *The internet and mobile telecommunications system of innovation: Developments in equipment, access and content*, Edward Elgar Publishing, Cheltenham, UK.
- Edquist, C. (2005). "Systems of innovation: Perspectives and challenges". *The Oxford Handbook of Innovation*, (Chapter 7), pp. 181-208.
- Edquist, C. and Hommen, L. (2000). "Public technology procurement and innovation theory", in Edquist, C., Hommen, L. and Tsipouri, L. (eds.), *Public technology procurement and innovation*. Boston/Dordrecht/London: Kluwer Academic Publishers.
- Edquist, C., Hommen, L., and McKelvey, M. (2001). *Innovation and employment: Process versus product innovation*, Edward Elgar Publishing, Cheltenham, UK.
- Edquist, C. and Johnson, B. (1997). "Institutions and organisations in systems of innovation", in Edquist, C. (ed.), *Systems of innovation: Technologies, institutions and organizations*, Pinter/Cassell Academic, London and Washington. (The book is out of print, but this chapter has been republished in Edquist, C. and McKelvey, M. 2000.)
- Edquist, C., Malerba, F, Metcalfe, J.S., Montobbio, F., and Steinmueller, E. (2004). "Sectoral systems: Implications for European innovation policy", in Malerba, F. (ed.), *Sectoral systems of innovation - Concepts, issues and analysis of six major sectors in Europe*, Cambridge University Press, Cambridge, UK.
- Edquist, C. and McKelvey, M. (2000). *Systems of innovation: Growth competitiveness and employment*, Edward Elgar, Cheltenham, UK.
- Edvinsson, L. and Malone, M. (1997). *Intellectual capital; realizing your company's true value by finding its hidden brainpower*, Harper Collins Publisher, New York, USA.
- European Commission (2003). "Study on the measurement of intangible assets and associated accounting practices". DG Enterprise.
- Fischer, M.F. (2001). "Innovation, knowledge creation and systems of innovation". *Regional Science*, (35), pp. 199-216.



- Freeman, C. (1987). *Technology policy and economic performance: Lessons from Japan*, Pinter, London, UK.
- Freeman, C. (2002). "Continental, national and sub-national innovation systems – complementarity and economic growth". *Research Policy*, (31:2), pp. 191-211.
- Furman, J., Porter, M., and Stern, S.. (2002). "The determinants of national innovative capacity". *Research Policy*, (31), pp. 899-933.
- Galli, R. and Teubal, M. (1997). "Paradigmatic shifts in national innovation systems", in Edquist, C. (ed.), *Systems of innovation - Technologies, institutions and organizations*, Pinter Publishers/Cassell Academic, London, UK.
- Guthrie, J. and Petty, R. (2000). "Intellectual capital literature review". *Journal of Intellectual Capital*, (1:2), pp. 155-176.
- Ingelstam, L. (2002). *System – att tänka över samhälle och teknik* (Systems – Reflecting on society and technology), Energimyndighetens förlag, Eskilstuna, Sweden.
- Johnson, A. and Jacobsson, S. (2003). "The emergence of a growth industry: A comparative analysis of the German, Dutch, and Swedish wind turbine industries", in Metcalfe, S. and Cantner, U. (eds.), *Transformation and development: Schumpeterian perspectives*. Physica/Springer, Heidelberg, Germany. Forthcoming.
- Liu, X. and White, S. (2001). "Comparing innovation systems: A framework and application to China's transitional context". *Research Policy*, (30), pp. 1091-1114.
- Lundvall, B-Å. (1992). *National systems of innovation: Towards a theory of innovation and interactive learning*, Pinter, London, UK.
- Lundvall, B-Å. (2003). "National innovation systems: history and theory" (to be published), in *Elgar companion to neo-Schumpeterian economics*, Edward Elgar Publishing Ltd, Cheltenham, UK.
- Lundvall, B-Å., Johnson, B., Andersen, E.S., and Dalum, B. (2002). "National systems of production, innovation and competence building". *Research Policy*, (31:2), pp. 213-231.
- Meeus, M., Oerlemans, L., and Hage J. (2001). "Patterns of interactive learning in a high tech region. An empirical exploration of complementary and competing perspectives". *Organization Studies*, (22:1), pp. 145-172.
- Mowery, D. (2005). "National security and national innovation systems". Paper presented at the PRIME/PREST workshop on 'Re-evaluating the role of defence and security R&D in the innovation system', University of Manchester, September 19 – 21, 2005.
- Mytelka, L.K. and Smith, K. (2002). "Policy learning and innovation theory: An interactive and co-evolving process". *Research Policy*, (31).
- Nelson, R.R. (1993). *National systems of innovation: A comparative study*, Oxford University Press, Oxford, UK.

- Nelson, R.R. and Rosenberg, N. (1993). "Technical innovation and national systems", in Nelson, R.R. (ed.), *National systems of innovation: A comparative study*, Oxford University Press, Oxford, UK.
- North, D.C. (1990). *Institutions, institutional change and economic performance*, Cambridge University Press, Cambridge, UK.
- Nooteboom, B. (2004). *Inter-firm collaboration, learning and networks. An integrated approach*, Routledge, London and New York.
- OECD (1999). *Managing national innovation systems*, OECD, Paris, France.
- OECD (2002a). *Dynamising national innovation systems*, OECD, Paris, France.
- OECD (2002b). *Main science and technology indicators, Volume 2002/2*, OECD. Paris, France.
- Rickne, A. (2000). *New technology-based firms and industrial dynamics: Evidence from the technological systems of biomaterials in Sweden, Ohio and Massachusetts*, Chalmers University of Technology, Department of Industrial dynamics, Chalmers, Sweden.
- Sánchez, P., Chaminade, C., and Olea, M. (2000). "Management of intangibles – an attempt to build a theory". *Journal of Intellectual Capital*, (1:4), pp. 312-327.
- Smith, K. (2000). "Innovation as a systemic phenomenon: Rethinking the role of policy". *Enterprise and Innovation Management Studies*, (1:1), pp. 73-102.
- Woolthuis, R. K., Lankhuizen, M., and Gilsing, V. (2005). "A system failure framework for innovation policy design". *Technovation*, (25), pp. 609-619.