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Systems of Innovation: Perspectives and Challenges

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Abstract and Keywords

This article presents an overview and assessment of the systems of the innovation approach. It focuses mainly on national systems of innovation, but in addition it addresses sectoral and regional systems of innovation. This article addresses the emergence and development of the systems of innovation (SI) approach, its strengths and weaknesses, the criticism that it is “undertheorized,” the constituents of SIs, the main function and activities in SIs, the boundaries of SIs, and proposals for further research. It also discusses how the rigour and specificity of the SI approach could be increased. The innovation concept used in this article is wide and includes product innovations as well as process innovations. Product innovations are new—or better—material goods as well as new intangible services. Process innovations are new ways of producing goods and services.

Keywords: systems of innovation, SI approach, innovation concept, product innovations, process innovations

7.1 Introduction[1]

THIS chapter presents an overview and assessment of the systems of innovation approach. I focus mainly on national systems of innovation, but in addition address sectoral and regional systems of innovation to a limited extent.[2] The chapter addresses the emergence and development of the systems of innovation (SI) approach, its strengths and weaknesses, the criticism that it is “undertheorized,” the constituents of SIs, the main function and activities in SIs, the boundaries of SIs, and proposals for further research. I also discuss how the rigour and specificity of the SI approach could be increased.[3] The most central terms used in this chapter are specified in Box 7.1.

(p. 182)

Box 7.1 Systems of innovation: main terms used

Innovations = product innovations as well as process innovations. Product innovations are new—or better—material goods as well as new intangible services. Process innovations are new ways of producing goods and services. They may be technological or organizational.

SI = system of innovation = the determinants of innovation processes = all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations.

Constituents of SIs = *components* + *relations* among the components.

Main components in SIs = organizations and institutions.

Organizations = formal structures that are consciously created and have an explicit purpose. They are players or actors.

Institutions = sets of common habits, norms, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups, and organizations. They are the rules of the game.

An SI has a *function*, i.e. it is performing or achieving something. The *main function* in SIs is to pursue innovation processes, i.e. to develop, diffuse and use innovations.

Activities in SIs are those factors that influence the development, diffusion, and use of innovations. The activities in SIs are the same as the determinants of the main function.

7.2 The Emergence and Development of the SI Approach

The chapter by Fagerberg in this volume highlights the systemic nature of innovation processes, noting that firms do not normally innovate in isolation, but in collaboration and interdependence with other organizations. These organizations may be other firms (suppliers, customers, competitors, etc.) or non-firm entities such as universities, schools, and government ministries. The behavior of organizations is also shaped by institutions—such as laws, rules, norms, and routines—that constitute incentives and obstacles for innovation. These organizations and institutions are components of systems for the creation and commercialization of knowledge. Innovations emerge in such "systems of innovation."

The innovation concept used in this chapter is wide and include product innovations as well as process innovations. Product innovations are new—or better—material goods as well as new intangible services. Process innovations are new ways of producing goods and services. They may be technological or organizational (Edquist, Hommen, and McKelvey 2001).

(p. 183)

The expression "national system of innovation" (NSI) was, in published form, first used in 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: 1). Two major books on national systems of innovation (NSI) are Lundvall (1992) and Nelson (1993), which employ different approaches to the study of NSIs. Nelson (1993) emphasizes empirical case studies more heavily than theory development[4] and some of the studies focus narrowly on nations' R&D systems. By contrast, Lundvall (1992) is more theoretically oriented and seeks to develop an alternative to the neo-classical economics tradition by placing interactive learning, user–producer interaction and innovation at the center of the analysis (Lundvall 1992: 1).

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: 10). In a similar way, Nelson and Rosenberg single out organizations supporting R&D, i.e. they emphasize those organizations that promote the creation and dissemination of knowledge as the main sources of innovation (Nelson and Rosenberg 1993: 5, 9–13).[5] Lundvall's broader approach recognizes that these "narrow" organizations 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: 195).

Both Nelson and Lundvall define national systems of innovation in terms of determinants of, or factors influencing, innovation processes.[6] However, they single out different determinants in their actual definitions of the concept, presumably reflecting what they believe to be the most important 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*b*: 14). 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 innovation systematically and in detail. It seems dangerous to exclude some potential determinants, since these might prove to be very important, once the state of the art has advanced. For example, twenty-five years ago it would have been natural to exclude the interactions between organizations 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 specifications of systems of innovation than national ones. Carlsson and colleagues focus on "technological systems," arguing that these are unique to technology fields (Carlsson 1995). The sectoral approach of Breschi and **(p. 184)** Malerba (1997) similarly focuses on a group of firms that develop and manufacture the products of a specific sector and that generate and utilize the technologies of that sector. The concept of "regional innovation system" has been developed and used by Cooke et al. (1997) and Braczyk et al. (1998), Cooke (2001), and Asheim and Isaksen (2002).

The three perspectives—national, sectoral and regional—may be clustered as variants of a single generic "systems of innovation" approach (Edquist 1997*b*: 3, 11–12). Much of the discussion in this chapter is relevant for the generic approach, and is based on the premise that the different variants of systems of innovation coexist and complement each other. Whether the most appropriate conception of the system of innovation, in a certain context, should be national, sectoral or regional, depends to a large extent on the questions one wants to ask.[7]

7.3 Strengths and Weaknesses of the SI Approach

7.3.1 The Diffusion of the SI Approach

The diffusion of the SI approach has been surprisingly rapid, and is nowwidely used in academic circles. The approach also finds broad applications in policy contexts—by regional authorities and national governments, as well as by international organizations such as the OECD, the European Union, UNCTAD and UNIDO. 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. The next section briefly addresses some of the strengths of the generic SI approach.

7.3.2 The Strengths of the SI Approach

The SI approach places innovation and learning processes at the center of focus. This emphasis on learning acknowledges that innovation is a matter of producing new knowledge or combining existing (and sometimes new) elements of knowledge in **(p. 185)** 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 organizational, 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 characterized as evolutionary. Therefore, an optimal or ideal system of innovation cannot be specified. 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 SI approach emphasizes 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 SI approach can encompass both product and process innovations, as well as subcategories of these types of innovation. Traditionally, innovation studies have, to a large extent, focused upon technological process innovations and to some extent upon product innovations, but less on non-technological and intangible ones, i.e. service product innovations and organizational process innovations (as specified in Section 7.2). As argued in this Handbook, there are good reasons to use a comprehensive innovation concept,[8] and the systems of innovation approach is well suited to this comprehensive perspective, since all the categories of innovations specified in this chapter can be analyzed within it. That non-technological forms of innovation deserve more attention is also argued in OECD (2002*a*: 24.d).

The SI approach emphasizes the role of institutions. Practically all specifications of the SI concept highlight the role of institutions, rather than assuming them away from the list of determinants of innovation. This is important since institutions strongly **(p. 186)** influence innovation processes. There is, however, no agreement about what the term "institutions" means (see Section 7.3.3).

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

7.3.3 The 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 organizational actors as well as to institutional rules. Sometimes the word means different kinds of organizations or "players" (according to the definitions in Section 7.4.2). At other times, the term means laws, rules, routines, and other "rules of the game." For Nelson and Rosenberg (1993), institutions are basically different kinds of organizations, while for Lundvall (1992) the term "institution" means primarily the rules of the game. Hence "institution" is used in several different senses in the literature (Lundvall 1992: 10; Nelson and Rosenberg 1993: 5, 9–13; Edquist

1997*b*: 26–8).

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*b*: 13–15). Nelson and Rosenberg provided "no sharp guide to just what should be included in the innovation system, and what can be left out" (Nelson and Rosenberg 1993: 5–6). Lundvall insisted that "a definition of the system of innovation must be kept open and flexible" (Lundvall 1992: 13).

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 (see Section 7.5). Because of the relative absence of well-established empirical regularities, "systems of innovations" should be labeled an approach or a conceptual framework rather than a theory (Edquist 1997*b*: 28–9).

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 "overtheorized" and it should remain an inductive one.[9] Another position argues that the SI approach is "undertheorized," that conceptual clarity should be increased and that the approach should be made more "theory-like."[10]

(p. 187)

Hence, the international community within innovation studies is currently divided on this issue. In what follows, I try to increase the rigor and specificity of the SI approach. This effort is intended as a step towards developing the approach further. If it reveals weaknesses associated with the approach, this is a good thing. Acknowledging such weaknesses may lead to additional research and new insights into the operation of innovation systems.

7.4 The Constituents, Function, Activities and Boundaries of SIs

7.4.1 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 the natural sciences than in the social sciences. In everyday language, as well as in large parts of the scientific literature, the term "system" is used generously and with limited demands for a precise definition. To the question "What is a system?" there is, however, a common answer in everyday language as well in scientific contexts (Ingelstam 2002: 19):

- A system consists of two kinds of constituents: There are, first, some kinds of components and, second, relations among them. The components and relations should form a coherent whole (which has properties different from the properties of the constituents).
- The system has a function, i.e. it is performing or achieving something.
- It must be possible to discriminate between the system and the rest of the world; i.e. 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 extent.[11]

Making the systems of innovations approach more theory-like does not require that all components and all relations among them must be specified. Such an ambition would certainly be unrealistic. At present, it is not a matter of transforming the SI approach into a "general theory of innovation," but rather we need to make it clearer and more consistent so 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 function of SIs, the activities and components in them and **(p. 188)** some important relations among these, would represent a considerable advance in the field of innovation studies. Used in this way, the SI approach can be useful for the creation of theories about relations between specific variables within the approach.

7.4.2 The Main Components of SIs

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 (as argued in Section 7.3.3). Let me therefore specify what organizations and institutions mean here.

Organizations are formal structures that are consciously created and have an explicit purpose (Edquist and Johnson 1997: 46–7). They are players or actors.[12] Some important organizations in SIs are firms, 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 and Johnson 1997: 46). 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: 5), discriminating between "the rules of the game" and "the players" in the game.

SIs may differ from one another in many respects. For example, the set-ups of organizations and institutions, constituting components of empirically existing SIs, vary among them. Research institutes and company-based research departments may be important R&D performers in one country (e.g., Japan) while research universities may play a similar role in another (e.g., the United States). In some countries, such as Sweden, most research is carried out in universities, while the independent public research institutes are weak. In Germany, the latter are much more important. That the organizational set-up varies considerably among NSIs is shown in profiles of the national systems in Austria, Belgium, Finland, Germany, Spain, Sweden, Switzerland, and the United Kingdom, presented in OECD (1999*a*: Annex 3).

Institutions such as laws, rules, and norms also differ considerably among national SIs. For example, the patent laws are different between countries. In the USA, an inventor can publish before patenting, whereas this is not possible according to European laws. With regard to the patent rights of university teachers, individuals in this category own their patents outright in Sweden, thanks to the so-called "university teachers' privilege." However, this is not the case in the USA, where different laws **(p. 189)** apply. In Denmark and Germany, new laws have recently transferred ownership from the teachers to the universities, while in Italy, a transfer has occurred in the opposite direction. Many OECD governments are currently experimenting with changes in the ownership of knowledge created in universities, in the belief (based on little evidence—see the chapter by Mowery and Sampat) that such changes will influence the propensity to patent and accelerate the commercialization of economically useful knowledge.

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

7.4.3 Functions and Activities in SIs

Although a system is normally considered to have a function, this was not addressed in a systematic manner in the early work on SIs. Somewhat later, some hints in this direction were made by Galli and Teubal (1997: 346–7). As we will see below, some recent contributions to the literature have started to address this theoretical gap.

7.4.3.1 Functions and Activities in SIs and Determinants of Innovation Processes

Xielin Liu and Steven White (2001) address what they call a fundamental weakness of national innovation system research, namely "the lack of system-level explanatory factors" (Liu and White 2001: 1092). To remedy this, they focus upon the "activities" in the systems, "activities" being related to "the creation, diffusion and exploitation of technological innovation within a system" (Liu and White 2001: 1093). On this basis, they compile a list of five fundamental activities in innovation systems.[13]

Johnson and Jacobsson (2003) emphasize that, for an innovation system "to support the growth of an industry, a number of functions have to be served within it, e.g. the supply of resources" (Johnson and Jacobsson 2003: 2). They suggest that "a technology or product specific innovation system may be described and analysed in terms of its 'functional pattern,' i.e. in terms of how these functions are served" (Johnson and Jacobsson 2003: 3). These authors present a list of five functions.[14] Rickne (2000: 175) provides a list of eleven functions that are important for new technology-based firms (i.e. not for innovations in an immediate sense).[15] Clearly, there is no consensus as to which functions or activities should be included in a system of innovation and this provides abundant opportunities for further research.

(p. 190)

One way of addressing what happens in SIs is the following. At a general level, the main function—or the "overall function"—in SIs is to pursue innovation processes, i.e. to develop, diffuse and use innovations. What I, from now on, call activities in SIs are those factors that influence the development, diffusion, and use of innovation.[16] 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, i.e. its transformation into innovations.

A satisfactory explanation of innovation processes almost certainly will be multicausal, and therefore should specify the relative importance of various determinants. These determinants cannot be expected to be independent of each other, but instead must be seen to support and reinforce—or offset—one another. Hence, it is important to also study the relations among various determinants of innovation processes. One way to try to do that would be to establish "a hierarchy" of causes à la E. H. Carr.

Carr argues that the study of history is a study of causes and that the historian continuously asks the question, "Why?" Further, the historian commonly assigns several causes to the same event (Carr 1986: 81, 83). He continues: "The true historian, confronted with this list of causes of his own compiling, would feel a professional compulsion to reduce it to order, to establish some hierarchy of causes which would fix their relation to one another, perhaps to decide which cause, or which category of causes, should be regarded 'in the last resort' or 'in the final analysis'… as the ultimate cause, the cause of all causes" (Carr 1986: 84). I do not believe that we will ever reach such an objective in a detailed and systematic manner or that we will be able to identify all determinants of innovation—because of the complexity of the task. However, there are good reasons to try to strive in this direction by developing theories about relations between specific variables within the approach in a pragmatic way (as proposed in Section 7.4.1.).

I believe that it is important to study the activities (causes, determinants) in SIs in a systematic manner. The hypothetical list of activities presented below is based upon the literature, e.g. the lists mentioned earlier, and onmy own knowledge about innovation processes and their determinants. The activities listed are not ranked in order of importance, but start with knowledge inputs to the innovation process, continues with the demand side factors, the provision of constituent of SIs, and ends with support services for innovating firms.

The following activities can be expected to be important in most SIs:

(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.
(3) Formation of new product markets.
(p. 191)
(4) Articulation of quality requirements emanating from the demand side with regard to new products.
(5) Creating and changing organizations needed for the development of new fields of innovation, e.g. enhancing entrepreneurship to create new firms and intrapreneurship to diversify existing firms, creating new research organizations, policy agencies, etc.
(6) 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.
(7) Creating and changing institutions—e.g. 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.
(8) Incubating activities, e.g. providing access to facilities, administrative support, etc. for new innovative 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, e.g. technology transfer, commercial information, and legal advice.

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 kinds 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.[17]

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 innovation 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. Centralized control over SIs is impossible and innovation policy can only influence the spontaneous development of SIs to a limited extent.

7.4.3.2 Three Kinds of Learning in the SI Approach

Regarding competence building as an important activity in SIs—and given that R&D has earlier been a central activity in SI studies—means that the SI approach focuses on three kinds of learning: **(p. 192)**

- *Innovation* (in new products as well as processes) takes place mainly in firms and leads to the creation of “structural capital,” which is a knowledge-related asset controlled by firms (as opposed to “human capital”); it is a matter of organizational learning.

- *Research and Development* (R&D) is carried out in universities and public research organizations as well as in firms and leads to publicly available knowledge as well as knowledge owned by firms and other organizations, as well as by individuals.

- *Competence Building* (e.g. training and education) which occurs in schools and universities (schooling, education) as well as in firms, and leads to the creation of "human capital." Since human capital is controlled by individuals, it is a matter of individual learning.

An important area for further research in the SI tradition concerns the relationship among these three kinds of learning, which appear to be closely related to one another. One objective of such studies would be to address what types and levels of education and training are most important for specific kinds of innovations—e.g. process innovations and product innovations, or incremental and radical innovations.

As exemplification, I will now discuss two central learning activities—R&D and competence building—in some greater detail. This discussion constitutes the beginning of an examination of the relations among activities and constituents in SIs that is continued in section 7.4.4. It also serves as a guide to and synthesis of some of the recent work on these issues within the systems of innovation literature.

A. Research and Development. Considerable work on NSIs has been carried out within the OECD. However, although most of the OECD contributions mentioned here have "systems of innovation" in the title, many of them actually use this approach more as a label than as an analytical tool. The first phase of this work included the development of quantitative indicators, country case studies, and work within six focus groups on innovative firms, innovative firm networks, clusters, mobility of human resources, organizational mapping, and catching-up economies. Some of the empirical results were presented in (OECD 1998*a*) and a synthesis is found in (OECD 1999*a*).

The second phase provided a deepening of the analysis in three areas: innovative clusters (OECD 2001*a* and 1999*b*), cooperation in national innovation systems (OECD 2001*b*), and mobility of skilled personnel in NSIs (OECD 2001*c*). Yet another study (OECD 2002*a*) summarizes the findings of the second phase of the project and derives policy implications. In the studies mentioned, R&D as well as competence building is addressed to some extent.

In most countries, universities are the most important public organizations performing R&D (OECD 1998*a*: ch. 3). Governments fund university R&D activities in a number of ways. Traditionally, they have provided general support via block grants from the Ministries of Education, part of which was used by university staff to carry out R&D. Such funding is still very important in small, highly R&D-intensive **(p. 193)** countries such as the Netherlands, Sweden, and Switzerland. Governments may also provide grants to encourage research "for the advancement of knowledge" or grants to obtain the knowledge needed for government missions such as defense or health care. In most countries, block grants have declined and direct support has grown in importance (OECD 1998*a*: ch. 3).

In certain countries, universities fall under the responsibility of the national government. In others, such as Germany, they are the responsibility of the regional governments. Whatever the form of organization, a growing regional influence can be observed in most countries. In Germany, the universities are financially very autonomous. In the UK, financial support is provided by research councils to individual projects selected on a competitive basis.

In many countries, the science system also includes public research institutes (or "national laboratories") which carry out the same type of R&D activities as universities, as well as more applied research and technical development work. Although the relative importance of universities in terms of performing R&D has increased in most countries (see Mowery and Sampat in this volume), public research organizations remain important. These organizations may be linked to the universities and included in the higher education sector, or they may be independent of them. The largest single case in the OECD area is the Centre National de la Recherche

Scientifique (CNRS) in France, which receives the lion's share of direct funding of R&D in the higher education sector. The CNRS provides support for projects that are normally carried out in collaboration with university researchers. In this regard, the CNRS can be clearly distinguished from its counterparts in Germany (Max Planck Gesellschaft), Italy (CNR) and Spain (CSIC) (Laredo and Mustar 2001*c*: 502). In the United States, the higher education sector contains a large number of public research laboratories. (OECD 1998*a*: 83–4). Other countries with a large institute sector include Norway, Taiwan and Germany (e.g. Max Planck Gesellshaft and Fraunhofer). A number of national governments have tried to change these organizations and promote their links with the rest of the economy and society. This has, for example, been done in quite different ways in France and the UK (Laredo and Mustar 2001*c*: 503).

As this short discussion suggests, different kinds of public organizations (such as universities and public research institutes) can perform the same activity (R&D) in an NSI. NSIs differ significantly with regard to which organizations that perform public R&D and with regard to the institutional rules that govern or influence these organizations (Laredo and Mustar 2001*b*: 6–7).

In most NSIs, especially in low- and medium-income nations, only modest sums are invested in R&D and most of the R&D is performed by public organizations. The few countries that invest heavily in R&D are all rich, and much of their R&D is carried out by private organizations. This group includes some large countries, such as the USA 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 **(p. 194)** rather little R&D, e.g. Denmark and Norway. As mentioned, a considerable part of the R&D in many rich countries is carried out and financed by the private sector, primarily firms (although there are also public financial support schemes to stimulate firms to perform R&D). The proportion of all R&D performed in high-income OECD member states that is financed by firms ranged between 21 per cent (Portugal) and 72 per cent (Japan) in 1999 (OECD 2002*b*). Acknowledging such differences may help to distinguish between different types of NSIs.

Most of the R&D carried out by private organizations may be characterized as development work rather than research. Innovation certainly does not depend solely on R&D results, but requires also other actions, such as technical experimentation, technology adoption, market investigations, and entrepreneurial initiative. R&D and innovation activities are normally driven by different rationales and motivations—i.e. the advancement of knowledge and the quest for profits, respectively.

One implication of the complex interface between “research” and “innovation” is that links between universities/public research organizations and innovating firms are especially important to the performance of NSIs.[18] Innovating firms often need to collaborate with public research organizations or universities. Here, publicly created institutions are important. Governments may, for example, support collaborative centers and programs, remove barriers to cooperation, and facilitate the mobility of skilled personnel among different kinds of organizations. This might involve the creation of institutional rules, such as those in Sweden stating that university professors should perform a “third task” in addition to teaching and doing research—i.e. interact with the society surrounding the university, including firms. However, such “linkage activity” is carried out in different ways and to different extents in different NSIs.

B. Competence building. The early work within the SI approach largely neglected learning in the form of education and training.[19] However, competence building is increasingly considered to be an important activity in systems of innovation, reflecting the importance of skilled personnel for most innovative activities (Smith 2001: 8).[20] But no rigorous analyses of competence building have, to my knowledge, been conducted as part of the analysis of innovation systems.

Nevertheless, there is a large literature on various aspects of competence building outside the SI context. Competence building (e.g. training and education) is the same as enhancement of human capital and is carried out largely, though not exclusively, in schools and universities. Competence building also occurs in firms (in the form of training, learning-by-doing, learning-by-using, and individual learning) often throughout working life.

A recent OECD study analyzed vocational and technical education and training in some detail in Australia, Austria, Denmark, England (including Wales and Northern Ireland), France, Germany, Italy, the Netherlands, Quebec, and Switzerland (OECD 1998*b*). This study pointed out many differences across countries with regard **(p. 195)** to vocational and technical training. One difference concerns the stage prior to vocational and technical training, i.e. the structure of middle and lower secondary education. This structure is unified in most countries, but is divided into distinct programs in Germany, Austria, the Netherlands, and Switzerland. One of these programs is the beginning of the academic pathway, while the others lead essentially to vocational and technical training. Another difference concerns the relative numeric importance of vocational and technical training as opposed to academic pathways in upper secondary education. In the countries of the British Common-wealth—Australia, Canada, and the UK—the academic pathway is very much in the majority, while in the countries of continental Europe, vocational and technical training dominates (OECD 1998*b*).

The ways in which people access skilled jobs (and then climb the career “ladders” of enterprises) differ greatly among NSIs:

> This may occur at a certain time after recruitment, when the young person has proved himself; after a fixed and codified period of service, according to a specific labour contract; or on recruitment, depending on the qualifications previously acquired. For vocational training, these three modes of access lead to three broad traditions: on-the-job training, formal apprenticeship, school training. (OECD 1998*b*: 12)

These practices coexist in various countries, but their relative importance varies considerably; frequently, one of them dominates and determines training policy.

The models for transition from education to employment also differ across countries. Apprenticeship is important in somecountries—e.g. in Germany, where it caters to about two-thirds of the age group (OECD 1996: 48). In other countries, schoolbased learning and productive work are combined in alternative ways—e.g. in Sweden, Australia, France, the United Kingdom, and Korea (OECD 1996: 146).

The organizational and institutional contexts of competence building thus 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 organization of education and training influences the development, diffusion and use of innovations. Since labor, including skilled labor, is the least mobile production factor, domestic systems for competence building remain among the most enduringly “national” elements of NSIs.

7.4.4 The Relations Between Activities and Components and among Components

This chapter has placed greater emphasis on “activities” than much of the early work on SIs. Nonetheless, this emphasis does not mean that we can disregard or **(p. 196)** neglect the “components” of SIs and the relations among them. Organizations or individuals perform the activities and institutions provide incentives and obstacles influencing these activities. In order to understand and explain innovation processes, we need to address the relations between activities and components, as well as among different kinds of components.

What then are the relations between the components and the activities in SIs? As we saw in Section 7.4.3.2. A, the activity of research (the creation of new knowledge) can be carried out by research institutes, universities, or research-oriented firms. Most of the other activities mentioned earlier can also be performed by different organizations. Further, many categories of organizations can perform more than one activity. For example, universities provide new knowledge and educate people (human capital). Hence, there is not a one-to-one relation between activities and organizations.[21] However, there are limits to this flexibility—for instance, primary schools cannot carry out basic research. The relations between activities and institutions are less direct, since institutions influence whether or not, and how, certain organizations perform certain activities. It seems that the set-up of activities can be expected to vary less across NSIs than the set-up of organizations performing them and the set-up of institutions influencing those organizations. However, the "quantity" of each activity and the efficiency with which each activity is performed might vary considerably among NSIs.[22]

As we saw in section 7.3.2, the SI approach emphasizes the relations or interactions among the components in SIs. Interactions among different organizations may be of a market or non-market kind. That market, as well as non-market, relations should be addressed in SI research is stressed in a recent OECD report. There the concept of interaction is specified as including:

- Competition, which is an interactive process wherein the actors are rivals, and which creates or affects the incentives for innovation.
- Transaction, which is a process by which goods and services, including technology-embodied and tacit knowledge, are traded between economic actors.
- Networking, which is a process by which knowledge is transferred through collaboration, cooperation and long term network arrangements. (OECD 2002*a*: 15)

With regard to interactions among organizations in their pursuit of innovations, empirical work inspired by and designed on the basis of the SI approach has been carried out in many countries. One example is the Community Innovation Surveys (CIS) that have been coordinated by Eurostat of the European Union and carried out in all EU countries and in several additional countries (see Smith, Chapter 6 in this volume, for a detailed discussion of CIS). The CIS results include data on collaboration among innovating organizations, and indicate that such collaboration is very common and important. This result is supported by other surveys which have shown that between 62 per cent and 97 per cent of all product innovations were achieved in collaboration between the innovating firm and some other **(p. 197)** organizations in Austria, Norway, Spain, Denmark, and the region of East Gothia in Sweden (Christensen et al. 1999; Örstavik and Nås 1998; Edquist, Ericsson, and Sjögren 2000: 47).

These findings constitute empirical support for one of the main tenets of the SI approach, i.e. that interactive learning among organizations is crucial for innovation processes. This also illustrates the dynamics of this field of research over time. The emergence of the SI approach in its Danish version (Lundvall 1992) took inspiration from case studies indicating that user–producer interaction was very important for innovations, e.g. in the Danish dairy industry; the SI approach was formulated partly on this basis. One of its central elements—the importance of relations of interactive learning among organizations—has since been verified by systematic empirical research in Denmark and elsewhere. This is a good example of fruitful interaction between theoretical and empirical work.

Another example of empirical work partly based on the NSI approach is Furman, Porter, and Stern (2002), who introduce the concept of national innovative capacity, which is the ability of a country to produce and commercialize a flow of new-to-theworld technologies over the long term. This concept is explicitly based upon ideasdriven endogenous growth theory à la Romer (see Verspagen, Ch. 18 in this volume), the cluster-based approach à la Porter (1990), and the NSI approach. On this basis, they estimate the relationship between international patenting (patenting by foreign countries in the USA) and observable measures of national innovative capacity. Their results suggest that a small number of observable factors describe a country's national innovative capacity—i.e. they identify determinants of the production of new-to-the-world technologies. They find that a great deal of variation in patenting across countries is due to differences in the level of inputs devoted to innovation (R&D manpower and spending). They also find that an extremely important role is played by factors associated with differences in R&D productivity, e.g. policy choices such as the extent of protection of intellectual property and openness to international trade, the share of research performed by the academic sector and funded by the private sector, the degree of technological specialization, and each individual country's knowledge "stock" (Furman et al. 2002).

The relations between organizations and institutions are important for innovations and for the operation of SIs. Organizations are strongly influenced and shaped by institutions, so that organizations can be said to be "embedded" in an institutional environment or set of rules, which include the legal system, norms, routines, standards, etc. But institutions are also embedded in and develop within organizations. Examples are firm-specific rules with regard to bookkeeping or concerning norms with regard to the relations between managers and employees. Hence, there is a complicated relationship of mutual embeddedness between institutions and organizations (Edquist and Johnson 1997: 59–60).

Some organizations create institutions that influence other organizations. Examples are organizations that set standards and public organizations that **(p. 198)** formulate and implement those rules that we might call innovation policy. Examples are the NMT 450and the GSM mobile telecom standards. The NMT 450was created by the Nordic public telephone operators, which were state-owned monopolies at the time. The development and implementation of NMT 450was an example of the importance of user–producer relations in innovation processes, which is stressed so strongly in the SI approach. The public organizations provided a technical framework for private equipment producers and thereby decreased uncertainty. The Nordic equipment producers, Ericsson and Nokia, greatly benefited from this, and it was an important factor contributing to their leading role in mobile telecommunications equipment production today. In essence, the NMT 450 provided the cradle for the development of mobile telecommunications in Europe (Edquist 2003: 21–3).

Institutions may also be the basis for the creation of organizations, as when a government makes a law that leads to the establishment of an organization. Examples of such organizations include patent offices or public innovation policy agencies.

There may also be important relations between different institutions, for example, between patent laws and informal rules concerning exchange of information between firms. Institutions of different kinds may support and reinforce each other, but may also contradict and be in conflict with each other, as discussed in some detail by Edquist and Johnson (1997). This work has been carried forward by Coriat and Weinstein (2002), who discuss different levels of institutions and focus on the principle of a hierarchy among rules themselves (Coriat and Weinstein 2002: 280).[23]

Our knowledge about the complex relations—characterized by reciprocity and feedback—between organizations and institutions is limited. Since the relations between two phenomena cannot be satisfactorily analyzed if they are not conceptually distinguished from each other, it is important to make a clear distinction between organizations and institutions when specifying the concepts.[24]

7.4.5 Boundaries of SIs: Spatial, Sectoral and in Terms of Activities

The distinction between what is inside and outside a system is crucial—i.e., the issue of the boundaries of SIs cannot be neglected (see Section 7.4.1). It is therefore necessary to specify the boundaries if empirical studies of specific SIs—of a national, regional, or sectoral kind—are to be carried out. As will be discussed later, one way to identify the boundaries of SIs is to identify the causes or determinants of innovations.

Although "national systems of innovation" is only one of several possible specifications of the generic SI concept, it certainly remains one of the most relevant. **(p. 199)** One reason is the fact that the various case studies in Nelson (1993) show that there are sharp differences among various national systems in such attributes as institutional set-up, organizational set-up, investments in R&D, and performance. For example, the differences in these respects between Denmark and Sweden are remarkable—in spite of the fact that these two small countries in northern Europe are very similar in many other respects (Edquist and Lundvall 1993: 5–6).

Another reason to focus on national SIs is that most public policies influencing innovation processes or the economy as a whole are still designed and implemented at the national level. For very large countries, the national SI approach is less relevant than for smaller countries, but institutions such as laws and policies are still mainly national, even in a country such as the USA. In other words, the importance of national SIs has partly to do with the fact that they capture the importance of the policy aspects of innovation. It is not only a matter of geographical delimitation, as the state, and the power attached to it, is also important.

SIs may be supranational, national, or subnational (regional, local)—and at the same time they may be sectoral within any of these geographical demarcations.[25] All these approaches may be fruitful, but for different purposes or objects of study. Generally, the variants of the generic SI approach complement rather than exclude each other and it is useful to consider sectoral and regional SIs in relation to—and often as parts of—national ones.

There are three ways in which we can identify boundaries of SIs:

(1) spatially / geographically;
(2) sectorally; and
(3) in terms of activities.

1. To define the *spatial* boundaries is the easiest task, although it also has its problems. Such boundaries have to be defined for regional and national SIs, and sometimes also for sectoral ones. The problem of *geographical* boundaries is somewhat more complicated for a regional than for a national SI. One question is which criteria should be used to identify a "region."

For a regional SI, the specification of the boundaries should not only be a question of choosing or using administrative boundaries between regions in a mechanical manner (although this might be useful from the point of view of availability of data). It should also be a matter of choosing geographical areas for which the degree of "coherence" or "inward orientation" is high with regard to innovation processes. One possible operationalization of this criterion could be a sufficient level of localized learning spill-overs (among organizations), which is often associated with the importance of transfer of tacit knowledge among (individuals and) organizations. A second could be localized mobility of skilled workers as carriers of knowledge, i.e. an operationalization which shows that the local labor market is important. A third possibility could be that a minimum proportion of the innovation-related collaborations among organizations should be with partners within **(p. 200)** the region. This is a matter of localized networks, i.e. the extent to which learning processes among organizations are contained within regions.

For a national SI, the country's borders normally provide the boundaries. However, it could be argued that the criteria for regional SIs are as valid for national ones. In other words, if the degree of coherence or inward orientation is very low, the country might not reasonably be considered to have a national SI. It was also mentioned above that the national SI approach is less relevant for large than for smaller countries. In Germany, for example, the appropriate unit of analysis may be "Länder." The choice of approach may not only be a question of size of the country, but also whether it is federally organized or not.

2. Leaving the geographical dimension, we can also talk about "sectorally" delimited SIs, i.e., systems that include only a part of a regional, national or international system. These are delimited to specific technological fields (generic technologies) or product areas. The "technological systems" approach belongs to this category (although it did not initially use language associated with systems of innovation) (Carlsson and Stankiewicz 1995: 49).

According to Breschi and Malerba, "a Sectoral Innovation System (SIS) can be defined as that system (group) of firms active in developing and making a sector's products and in generating and utilising a sector's technologies" (Breschi and Malerba 1997: 131; see also Ch. 14 by Malerba in this volume). Specific technologies or product areas are used to define the boundaries of sectoral systems, but they must also normally be geographically delimited (if they are not global). However, it is not self-evident what a sector is, i.e., the *sectoral* boundaries are partly a theoretical—or social—construction, which may reflect the specific purpose of the study. It should also be noted here that the specification of sectoral boundaries is particularly difficult with regard to new sectors or sectors going through radical technological shifts.

3. Within a geographical area (and perhaps also limited to a technology field or product area), the whole socio-economic system cannot, of course, be considered to be included in the SI. The question is, then, which parts should be included? This is a matter of defining the boundaries of SIs in terms of activities. These have to be defined for all kinds of SIs: national, regional, and sectoral. This is more complicated than in the cases of spatial and sectoral boundaries.

Early work in the SI approach did not address the activities in SIs in a systematic way, and therefore failed to provide clear guidance as to what should be included in a system of innovation. Nor have the boundaries of the systems in terms of activities been defined in an operational way since then.

In Section 7.2, a system of innovation was defined as including "all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations." If the concept of innovations has been specified (e.g., as in the beginning of Section 7.2), and if we know the determinants of their development, diffusion, and use, we will be able to **(p. 201)** define the boundaries of the SIs in terms of activities. This is one reason why it is so important to identify the activities in SIs. Admittedly, this is not as easy in practice as in principle, since we simply do not know in detail and systematically all the activities in SIs or determinants of innovation processes. As pointed out in Section 7.4.3.1, any list of activities in an SI must be treated as provisional and subject to change as our knowledge increases.

7.5 Research Gaps and Opportunities

In innovation studies, there has traditionally been a tendency to focus much more on technological process innovations and goods product innovations than on organizational process innovations and service product innovations. There are strong reasons to use a comprehensive innovation concept and give more attention to non-technological and intangible kinds of innovation (as proposed in Section 7.3.2). Such an orientation is implicit in the fact that we talk about systems of innovation and not systems of technological change.

More research should be done on the activities in SIs, i.e., on the determinants of the development, diffusion, and use of innovations. One particular task may be to revise and restructure the preliminary list of important activities in SIs presented in Section 7.4.3.1. Such a list can provide an important point of entry for empirical innovation studies.

A stronger focus on activities would increase our knowledge of, and capacity for, explaining innovation processes. Given our limited systematic knowledge about determinants of innovations, *case studies* of the determinants of specific innovations or specific (and narrow) categories of innovations would be very useful. In particular, I believe that *comparative* case studies have great potential, comparing innovations systems of various kinds as well as the determinants of innovation processes within them. Relevant questions to ask would include: Which activities of which organizations are important for the development, diffusion, or use of specific innovations? Is it possible to distinguish between important activities and less important ones? Which institutional rules influence the organizations in carrying out these activities? Suchwork could further develop the SI approach and contribute to the creation of partial theories about relations between variables within SIs. Such theories would also improve our ability to specify the boundaries of innovation systems.

In this chapter, I have accounted for many of the existing empirical studies that claim to have been carried out within a SI framework. The result has, on the whole, **(p. 202)** been rather disappointing in the sense that many of the studies cited have not been related to the SI approach in a profound way, although there are exceptions. The SI approach has often been used more as a label than as an analytical tool. It has not influenced the empirical studies in depth; for example, it has not been used to formulate hypotheses to be confronted to empirical observations. This has made a virtuous fertilization between conceptual and empirical work, that is so important to scholarly progress in this and other fields of research, difficult to achieve. The state of the art of the SI approach is partly responsible for this: it is often presented in too vague and unclear a way.

Clearly defined concepts are necessary in order to identify empirical correspondents to theoretical constructs and to identify the data that should be collected. Therefore, conceptual specifications are crucial for empirical studies and it is important to increase the rigor and specificity of the SI approach. This can be done by clarifying the meaning of key concepts such as innovation, function, activities, components, organizations, and institutions, as well as the relations among them. Moving in this direction does not mean transforming social science into something similar to natural science. For example, one cannot abstract from time and space, since there are no universal laws in the social sciences. It is also important to continue the work of specifying the boundaries of SIs of various kinds.

There are strong reasons to integrate conceptual and theoretical work with empirical studies in an effort to identify determinants of the development, diffusion, and use of innovations. Such integration can be expected to lead to cross-fertilization—just as in the case of work on interactive learning referred to in Section 7.4.4. The SI approach should be used as a conceptual framework in specific empirical analyses of concrete conditions. Testable statements or hypotheses should be formulated on the basis of the approach and these should be investigated empirically, by using qualitative as well as quantitative observations. Theoretically based empirical work is the best way to straighten up the SI approach conceptually and theoretically; the empirical work will, in this way, serve as a “disciplining” device in an effort to develop the conceptual and theoretical framework. Such work would increase our empirical knowledge about relations between the main function, activities, organizations, and institutions in SIs. This knowledge could then be a basis for further empirical generalizations to develop the framework—including theory elements. In other words, empirically based theoretical work is also very fruitful. Independently of where one starts, the important thing is that there should be a close relationship between theoretical and empirical work.

The array of determinants of innovations and the relations among them can be expected to vary over time and space, i.e. between innovation systems, as well as among different categories of innovation. For example, the determinants will probably vary between process and product innovations as well as between incremental and radical innovations (and between subcategories of these). It is therefore important to pursue the explanatory work at a meso- or micro-level of aggregation. **(p. 203)** *Taxonomies* of different categories of innovations can therefore be expected to be an important basis for this work.

Innovation studies have traditionally included research on R&D and its significance for innovation processes. A well-educated labor force is necessary for both R&D and innovation, and competence building therefore should receive greater emphasis in innovation studies and in the SI approach. We should not only address those learning processes that lead directly to process and product innovations, but also address the knowledge infrastructure and learning in a more generic way.

This "widening" might eventually transcend the SI approach and move into thinking along the lines of "Systems of Learning" rather than "Systems of Innovation." Systems of Learning would include individual learning (leading to the creation of human capital) as well as organizational learning (leading to the creation of structural capital, e.g. innovations). It would include work on three kinds of learning: R&D, innovation, and competence building, and, above all, the relations between them. This also points out one direction in which the SI approach is currently developing.

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Notes:

(*) Asterisked items are suggestions for further reading.

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(2.) The regional and sectoral versions are dealt with in more detail in Ch. 11 by Asheim and Gertler and in Ch. 14 by Malerba in this volume.

(3.) In this sense, this chapter is a continuation along the same trajectory as earlier attempts, e.g. Edquist (1997*b*), Edquist and Johnson (1997) and Edquist (2001).

(4.) "[T]he 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" (Nelson and Rosenberg (1993: 4).

(5.) They mention organizations such as firms, industrial research laboratories, research universities, and government laboratories.

(6.) Their definitions of NSIs do not include, for example, consequences of innovation—which does not, of course, exclude the fact that innovations, emerging in innovation systems, have tremendously important consequences for socio-economic variables such as productivity growth and employment. To distinguish between determinants and consequences does not, of course, exclude feedback mechanisms.

(7.) It should also be mentioned that the publications mentioned in Section 7.2 by no means exhaust the stock of literature addressing or using the SI approach. Edquist and McKelvey (2000) is a reference collection containing forty-two articles on SIs, some of which are reviewed in this chapter. Other contributions will be addressed in later sections of this chapter.

(8.) There are chapters in the Handbook on service product innovations (Ch. 16 by Ian Miles) and on organizational process innovations (Ch. 5 by Alice Lam).

(9.) See Lundvall et al. (2002: 221) and Lundvall (2003: 9), where it is argued that the pragmatic and flexible character of the concept may be seen to be a great advantage. However, Lundvall et al. (2002: 221) also argue that efforts should be made to give the concept a stronger theoretical foundation.

(10.) 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 2002*a*: 11). A similar position is taken by Fischer (2001: 213–14).

(11.) 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 rather be considered to be an approach than a theory.

(12.) Although there are other kinds of actors than organizations—e.g. individuals—the terms "organizations" and "actors" are used interchangeably in this chapter.

(13.) The five activities are R&D, implementation, end-use, education, and linkage.

(14.) These are: to create new knowledge, to guide the direction of the search process, to supply resources, to create positive external economies, and to facilitate the formation of markets (Johnson and Jacobsson 2003: 3–4). Anna Johnson—now Anna Bergek—previously discussed these issues in Johnson (1998). There she identified functions mentioned or implicitly addressed in various previous contributions to the development of the SI approach. She also listed and stressed various benefits of using the concept of "function" in SI studies.

(15.) These functions are to create human capital, to create and diffuse technological opportunities, to create and diffuse products, to incubate (provide facilities, equipment, and administrative support), to facilitate regulation that may enlarge the market and facilitate market access, to legitimize technology and firms, to create markets and diffuse market knowledge, to enhance networking, to direct technology, market and partner search, to facilitate financing, and to create a labor market that the new technology-based firms can utilize.

(16.) The activities in SIs are the same as the determinants of the main function. An alternative term to "activities" could have been "subfunctions." I chose "activities" in order to avoid the connotation with "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.

(17.) The activities in this sectoral system are discussed in Edquist (2003: 11).

(18.) Specific ways in which knowledge transfer takes place between universities and firms are analyzed in detail for the case of Austria in Schibany and Schartinger (2001).

(19.) When designing the anthology edited by Lundvall (1992), the Aalborg group planned to have a chapter on the education system. However, in the end it was not included (Lundvall and Christensen (1999: 3).

(20.) Competence building has also been addressed in some OECD publications, including a study on knowledge management in the learning society, managed by the Centre for Educational Research and Innovation (CERI) (OECD 2000). Another CERI study includes a conceptual framework which tries to integrate "individual learning" (e.g. education) and "organizational learning" (e.g. innovation) into a generic conceptual framework on "learning." It also contains empirical studies of the respective roles of education and innovation for economic growth at a regional level (OECD 2001*d*). Another contribution is the DISKO project in Denmark as reported by Lundvall (2002).

(21.) In Rickne 2000: ch. 7, there is a more detailed discussion of the relations between activities and organizations.

(22.) As we saw in Section 7.4.3.1, there are also important relations between activities, i.e. relations between determinants of innovations processes.

(23.) Coriat and Weinstein address the relations between organizations and institutions as well, although they consider firms to be both institutions and organizations (Coriat and Weinstein 2002: 279).

(24.) The so-called "varieties of capitalism" literature has a wider perspective and focuses on a broader range of institutions and organizations. Examples are Hollingsworth and Boyer (1997), Whitley (1999), Hall and Soskice (2001), and Whitley (2002). Space limitations prevent mefrom going into this literature here. The same applies to "the social systems of innovation" perspective (e.g. Amable 2000) and the Triple-Helix perspective (e.g. Etzkowitz and Leydesdorff (2000).

(25.) An "industrial complex" or "cluster" as used by Porter (1990, 1998) can, if it is regionally delimited, be seen as a combination of a sectoral and a regional SI.

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