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Innovation, Knowledge Creation and Systems of Innovation

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Abstract: The main objective of this paper is to provide greater understanding of the systems of innovation approach as a flexible and useful conceptual framework for spatial innovation analysis. It presents an effort to develop some missing links and to decrease the conceptual noise often present in the discussions on national innovation systems. The paper specifies elements and relations that seem to be essential to the conceptual core of the framework and argues that there is no a priori reason to emphasize the national over the subnational (regional) scale as an appropriate mode for analysis, irrespective of time and place. Localised input-output relations between the actors of the system, knowledge spillovers and their untraded interdependencies lie at the centre of the argument.

The paper is organized as follows. It introduces the reader, first, to some basic elements and concepts that are central to understanding the approach. The characteristics of the innovation process are examined: its nature, sources and some of the factors shaping its development. Particular emphasis is laid on the role of knowledge creation and dissemination based on the fundamental distinction between codified and tacit forms. These concepts recur throughout the paper and particularly in discussions on the nature and specifications of the systems approach. The paper concludes by summarizing some of the major findings of the discussion and pointing to some directions for future research activities.

Keywords: innovation, interaction, knowledge, systems, territory

1. Introduction

At the turn of the century the world economy is undergoing a process of profound restructuring. Three developments have set the stage for this process. The first is a technological revolution, centering initially on telecommunications and microprocessors, but now extending to biological science that has created new industries and changed the methods that many established industries employ for production and distribution. The second has been a managerial revolution, initially associated with the diffusion of Japanese techniques for quality control, team production and supplier relations, but now extending to many innovative forms of production employed around the world including increasing individualisation and diversification of working relationships. The third development, reinforcing the first two, is the considerable empowerment of capital accompanied by a decline of the influence of labour unions. Under these conditions nation-states and regions come increasingly under stress to sustain competitiveness and, thus, economic welfare.

Today, it is widely recognized that technological change is the primary engine for economic development. Innovation - the heart of technological change - is essentially the innovation process that depends upon the accumulation and development of relevant knowledge of a wide variety. Certainly individual firms play a crucial role in the development of specific innovations but the process that nurtures and disseminates technological change involves a complex web of interactions among a range of firms, other organisations and institutions.

The systems of innovation approach has recently received considerable attention as a promising conceptual framework for advancing our understanding of the innovation process in the economy. The approach contrasts with previous attempts such as the traditional OECD approach to technological change and innovation that focused on the R&D system in the narrower sense, primarily by analysing resource inputs and outputs of the system. A too narrow focus on R&D overlooks the importance of other types of innovative efforts in the business sectors and, thus, the innovative performance of low-tech sectors in the economy.

The main objective of this paper is to provide greater understanding of the approach as a flexible and useful conceptual framework for innovation analysis. It presents an effort to develop some missing elements and to decrease the conceptual noise often present in the discussions. The subsequent part of the paper examines the characteristics of the innovation process: its nature, sources and some of the factors that shape its development. It aims to introduce the reader to concepts that are central to understanding the systems approach and to emphasize the role of knowledge creation and dissemination.

A system of innovation may be thought of as a set of actors such as firms, other organisations, and institutions that interact in the generation, diffusion and use of new - and economically useful - knowledge in the production process. Institutions may be viewed as sets of common habits, routines, established practices, rules or laws that regulate the relations and interactions between individuals within as well as between and outside the organisations. Part 3 specifies elements and relations that are essential to the conceptual core of the systems of innovation approach. Territorially based systems build on spatial proximity - as either regional (subnational), national or global systems of innovation. Current research practice is focusing almost exclusively on the national scale in systems of innovation research (see, for example, Lundvall 1992, Nelson 1993, OECD 1994, Edquist 1997a). But - as argued - there is no a priori reason to emphasize this particular spatial scale, irrespective of time and place. A strong case is made for the importance of the subnational scale as an appropriate mode of analysis. Localised input-output relations between the actors of the system, knowledge spillovers and their untraded interdependencies lie at the heart of this reasoning. The concluding part of the paper summarizes some of the major findings of the discussion and points to some directions for future research.

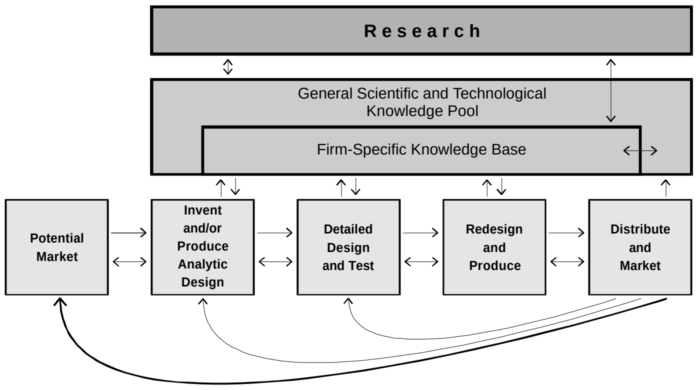
2. Innovation and Technological Change

The discussion that follows in this section builds on the converging elements from two different traditions of theoretical and empirical work in technological change. The first tradition - which might be labelled evolutionary or neo-Schumpeterian - has always stressed the dynamic and systemic nature of the innovation and diffusion processes, as well as the close links between the two. It has illustrated its theoretical framework empirically with detailed case studies as well as with work related to the history of technology. The second tradition that might be labelled neoclassical has steadily moved towards a view that emphasizes dynamic and systemic aspects and, thus, shares many common elements with the first. Its rigorous theoretical and empirical framework is contributing to the clarification and quantification of many of the, as yet, unanswered questions in this field.

2.1 Innovation as an Interactive Process

Technological change is a complex process that is not yet fully understood. This complexity stems partially from the diverse set of phenomena that are subsumed under the term innovation. Bienaymé (1986), for example, distinguishes between product innovations; innovations destined to resolve, circumvent or eliminate a technical difficulty in manufacture or to improve services; innovations for the purpose of saving inputs (e.g. energy conservation, automation); and, innovations to improve the conditions of work. These very different phenomena have made generalization difficult (Malecki 1997). For a long time thinking about technological change and innovation has been guided by linear models - in the 1950s and 1960s by the technology-push and then the need-pull model. In the former, the development, production and marketing of new technology [defined in the sense of Mansfield et al. (1982) as consisting of a pool or set of knowledge] was assumed to follow a well defined time sequence which began with basic and applied research activities, involved a product development stage, and then led to production and possibly commercialisation. In the second model, this linear sequential process emphasized demand and markets as the source of ideas for R&D activities. These models that have guided the formulation of national R&D policies in the past have come under increasing attack in recent years for several reasons, not the least of which is the absence of feedback loops between the downstream (market-related) and upstream (technology-related) phases of innovation. Intensifying competition and shorter product life cycles are necessitating a closer integration of R&D with the other phases of the innovation process.

This criticism has led to a broader view of the process of innovation as an interactive process. The presently emerging innovation theory emphasizes the central role of feedback effects between the downstream and upstream phases of innovation and the numerous interactions between science, technology and innovation related activities within and among firms. Through interaction and feedback different pieces of knowledge become combined in new ways or new knowledge is created.



Source: Adapted with minor changes from Kline and Rosenberg (1986), Myers and Rosenbloom (1996), Malecki (1997).

Fig. 1 An interactive model of the innovation process: feedbacks and interactions (Fischer 1999)

Figure 1 represents what is referred to as the chain-linked model (Kline and Rosenberg 1986, OECD 1992, Malecki 1997). The innovation process at the firm level is portrayed as a set of activities that are linked to one another through complex feedback loops. The process is visualized as a chain, starting with the perception of a new market opportunity and/or a new invention based on novel pieces of scientific and/or technological knowledge followed by the analytical design for a new product or process and testing, redesign and production, and distribution and marketing. Short feedback loops link each downstream phase in the central chain with the phase immediately preceding it. Longer feedback loops link perceived market demand and product users with phases upstream. The second set of relationships visualized in figure 1 link the innovation process embedded in the firm with its firm-specific knowledge base, the general scientific and technological pool and with research in general.

The model combines two types of interaction. One concerns processes that occur through new forms of product development practice within the firm and create appropriate feedback relationships (see, for example, Nonaka and Takeuchi 1995). The second refers to relationships external to a given firm with other companies such as customers, suppliers of inputs (including finance and knowledge), research institutions and even competitors. Cooperation can take place with various mixes of internal and external actors. Under this model technological innovation is seen to be the result of a complex interplay among various actors, with partly common and partly conflicting interests. Technological progress is, thus, dependent on how the actors interact with each other, internally and externally.

In recent years, new forms of interfirm agreements bearing on technology have developed alongside the traditional means of technology transfer – licensing and trade in patents – and they often have become the most important way for firms, regions and nation-states to gain access to new knowledge and key technologies. The network form of governance - involving both action by mediating third parties as well as 'relational contracting' between firms - can overcome market imperfections as well as the rigidities of vertically integrated hierarchies. The limitations of these two modes of transaction in the context of knowledge and innovation diffusion have pushed interfirm agreements to the forefront of corporate strategy in the last few decades (Chesnais 1988).

There are many definitions of *innovation networks* (see De Bresson and Amesse 1991; Freeman 1991); however, the one offered by Tijssen (1998, p. 792) captures the most important features of the network mode. He suggests defining a network as

> ‘an evolving mutual dependency system based on resource relationships in which their systemic character is the outcome of interactions, processes, procedures and institutionalisation. Activities within such a network involve the creation, combination, exchange, transformation, absorption and exploitation of resources within a wide range of formal and informal relationships.’

In a network mode of resource allocation, transactions occur neither through discrete exchanges nor by administrative fiat, but through networks of individuals or institutions, engaged in reciprocal, preferential and supportive actions (Powell 1990).

Networks show a considerable range and variety in content, which differs according to specific circumstances. Their nature is shaped by the objectives for which network linkages are formed. For example, they may focus on a single point of the R&D-to-commercialisation process or may cover the whole innovation process. The content and shape of a network will also differ according to the nature of relationships and linkages between the various actors involved (see Chesnais 1988). At the one end of the spectrum lie highly formalised relationships. The formal structure may consist of regulations, contracts and rules that link actors and activities with varying degrees of constraint. At the other end are the network relations of a mainly informal nature, linking actors through open chains. Such relations are very hard to measure (Freeman 1991). Whenever interfirm transactions tend to be small in scale, variable and unpredictable in nature, requiring face-to-face contact, then network formation will focus on the close proximity of the partners involved (Storper 1997).

For firms, networks represent a response to quite specific circumstances. Where complementarity is a prerequisite for successful innovation, network agreements may be formed in response to specific proprietary tacit knowledge. The exchange of such complementary assets can take place only through very close contacts and personalised, and generally localised, relationships (OECD 1992). It is especially shared trust that establishes an environment which facilitates exchange of knowledge (Maskell and Malmberg 1999). When technology is moving rapidly, flexibility and reversibility along with risk sharing represent another reason for preferring a network mode. The network mode provides a far higher degree of flexibility (OECD 1992). Interfirm agreements are easier to dissolve than internal developments or mergers. Porter and Fuller (1986) stress speed as being among the advantages that networks have over acquisition or internal development through arm's length relationships. This advantage is becoming increasingly important as product life cycles have shortened and competition has intensified. High R&D costs may be another distinct reason for networking and can force management, especially in smaller firms, to pool resources with other firms, in some cases even with competitors (OECD 1992).

2.2 Knowledge Generation and Diffusion

Recognition of the interactive nature of the innovation process has resulted in the break down of the earlier distinction between innovation and diffusion. The creation of knowledge and its assimilation are part of a single process. Firms need to absorb, create and exchange knowledge interdependently. In other words, innovation and diffusion usually emerge as a result of an interactive and collective process within a web of personal and institutional connections which evolve over time.

Knowledge transfer may occur through disembodied or equipment-embodied diffusion. The latter is the process by which innovations spread in the economy through the purchase of technology-intensive machinery, such as computer-assisted equipment, components and other equipment. Disembodied technology diffusion refers to the process where technology and knowledge spread through other channels not embodied in machinery (OECD 1992). This type of knowledge transfer may occur via descriptions of new products or production processes found in catalogues, publications or patent applications, but also via seminars and conferences, and R&D personnel turnover. It can also be the by-product of mergers and acquisitions, joint ventures or other forms of interfirm co-operation.

Two notions are central to an understanding of disembodied technology diffusion: absorption capacity and knowledge spillovers. The *absorption capacity* of firms and other organisations refers to the ability to learn, assimilate and use knowledge developed elsewhere through a process that involves substantial investments, especially of an intangible nature (Cohen and Levinthal 1989). This capacity depends crucially on learning experience, which in turn may be enhanced by in-house R&D activities. The concept of absorption capacity implies that in order to have access to a piece of knowledge developed elsewhere, it is necessary to have done R&D on something similar (Saviotti 1998). Thus, R&D may be viewed as serving a dual, but strongly interrelated role: first, developing new products and production processes, and second, enhancing the learning capacity.

Firms, especially smaller firms, that lack appropriate in-house R&D facilities have to develop and enhance their absorption capacity by other means, such as learning from customers and suppliers, interacting with other firms and taking advantage of knowledge spillovers from other firms and organisations (Lundvall 1988). These sources provide the know-why (i.e. procedural knowledge), know-how (i.e. skills and competences) and know-what (i.e. factual knowledge) important for entrepreneurial success (Johannisson 1991; Malecki 1997). Network arrangements of different kinds provide a firm the assistance necessary to take advantage of outside knowledge.

Knowledge spillovers [i.e. knowledge created by one firm can be used by another without compensation or with compensation less than the value of the knowledge] arise because knowledge and innovation are partially excludable and non-rivalrous goods (Romer 1990). Lack of *excludability* implies that knowledge producers have difficulty in fully appropriating the returns or benefits and thereby preventing other firms from utilising the knowledge without compensation (Teece 1986). Patents and other devices, such as lead times and secrecy, are a way for knowledge producers to partially capture the benefits related to their knowledge creation. It is important to recognise that even a completely codified piece of knowledge cannot be utilised at zero cost by everyone. Only those economic agents who know the code are able to do so (Saviotti 1998).

By non-rivalry knowledge distinguishes itself from all other inputs in the production process. *Non-rivalry* means essentially that a new piece of knowledge can be utilised many times and in many different circumstances, for example by combining with knowledge coming from another domain. The interest of the knowledge users is, thus, best served if innovations, once produced, are widely available and diffused at the lowest possible cost. This implies an environment rich in knowledge spillovers (OECD 1992).

Recent understanding of the nature of knowledge associated with technological innovation processes is at the heart of conceptual advance. Innovation - in the form of advancing technology - combines two types of knowledge: *codified* [also termed explicit] knowledge drawn from previous experience and *uncodified* [implicit] knowledge which is industry-specific, firm-specific or even individual-specific, and has some degree of tacitness. In each technology there are elements of tacit and specific knowledge. Following Polanyi (1966) *tacitness* refers to those elements of knowledge that persons have which are ill-defined, uncodified and which they themselves can not fully articulate and which differ from person to person, but which may to some degree be shared by collaborators who have a common experience. Most shared knowledge is seldom completely tacit or completely codified [i.e. explicit]. In most cases a piece of knowledge can be located between these two two extremes. Knowledge is not created codified and is always at least partly tacit in the minds of those who create it. Codification is required because knowledge creation is a collective process that requires complex mechanisms of communication and transfer (Saviotti 1988). As tacit components - such as common practice based on modes of interpretations, perceptions and value systems - in the firm's knowledge base increase, knowledge accumulation becomes more experience based, i.e. based on firm specific skills and competences like reliability and reputation. Such forms of knowledge can only be shared, communicated or transferred through network types of relationships.

In an economic system where innovation is crucial for competitiveness, the organisational ability to create knowledge becomes the foundation of innovating firms. Nonaka and Takeuchi (1995) have recently proposed a simple, but elegant model to account for the generation of knowledge in the firm. What they label the knowledge-creating company is based on the organisational interaction between codified [explicit] knowledge and implicit knowledge at the source of innovation. Organisational knowledge creation that reflects the importance of institutional learning processes involves two forms of interactions: between tacit and explicit knowledge, and between individuals and the organisation. The interaction between the two forms of knowledge is central to the dynamics of knowledge creation in the business organisation. It will bring about four major processes of knowledge conversion that require special learning processes and all together constitute knowledge creation (see figure 2):

- *from tacit into explicit knowledge*, the externalisation mode that holds the key to knowledge creation because it generates new explicit concepts from tacit knowledge; codification is at the heart of this mode,
- *from explicit to tacit knowledge*, the internalisation mode that is closely related to learning-by-doing and leads to operational/procedural knowledge,
- *from tacit into tacit knowledge*, the socialisation mode that is a procss of sharing experiences and thereby creating some sort of novel tacit knowledge such as, e.g., technical skills;
- *from explicit to explicit knowledge*, the combination mode that is a process which involves combining different bodies of explicit knowledge in order to create systemic knowledge; a mode that is widely occurring in instructing, training and supervision of employees.

It is important to note that knowledge is performed by individuals, not by the organisation itself. If the knowledge can not be shared with others or is not amplified at the group level the knowledge does not move up to the organisational level.

The core of the organisational knowledge creation process, Nonaka and Takeuchi (1995) argue, takes place at the group level, but the organisation provides the necessary enabling conditions, the organisational context formed by conventions, managerial ideologies, customs, habits and established business practices that facilitate the creation and accumulation of knowledge at the organisational level. Organisational knowledge creation is, thus, a complex non-linear interactive process characterized by a continuous and dynamic interaction between tacit and explicit forms of knowledge that is shaped by shifts between the above four different modes of knowledge transformation. This organisational knowledge creation process requires the participation of the workers in the innovation process so that they do not keep their tacit knowledge solely for their own profit. It also requires stability of the labour force in the firm because only then it is rational for the individual to transfer his/her knowledge to the organisation, and for the firm to diffuse explicit knowledge (Castells 1996). On-line communication along with artificial agents and expert systems have become powerful tools in recent times in assisting to manage the complexity of necessary organisational links in the knowledge creation process.

	Tacit Knowledge *To* Explicit Knowledge	
Tacit Knowledge	Sympathized Knowledge *Socialisation*	Conceptual Knowledge *Externalisation*
From		
Explicit Knowledge	Procedural Knowledge *Internalisation*	Systemic Knowledge *Combination*

Fig. 2 Four major processes of knowledge conversion (Nonaka and Takeuchi 1995)

3. Systems of Innovation: Conceptual Framework and Localised Systems

Actions that aim at favouring the building and consolidation of innovation-related networks have always been an implicit component of national science and technology policies. Today, it seems possible to approach this dimension of policy making more explicitly on the basis of the systems of innovation approach, a conceptual framework that has recently received considerable attention both in academia and in the policy arena (Freeman 1987, Lundvall 1992, Nelson 1993, OECD 1994, Edquist 1997a).

3.1 A Conceptual Framework to Innovation Systems Research

The systems of innovation approach is not a formal theory, but a conceptual framework - a framework in its early stage of development. The idea that lies at the centre of this framework is - as already mentioned above - that the economic performance of territories (regions or countries) depends not only on how business corporations perform, but also on how they interact with each other and with the public sector in knowledge creation and dissemination. Innovating firms operate within a common institutional set-up, and they jointly depend on, contribute to and use a common knowledge infrastructure. Consequently, the approach places innovation, knowledge creation and diffusion at its very centre. Innovation and knowledge creation are viewed as interactive and cumulative processes contingent on the institutional set-up. It departs from the network school of research (Håkansson 1987) with its emphasis on the role of the institutional set-up, i.e. that institutions play in the innovation process (see Edquist and Johnson 1997). The concept of institutions refers at an abstract level to the recurrent patterns of behaviour: socially inherited habits, conventions including regulation, values and routines (Morgan 1997) that assist in regulating the relations between people and groups of people within as well as between and outside the organisations.

A *system of innovation* can be thought of as consisting of a set of actors or entities such as firms, other organisations and institutions that interact in the generation, use and diffusion of new - and economically useful - knowledge in the production process. At the current stage of development there is no general agreement as to which elements and relations are essential to the conceptual core of the framework and what is their precise content (Edquist 1997b). This leaves room for a conceptual discussion.

Systems that attempt to encompass the whole innovation process may be expected to include four key building blocks that comprise groups of actors sharing some common characteristics and institutions governing the relations within and between the groups (see figure 3):

- *The Manufacturing Sector*

  This sector is made up of manufacturing firms [the central actors in the system of innovation] and their R&D laboratories that play a fundamental role in performing research and technological development.

- *The Scientific Sector*

  The scientific sector plays a very important role in technological innovation. It consists of two components: a training component that includes educational and training organizations on which the supply of scientists, engineers, technicians and other skilled workers possessing appropriate skill profiles depends, and a research component including universities and other research organizations that generate and diffuse knowledge and produce documents in the form of scientific publications. This sector involves those agents [government, private non-profit, universities, higher education] that both fund and carry out research or offer education.

- *The Sector of Producer Services*

  This sector includes organisations or units within larger organisations which provide assistance or support to industrial firms for the development and/or introduction of new products or processes. This may take any of the following forms: financial, technical advice or expertise, physical (equipment, software, computing facilities), marketing or training related to new technologies or procedures.

- *The Institutional Sector*

  Many of the tasks that a typical firm must perform require coordination, either within the firm between various groups of employees or outside it with other suppliers, other firms, and providers of producer services including finance. There is a variety of ways in which the performance of these tasks can be coordinated, each involving different kinds of firm behaviour. But in general one can distinguish market coordination that relies on the kind of market institutions neo-classical economics usually assumes to be important, and non-market coordination that utilizes a greater range of institutional arrangements. The latter depends upon the presence of formal and informal institutions that regulate the relations between the actors of the system, enhance their innovation capacities and manage conflicts and cooperation. Two types of such institutions may be distinguished (see, for example, Edquist and Johnson 1997): formal institutions including, e.g., employer associations, legal and regulatory frameworks, and informal institutions including the prevailing set of rules, conventions and norms that prescribe behavioural roles and shape expectations.

To describe and compare systems of innovation in the broad sense one has to open the boxes of the subsystems, identify the constituent elements and specify those relations between and within the subsystems that have importance for innovation performance. A first source of diversity among different systems might be due to differences in the macroeconomic context, the quality of information and communication infrastructures as well as in factor and product market conditions.

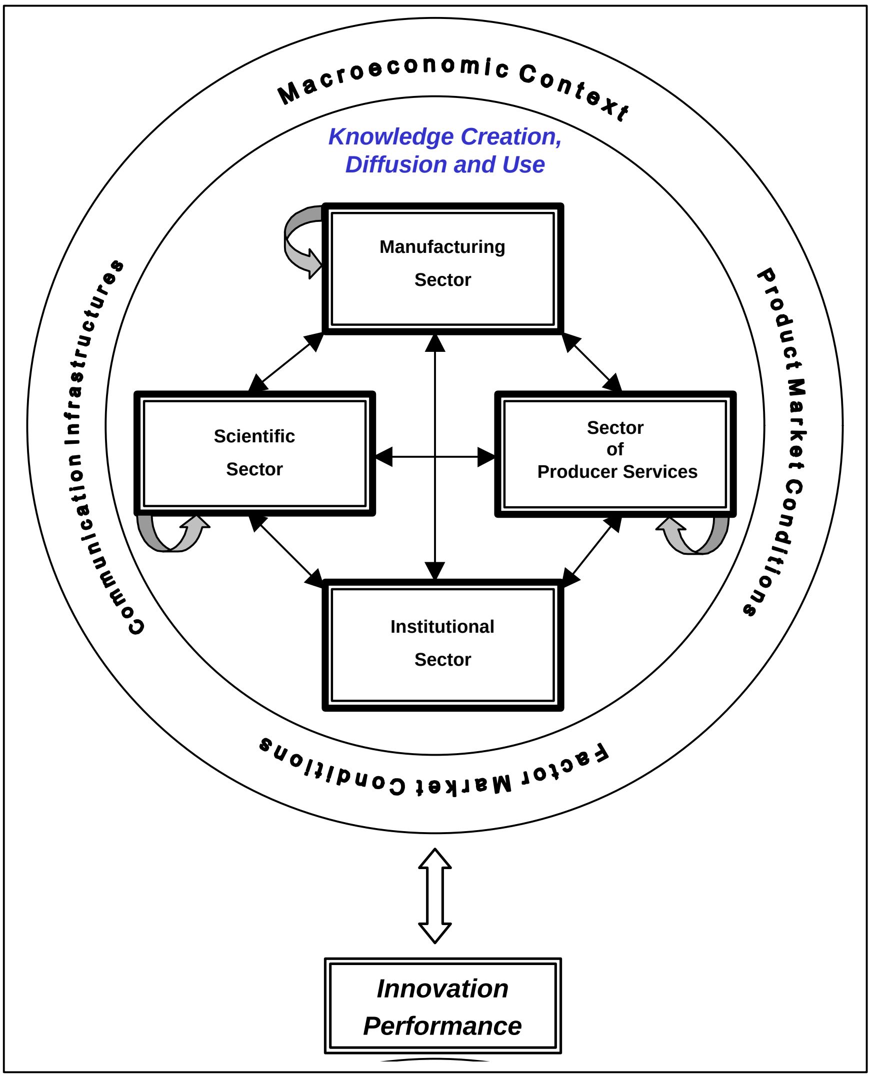


Fig. 3 The major building blocks of a System of Innovation

The innovation performance of an economy is notably determined by the characteristics and abilities of its individual firms and other organisations contingent on its institutions, but also very much by the different kinds of relations between them, i.e. the ways they interact with each other and with the sector of institutions. The character as well as the change of these interaction patterns are central aspects of innovation systems. Linkages within and between the sectors can be specified in terms of knowledge and information flows, flows of investment funding, flows of authority and labour mobility (scientists, technicians, engineers and other skilled workers) as important mechanisms for the transfer of tacit forms of knowledge particularly from the scientific to the manufacturing sector, but also within the latter.

Network analysis may assist to identify the central actors in the four subsystems (building blocks) in specific cases, and of the type of information and knowledge they exchange.

Different kinds of norms, conventions and established practices that are expected to have important implications for knowledge creation and learning are forming the economy's patterns of interaction, both inside firms and other orgnisations and between them. Searching for and explaining interaction patterns that lead to the creation, dissemination and use of knowledge is part of the systems of innovation approach (Johnson 1997). It can be hypothesized, for example, that there will be strong and weak, regular and irregular interactions which shape the system.

Firms are the main carriers of technological innovation. Their capacity to innovate is partly determined by their own capabilities, and partly by their absorption capacities. Increasing complexity, costs and risks in innovation enhance the role of collaboration and networking in the innovation process to reduce moral hazard and transaction costs. In addition to traditional market-mediated relations such as the purchase of equipment and licensing of technology, firms exchange information and engage in mutual learning in their roles as customers, suppliers and subcontractors, and even competitors. A coherent system of innovation has necessarily to include a series of more or less coordinated network-like relations such as (Fischer 1999):

- *Customer-producer relations,* i.e., forward linkages of manufacturing firms with distributors, value-added resellers and end users,
- *Producer-manufacturing supplier relations* which include subcontracting arrangements between a client and its manufacturing suppliers of intermediate production units,
- *Producer-service supplier relations* which include arrangements between a client and its producer service partners [especially computer and related service firms, technical consultants, business and management consultants],
- *Producer network relations* which include all co-production arrangements [bearing on some degree or another on technology] that enable competing producers to pool their production capacities, financial and human resources in order to broaden their product portfolios and geographic coverage,
- *Science-industry collaboration* between universities and industrial firms at various levels pursued to gain rapid access to new scientific and technological knowledge and to benefit from economies of scale in joint R&D, such as direct interactions between particular firms and particular faculty members, or joint research projects, as through consulting arrangements, or mechanisms that tie university or research programs to groups of firms.

3.2 Territorially Based Systems of Innovation - National or Regional?

Within the systems of innovation approach to innovation analysis, different types of systems have been defined. A major distinction can be made (see Gregersen and Johnson 1997) between

- *sectoral* or *technological systems* that are based on the concept of technological regimes and take a specific sector or a specific technology as their point of departure (see, for example, Carlsson 1995, Breschi and Malerba 1997), and
- *localised* [or territorially based] *systems* which - built on some kind of spatial proximity - may be manifested at different geographical scales - as either *local*, *regional* [i.e. subnational], *national* or *global systems of innovation* (see, for example, Lundvall 1992, Nelson 1993, Braczyk et al. 1998, Malecki and Oinas 1999).

Whether a system of innovation should be sectorally/technologically or spatially defined depends on the objective and context of a study at hand. These two basic variants of the systems of innovation approach complement rather than exclude each other.

Geographical proximity can be considered as a *necessary*, *but not sufficient* precondition for the existence of a territorially based system of innovation. A proximity that is only geographic in nature can provide the basis for the presence of an agglomeration of firms, but not necessarily for the presence of a system of innovation. The potential of an innovation system crucially depends, above all else as discussed above, on two factors: geographic proximity and technological proximity. *Geographic proximity* indicates the positioning of actors within a given spatial framework, while *technological proximity* pertains to the association with the set of vertical or horizontal interdependencies within the scope of production relationships. The transformation of these two types of proximity into a territorially based system of innovation assumes that they be institutionally organized and structured (Kirat and Lung 1999). Thus, territorially defined systems of innovation are grounded in collective action at a territorial level. The cohesiveness of a territorially based system of innovation is provided by a spectrum of informal institutions, i.e. the territorially prevailing set of rules, conventions and norms (Kirat and Lung 1999).

The concept of territorially based systems of innovation evolved first in a national context (Freeman 1987), and then in a regional context (see, for example, Cooke et al. 1997, Brazcyk et al. 1998, Malecki and Oinas 1999). The tradition of studying national systems of innovation has been a recent development (see, for example, Lundvall 1992, Nelson 1993, Niosi et al. 1993, OECD 1994, Edquist 1997a). Interesting questions and findings have emerged from this literature that sought to establish the extent of convergence and divergence among national innovation systems. This question was of special interest in Europe, given the emergence of European innovation-related institutions that have developed simultaneously with European Community institutions (see Caracostas and Soete 1997).

It is increasingly being recognized that important elements of the process of innovation become transnational and global, or regional rather than national. The driving forces behind this recognition are two processes that are simultaneously at work today: the process of globalisation of factor and commodity markets and the regionalisation of knowledge creation and learning. This concurs with the view expressed in Ohmae's work on the hollowing-out of the nation state in an increasingly borderless economic world and its identification of the regional rather than the national scale as the relevant economic scale at which leading edge business competitiveness is being organised in practical terms (Ohmae 1995). Regions like Baden-Württemberg, Wales, Hongkong-Canton are conceived as much more economically meaningful than, for example, Italy with its abiding north/south divide (Brazcyk et al. 1998).

This awareness does not claim that the national scale is unimportant or irrelevant. This scale continues to be crucial in some circumstances. But it is becoming increasingly clear that there is no a priori reason to privilege this particular spatial scale in systems of innovation research, irrespective of time and place (see also Hudson 1999).

A strong case is made today that the regional [i.e. subnational] scale is growing in importance as a mode for innovation systems research. The main argument for this is that regional agglomeration provides the best context for an innovation-based learning economy (Hudson 1999), for knowledge creation and diffusion and learning. Specific forms of knowledge creation, especially the tacit forms, and of technological learning are both localised and territorially specific. The firms that master knowledge that is not fully codifiable are tied into various kinds of networks with other firms and organisations through localised input-output relations, knowledge spillovers and their untraded interdependencies (Storper 1997). In some cases market exchange, knowledge spillovers and untraded relations are woven between the various activities within the scope of vertical or horizontal production relationships, but often they are separated.

Formal exchange [i.e. traded interdependencies] and - more importantly - knowledge spillovers and their untraded interdependencies lie at the heart of this line of reasoning:

- *First*, localised input-output relations constitute webs of customer-producer and producer-supplier relations that are essential to communicate information about both technological opportunities and user needs. The user/supplier and producer will gradually develop a common code of communication, making the exchange of information more efficient. To leave a well-established user-producer or producer-supplier relationship becomes increasingly costly and involves a loss of information capital (Lundvall 1992).

- *Second*, knowledge spillovers occur because knowledge created by one firm or another organisation is typically not contained within that organisation, and thereby creates value for other firms and other firms' customers. Knowledge spillovers are especially likely to result from basic research, but they are also generated from applied research and technological development. This can occur, for example, in obvious ways such as reverse engineering of products, but also in less obvious ones such as when one firm's abandonment of a particular research line signals to others that the line is unproductive and, thus, saves them the expense of learning this themselves. The spillover beneficiary may use the new knowledge to copy or imitate the commercial products or processes of the innovator, or may use the knowledge as an input to R&D leading to other new products or processes. Three vehicles of such spillovers may be distinguished: first, the scientific sector with its general scientific and technological knowledge pool; second, the firm-specific knowledge pool; and, third, the business-business and industry-university relations that make them possible. Once the central role of knowledge spillovers is recognized, a place for informal institutions appears.

- *Third*, untraded interdependencies or regional assets are less tangible benefits that attach to the process of economic coordination and organisational knowledge creation. They are derived from geographical clustering, both economic - such as the development of a pooled labour market - and sociocultural - such as developed routines, shared values, norms, rules and trust that facilitate interactive processes and mutual understanding in the transmission of information and knowledge. Because tacit knowledge is collective in nature and wedded to its sociocultural context, it is more territorially and place specific than is generally thought.

Thus, from a more general perspective it can be argued that it is the combination of territorially embedded Marshallian agglomeration economies, knowledge creation and spillovers and their untraded interdependencies that defines the importance of the regional scale in innovation systems research.

4. Summary and Outlook

The diffusion of the systems innovation approach - in different versions and variations - has been surprisingly fast in academic circles, and is also very much used in a national context by national governments as well as supranational organizations like the European Union and the Organisation for Economic Co-operation and Development. The approach seems to be very attractive to policy makers who look for frameworks to understand differences between national and regional economies and various ways to support technological change. The attractivity stems from three basic characteristics of the approach that deserve to be summarized here:

- *First*, it places innovations and knowledge creation at the very centre of focus, and goes beyond a narrow view of innovation to emphasize the interactive and dynamic nature of innovation.

- *Second*, it represents a considerable advance over the network school of innovation (Håkansson 1987) by a decisive shift in focus from firm to territory, from the knowledge-creating firm to the knowledge-creating territory.

- *Third*, it views innovation as a social process that is institutionally embedded, and, thus, puts special emphasis on the institutional context and forms [i.e. formal and informal institutions] through which the processes of knowledge creation and dissemination occur.

Adoption of this approach overcomes the weaknesses of case studies because a common conceptual framework is used. Its advantage is that it allows for a systematic comparison of innovation activities in different localised systems. Conducting comparative studies can lead to the identification of functional communalities as well as to the discovery of specific and generic problems within the innovation process. Three types of innovation analysis may be performed, depending on the context of analysis:

- the first refers to the *micro-level of the system* and attempts to analyse the internal capabilities of selected firms and the links surrounding them [knowledge relationships with other firms and with non-market institutions] with the purpose to identify unsatisfactory or problematic links in the value chain;

- the second refers to the *meso-level of the system* and focuses on specific subsystems and attempts to map knowledge and other interactions within and between subsystems. This may involve the measurement of various types of knowledge flows: interactions among manufacturing firms; interactions between manufacturing firms and universities including joint research, co-patenting, co-publications and more informal relations; interactions between manufacturing firms and other innovation supporting units such as innovation funding; and personnel mobility focusing on the movement of scientific and technical personnel within the enterprise sector and between the scientific and the enterprise sector;

- the third refers to the *macro-level of the system* and typically involves the use of macro-indicators such as, for example, R&D personnel ratios, R&D expenditure intensity rates, innovation rates, patent intensity rates, networking indicators of various kinds to characterize the system at hand in general terms.

In concluding it should be stressed that many of the fundamental ideas in the approach discussed in this paper still lack a firm and more rigid conceptual foundation, and definitional and conceptual dimensions are important. The topics include the character and changeableness of a system of innovation's knowledge base and its dependence on specific innovation infrastructures, as well as the nature and importance of formal and especially informal institutions, technologies and territories as levels of analysis (Johnson 1997). There are several unresolved problems, for example, of how to define and describe the structure and change of the institutional set-up and to connect it to innovation. Different kinds of rules, norms, conventions and shared practices that form regional and national economy's patterns of interaction have important implications for the creation, application and dissemination of knowledge. It follows from this that there is a need for much more specific conceptual categories, sharp enough to tightly guide empirical work. Empirical research still often lacks the ability to dig into the specifics of hard-to-measure issues, such as trust-building, coalition-building, control relations or culturally loaded industrial practices (Malecki et al. 1999).

Another line for future research efforts refers to the complex interplay of processes taking place at different spatial scales. We need to bear in mind that spatial scales are not independent entities. Individual production/commodity chains can be viewed as vertically organized structures that operate across increasingly extensive geographical scales. Cutting across these vertical structures are the territorially based systems that are manifested at different spatial scales. It is at the points of intersection of these dimensions in geographic space where specific outcomes occur and the problems of existing within globalizing economy have to be resolved (Dicken 1998). This, however, means that there is a need to acknowledge the importance of external linkages, network relations, and non-market connections as one of the determining factors to economic success and to move beyond the simple statement that localised innovation systems are open systems.

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