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Sectoral systems of innovation and production☆

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Abstract

The concept sectoral system of innovation and production provides a multidimensional, integrated and dynamic view of sectors. It is proposed that a sectoral system is a set of products and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral systems has a specific knowledge base, technologies, inputs and demand. Agents are individuals and organizations at various levels of aggregation. They interact through processes of communication, exchange, co-operation, competition and command, and these interactions are shaped by institutions. A sectoral system undergoes change and transformation through the co-evolution of its various elements. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Sectors provide a key level of analysis for economists, business scholars, technologists and economic historians in the examination of innovative and production activities. We have mainly two traditions dealing with sectors. The first one is related to the industrial economics literature. The structure–conduct–performance tradition, the transaction costs approach, sunk cost models, game theoretic models of strategic interaction and co-operation, and econometric industry studies have emphasized differences across industries in the contexts in which economic agents act. Most of these approaches have considered the sectoral boundaries static and delimited in terms of similarity in techniques or similarity in demand. Sometimes strategic interdependence has been added as another criteria for delimiting sectors. Differences in the equilibrium structure of sectors have been identified as determined by the underlying patterns of technology and demand, in addition to the type of sunk costs. These studies in the industrial economics tradition have examined the structure of sectors in terms of concentration, vertical integration, diversification, and so on; the dynamics of sectors in terms of technical progress, entry, firms' growth and so on; the interaction among firms in terms of strategic behavior (Bain, 1956; Scherer, 1990; Tirole, 1988; Sutton, 1991, 1998). This tradition has obtained tremendous progress and major results in all the above mentioned topics. In most of these studies, however, not much emphasis has been paid to the role of non-firms organizations, to knowledge and learning processes by firms, to the wide range of relations among the agents, to the transformation of sectors in their boundaries, actors,

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products and structure. These remarks could be coupled with the complementary observations by Geroski (1998) who points to some limits of the concept of market boundaries and emphasizes the concept of strategic market. The second tradition dealing with sectors is much richer empirically, but much more heterogeneous, eclectic and dispersed. Here, one finds very rich empirical evidence on the features and working of sectors, on their technologies, production features, innovation, demand and on the type and degree of change. But most of the sector case studies focus on a single dimension (such as innovation, firms' competencies, structure of production and so on), ask different research questions, are done with different methodologies and have a different level of aggregation in terms of unit of analysis. As a consequence, the possibility of having integrated and consistent analyses of sectors in their interrelated features, understanding fully their working and transformation or comparing different sectors with respect to several dimensions (such as the type and role of agents, the structure and dynamics of production, the rate and direction of innovation and the effects of these variables on the performance of firms and countries) is still very limited.

The concept of *sectoral system of innovation and production* advanced in this paper tries to provide this multidimensional, integrated and dynamic view of sectors. As a way of introduction, the definition that will be presented in Section 3and discussed in Sections 4 and 5, is anticipated here. In this paper, it is proposed that a sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. Sectoral systems have a knowledge base, technologies, inputs and demand. The agents are individuals and organizations at various levels of aggregation, with specific learning processes, competencies, organizational structure, beliefs, objectives and behaviors. They interact through processes of communication, exchange, co-operation, competition and command, and their interactions are shaped by institutions. A sectoral system undergoes processes of change and transformation through the co-evolution of its various elements. [1]

[1] Of course, the concept of sectoral system applies to manufacturing as well as services.

In the following pages, this paper is going to discuss at length this definition, the various dimensions of a sectoral system and its dynamics. The main advantages of a sectoral system view can be identified in a better understanding of: the structure and boundaries of a sector; the agents and their interactions; the learning, innovation and production processes; the transformation of sectors and the factors at the base of the differential performance of firms and countries in a sector.

The theoretical and analytical approach from which this paper draws comes form evolutionary theory and the system approach. It is in the evolutionary camp that key concepts such as learning, knowledge, competencies and a major focus on dynamics are present. And it is in the innovation system literature that one finds relationships and networks as key elements of the innovation and production processes (Edquist, 1997).

In particular, the notion of sectoral system of innovation and production complements other concepts such as national systems of innovation which has a focus on national boundaries and on non-firms organizations and institutions (Freeman, 1987; Nelson, 1993; Lundvall, 1993); regional/local innovation systems in which the focus is on the region (Cooke et al., 1997); and technological systems, in which the focus is mainly on networks of agents for the generation, diffusion and utilization of technologies (Carlsson and Stankiewitz, 1995; Hughes, 1984; Callon, 1992).

Rather than providing conclusive and coherent results, this paper is conceptual and methodological. It aims to discuss the theoretical foundations of the notion of sectoral systems of innovation, to propose a definition of a sectoral system, to identify the major dimensions and the main variables, to analyze the main factors affecting structure, agents' heterogeneity and change, and to set the main research questions and the key challenges that lie ahead.

The paper is organized in the following way. In Section 2, the theoretical foundations of the notion of sectoral systems is presented. In Section 3, a definition and a framework is proposed. In Section 4, the main building blocks of a sectoral system are examined: knowledge and learning processes; basic technologies, inputs and demand with key links and dynamic complementarities; types and structure of interactions among heterogeneous firms and non-firms organizations; institutions and the processes of selection and generation of variety. Then in Section 5, the dynamics and transformation of sectoral systems are discussed, while in Section 6, the geographical boundaries are analyzed. In Section 7, the challenges that lie ahead in terms of research and policy implications are discussed.

2. Theoretical basis

The notion of a sectoral system of innovation and production relates to relevant intellectual and theoretical traditions.

A first group of contributions has emphasized change and transformation in sectors. Sectors change over time, and therefore, a lot of attention should be placed on their laws of motion, dynamics, emergence and transformation. This point is related both to the industry life cycle literature (Utterback, 1994; Klepper, 1996) and to broader analyses of the long-term evolution of industries, as one can find in Schumpeter, Kuznetz and Clark. In particular, this long-term view has been lost in the 1950s and 1960s literature on structure conduct and performance (in which the focus has been on comparative static analyzes of industry structure), and in modern industrial economics—game theory and transaction cost, but has regained considerable attention in recent years (Malerba and Orsenigo, 1996).

The second tradition is the about links and interdependencies and sectoral boundaries. It has stressed that the boundaries of sectors should include interdependencies and links among related industries and services and that these boundaries are not fixed, but change over time. Dynamic complementarities among artefacts and activities, thus, provide force and trigger mechanisms of growth and innovation. The concept of filiere has highlighted the role of major vertical links among sectors in production activities. The notion of development blocks introduced by Dahmen (1989) has stressed the idea that sequences of complementarities create dynamism in the system and generate development potential. Investments are often closely interrelated and span over different technologies or activities: they may originate tensions and virtuous cycles among related products in the process of economic development.

The third tradition is the innovation system approach, which considers innovation as an interactive process among a wide variety of actors. It stresses the point that firms do not innovate in isolation, so that innovation has to be seen as a collective process. In the innovative process firms interact with other firms as well as with non-firms organizations such as universities, research centers, government agencies, financial institutions and so on. Their action is shaped by institutions (Lundvall, 1993; Carlsson, 1995; Edquist, 1997). This approach places a lot of emphasis on interdisciplinarity emphasizes a historical perspective and has put learning as a key determinant of innovation (Edquist, 1997).

Finally, evolutionary theory provides a broad theoretical framework for the concept of sectoral system of innovation and production. Evolutionary theory places a key emphasis on dynamics, process and transformation. Learning and knowledge are key elements in the change of the economic system. "Boundedly rational" agents act, learn and search in uncertain and changing environments. Relatedly, competencies correspond to specific ways of packaging knowledge about different things and have an intrinsic organizational content. Different agents know how to do different things in different ways. Thus, learning, knowledge and behavior entails agents' heterogeneity in experience, competencies, and organization and their persistent differential performance. In addition, evolutionary theory places emphasis on cognitive dimensions such as beliefs, objectives and expectations, in turn affected by previous learning and experience and by the environment in which agents act (Nelson, 1995; Dosi, 1997; Metcalfe, 1998). A central place in an evolutionary approach is occupied by three economic processes driving economic change: processes of variety creation in technologies, products, firms and organizations, processes of replication, that generate inertia and continuity in the system and processes of selection, that reduce variety in the economic system (Nelson, 1995; Metcalfe, 1998). Finally, for evolutionary theory aggregate phenomena are emergent properties of far from equilibrium interactions and have a metastable nature (Lane, 1993).

For evolutionary theory the environment and conditions in which agents operate may drastically differ.[2] Evolutionary theory stresses major differences in opportunities conditions related to science and

[2] Of course, in an evolutionary framework, there is not a sharp distinction between the learning environment and the unit of learning.

technologies. The same holds for the knowledge base underpinning innovative activities, as well as for the institutional context. Thus, the learning, behavior and capabilities of agents is constrained and "bounded" by the technology, knowledge base and institutional context in which firms act. Heterogeneous firms facing similar technologies, searching around similar knowledge bases, undertaking similar production activities and "embedded" in the same institutional setting, share some common behavioral and organizational traits and develop a similar range of learning patterns, behavior and organizational forms. For example, a specific technological regime defines the nature of the problems firms have to solve in their innovative activities, affects the type of technological learning, shapes the incentives and constraints to particular behavior and organization and affects the basic processes of variety generation and selection (and, therefore, the dynamics of evolution of firms) (Nelson and Winter, 1982; Malerba and Orsenigo, 1996).

This paper will take these broad points coming from evolutionary theory and will develop them into a sectoral system perspective. The starting point will be the empirical recognition, as emerged from the rich literature of empirical case studies, first that sectors are characterized by specific knowledge bases, technologies, production processes, complementarities, demand, by a population of heterogeneous firms and non-firms organizations and by institutions, and, second, that sectors differ greatly in several of these dimensions. In the following pages, an attempt to spell out and link several of these dimensions and place them in a dynamic perspective is presented.

3. Sectoral systems of innovation and production: a proposed definition and a framework

A workable definition of a sectoral system of innovation and production is the following. A sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral system has a knowledge base, technologies, inputs and an existing, emergent and potential demand. The agents composing the sectoral system are organizations and individuals (e.g. consumers, entrepreneurs, scientists). Organizations may be firms (e.g. users, producers and input suppliers) and non-firm organizations (e.g. universities, financial institutions, government agencies, trade-unions, or technical associations), including sub-units of larger organizations (e.g. R&D or production departments) and groups of organizations (e.g. industry associations). Agents are characterized by specific learning processes, competencies, beliefs, objectives, organizational structures and behaviors. They interact through processes of communication, exchange, co-operation, competition and command, and their interactions are shaped by institutions (rules and regulations). Over time, a sectoral system undergoes processes of change and transformation through the co-evolution of its various elements.

As mentioned previously, this notion of sectoral system of innovation and production draws from basic concepts of evolutionary theory and from key aspects of the innovation system approach. It departs from the traditional concept of sector used in industrial economics because it examines other agents in addition to firms, it places a lot of emphasis on non-market as well as on market interactions, and focuses on the processes of transformation of the system it does not consider sectoral boundaries as given and static.

In sum, the basic elements of a sectoral system are

- *Products*.
- *Agents*: Firms and non-firm organizations (such as universities, financial institutions, central government, local authorities), as well as organizations at lower (R&D department) or higher level of aggregation (e.g. firms' consortia); individuals.
- *Knowledge and learning processes*: The knowledge base of innovative and production activities differ across sectors and greatly affect the innovative activities, the organization and the behavior of firms and other agents within a sector.
- *Basic technologies, inputs, demand, and the related links and complementarities*: Links and complementarities at the technology, input and demand levels may be both static and dynamic. They include interdependencies among vertically or horizontally related sectors, the convergence of previously separated products or the emergence of new demand from existing demand. Interdependencies and complementarities define the real boundaries of a sectoral system. They may be at the input, technol-

ogy or demand level and may concern innovation, production and sale.
- *Mechanisms of interactions both within firms and outside firms*: Agents are examined as involved in processes of market and non-market interactions.
- *Processes of competition and selection*.
- *Institutions*: Such as standards, regulations, labor markets and so on.

This notion of sectoral system places emphasis on the structure of the system in terms of products, agents, knowledge and technologies and on its dynamics and transformation. In broader terms, one could say that a sectoral system is a collective emergent outcome of the interaction and co-evolution of its various elements.

One last remark regards the aggregation issue. When agents are considered, in addition to firms and non-firms organizations also agents at lower and higher levels of aggregation may be the key actors in a sectoral system. Similarly, because the notion of sectoral systems includes innovation and production with the related demand and market processes, for analytical purposes one could examine separately a sectoral innovation system, a sectoral production system and a sectoral distribution-market system, which in turn could be related more or less closely. Finally, sectoral systems may be examined according to different levels of aggregation of products. So sectoral systems may be very broad, such as computer hardware and software, or much more narrow, such as computer software. The main conclusion here is that the appropriate level of analysis in terms of agents, functions, products and agents depends on the specific research goal.

In the following pages, a more in-depth examination of the various elements of the sectoral systems will be presented.

4. The building blocks of a sectoral system

What are the main building blocks of a sectoral system of innovation and production? It is possible to identify the following ones:

- knowledge base and learning processes;
- basic technologies, inputs and demand, with key links and dynamic complementarities;
- type and structure of interactions among firms and non-firms organizations;
- institutions;
- processes of generation of variety and of selection.

4.1. Knowledge and learning processes

Knowledge plays a central role in innovation and production. As mentioned in the previous discussion, this point has been strongly emphasized by the evolutionary literature (Nelson, 1995; Dosi, 1997; Metcalfe, 1998) as well as by the literature on the knowledge based economy (Lundvall, 1993; Lundvall and Johnson, 1994; Cowan et al., 2000). In these contributions, knowledge becomes highly idiosyncratic at the firm level, does not diffuse automatically and freely among firms and it has to be absorbed by firms through their differential abilities accumulated over time.

The evolutionary literature has proposed that sectors and technologies differ greatly in terms of the knowledge base and learning processes related to innovation. Knowledge differs across sectors in terms of domains. One knowledge domain refers to the specific scientific and technological fields at the base of innovative activities in a sector (Dosi, 1988; Nelson and Rosenberg, 1993). The second domain regards applications, users and demand for sectoral products. In addition, other dimensions of knowledge may be relevant for explaining innovative activities in a sector.

First, knowledge may have different degrees of accessibility (Malerba and Orsenigo, 2000), i.e. opportunities of gaining knowledge that are external to firms. Knowledge that is accessible may be internal or external to the sector. In both cases, greater accessibility of knowledge decreases industrial concentration. Greater internal accessibility implies lower appropriability: competitors may gain knowledge about new products and processes and, if competent, imitate those new products and processes. Accessibility of knowledge which is external to the industry may be related to scientific and technological opportunities, in terms of level and sources. Here, the external environment may affect firms through human capital with a certain level and type of knowledge or through scientific and technological knowledge developed in firms or non-firms organizations such as universities or research laboratories.

The sources of technological opportunities markedly differ among sectors. As Freeman (1982) and Rosenberg (1982) among others have shown, in some sectors opportunity conditions are related to major scientific breakthroughs in universities. In other sectors, opportunities to innovate may often come from advancements in R&D, equipment and instrumentation. In still other sectors, external sources of knowledge in terms of suppliers or users may play a crucial role. Not all external knowledge may be easily used and transformed into new artifacts. If external knowledge is easily accessible, transformable into new artifacts and exposed to a lot of actors (such as customers or suppliers), then innovative entry may take place (Winter, 1984). On the contrary, if advanced integration capabilities are necessary (Cohen and Levinthal, 1989) the industry may be concentrated and formed by large established firms.

Second, knowledge may be more or less cumulative, i.e. the degree by which the generation of new knowledge builds upon current knowledge. One can identify three different sources of cumulativeness. The first source is learning processes and dynamic increasing returns at the technology level. The cognitive nature of learning processes and the past knowledge constrain current research, but also generate new questions and new knowledge. The second source is related to organizational capabilities. These capabilities are firm-specific and can be improved only gradually over time. They implicitly define what a firm learns and what it can hope to achieve in the future. A third source is the feed-backs from the market, such as "success–breeds–success" processes. Innovative success yields profits that can be reinvested in R&D, thereby increasing the probability to innovate again. From this discussion, it follows that cumulativeness may be observed at various levels of analysis. One is at the technological level. The other is at the firm level. Here, high cumulativeness implies an implicit mechanism leading to high appropriability of innovations. In case of low appropriability conditions and knowledge spillovers within an industry, however, it is also possible to observe cumulativeness at the sectoral level. Cumulativeness may be present at the local level. In this case, high cumulativeness within specific locations is more likely to be associated with low appropriability conditions and spatially localized knowledge spillovers. Cumulativeness at the technological and the firm levels creates first mover advantages and generates high concentration. Firms that have a head start develop a new knowledge based on the current one and introduce continuous innovations of the incremental type.

Accessibility, opportunity and cumulativeness are key dimensions of knowledge related to the notion of technological and learning regimes, which differ across sectors. The notion of technological regimes dates back to Nelson and Winter (1982) and provides a description of the knowledge environment in which firms operate. More generally, Malerba and Orsenigo (1996, 1997) have proposed that a technological regime is composed by opportunity and appropriability conditions; degrees of cumulativeness of technological knowledge and characteristics of the relevant knowledge base. More specifically, technological opportunities reflect the likelihood of innovating for any given amount of money invested in search. High opportunities provide powerful incentives to the undertaking of innovative activities and denote an economic environment that is not functionally constrained by scarcity. In this case, potential innovators may come up with frequent and important technological innovations. Appropriability of innovations summarizes the possibilities of protecting innovations from imitation and of reaping profits from innovative activities. High appropriability means the existence of ways to successfully protect innovation from imitation, while low appropriability denotes an economic environment characterized by the widespread existence of externalities (Levin et al., 1987).[3] The properties of the knowledge base relate to the nature of knowledge underpinning firms' innovative activities. Technological knowledge involves various degrees of specificity, tacitness, complementarities and independence and may greatly differ across sectors and technologies (Winter, 1987).

Here, one could advance the following general propositions on the relationship between technological regimes and patterns of innovation in sectoral systems (Winter, 1984; Malerba and Orsenigo, 1997). Technological regimes characterized by high levels of opportunities are expected to show patterns of innovation characterized by a remarkable turbulence

[3] Pavitt has introduced the distinction between appropriability and technological barrier to entry. According to Pavitt, appropriability refers to all the competitors, both within and outside the industry, while technological barriers to entry refers to the ease of innovative entry into an industry by potential entrants (Pavitt, 1984). Needless to say, this distinction is quite helpful in grouping sectors with respect to the ease of entry in an industry.

in terms of technological entry and exit and a high instability in firms' hierarchies. High technological opportunities allow for the continuous entry of new innovators. However, if successful, also established firms may end up in gaining a substantial leap in their relative competitiveness, thus, leading to the elimination from the market of the less successful innovators. Conversely, low opportunity conditions limit innovative entry and restrict the innovative growth of successful established firms. As a consequence, a higher stability of the major innovators may emerge. High degrees of appropriability, by limiting the extent of knowledge spillovers and by allowing successful innovators to maintain their innovative advantages, are expected to result in a relatively higher level of industrial concentration and a lower number of innovators. Conversely, by discouraging investments in innovative activities and by determining a wider diffusion of the relevant knowledge across firms, low appropriability conditions are more likely to lead to a sectoral structure characterized by the presence of a large population of innovators. Finally, high levels of cumulativeness at the firm level are expected to be associated to persistence in innovative activities. At the sectoral level, technological cumulativeness is expected to be associated with a rather high degree of stability in the hierarchy of innovative firms and a low rate of innovative entry. In such circumstances, the selection process favors established technological leaders. Existing innovators accumulate technological knowledge and capabilities and build up innovative advantages which play a relevant role in affecting their competitiveness and act as powerful barriers to the entry of new innovators.

This difference in the organization of innovative activities at the sectoral level may be related to a fundamental distinction between Schumpeter Mark I and Schumpeter Mark II models. Schumpeter Mark I is characterized by "creative destruction" with technological ease of entry and a major role played by entrepreneurs and new firms in innovative activities. Schumpeter Mark II is characterized by "creative accumulation" with the prevalence of large established firms and the presence of relevant barriers to entry for new innovators. This regime is characterized by the dominance of a stable core of few large firms, with limited entry. High technological opportunities, low appropriability and low cumulativeness (at the firm level) conditions lead to a Schumpeter Mark I pattern. On the contrary, high appropriability and high cumulativeness (at the firm level) conditions lead to a Schumpeter Mark II pattern (Breschi et al., 2000).

Technological regimes and Schmpeterian patterns of innovation change over time (Klepper, 1996). According to an industry life cycle view, Schumpeter Mark I pattern of innovative activities may turn into a Schumpeter Mark II. Early in the history of an industry, when knowledge is changing very rapidly, uncertainty is very high and barriers to entry very low, new firms are the major innovators and are the key elements in industrial dynamics. When the industry develops and eventually matures and technological change follows well defined trajectories, economies of scale, learning curves, barriers to entry and financial resources become important in the competitive process. Thus, large firms with monopolistic power come to the forefront of the innovation process (Utterback, 1994; Gort and Klepper, 1982; Klepper, 1996). On the contrary, in the presence of major knowledge, technological and market discontinuities, a Schumpeter Mark II pattern of innovative activities may be replaced by a Schumpeter Mark I. In this case, a rather stable organization characterized by incumbents with monopolistic power is displaced by a more turbulent one with new firms using the new technology or focusing on the new demand (Henderson and Clark, 1990; Christensen and Rosenbloom, 1995; Ehrnberg and Jacobsson, 1997).

The empirical evidence (Malerba and Orsenigo, 1996) suggests also the existence of differences across sectoral systems in the patterns of innovative activities and, for each sectoral system, of similarities across countries. This result provides support for the relevance of technological regimes in determining sectoral invariances across countries in innovation patterns. This is so as long as appropriability and cumulativeness conditions are rather similar across countries. The ability to generate and exploit opportunity conditions seems less similar across countries. This ability is related to the presence of natural innovation systems: the level and range of university research, the presence and effectiveness of science–industry bridging mechanisms, vertical and horizontal links among local firms, user–producer interaction and the types and level of firms' innovative efforts (Nelson, 1993).

The specificities of technological regimes and the knowledge base provide a powerful restriction on the patterns of firms' learning, competencies, behaviors and organization of innovative and production activities in a sectoral system. Case studies in the managerial and economic history literature shed light on this aspect. Think, for example, of the differences in the types of competencies among sectors such as computers, auto or pharmaceuticals (Iansiti, 1998; Iansiti and Clark, 1994; Henderson, 1994). As a first approximation, it is possible to link basic innovative behavior and strategies to some differences in the underlying knowledge and learning regime. An exercise in this respect has been done by Malerba and Orsenigo (1993) by linking the specific learning regimes in terms of opportunity, cumulativeness and appropriability of innovations, to the type and range of basic innovative behavior (radical versus innovative versus imitative) in sectors such as computers, biotechnology and semiconductors. In addition, basic knowledge and complementarities, together with firms' idiosincratic experience and competencies, also affect agents' beliefs, visions or cognitive representations of the sectoral context (basic economic processes, technology, demand, users, suppliers, competitors and so on). For fascinating examples about this aspect, see Fransmann (1994) and Langlois (Langlois, 1995) on computers.

Although rather archetipical, these analyzes point to the direction of placing a lot of attention to differences across sectors in some key factors related to knowledge and learning regimes. Much more work has to be done first to develop a finer grained analysis of the relationship between knowledge and innovative activities at the sectoral level, and second to enlarge the scope of the analysis from sectoral innovation systems to sectoral production systems and sectoral sale and distribution systems.

4.2. Basic technologies, inputs and demand with key links and dynamic complementarities

Sectoral systems differ in basic technologies, inputs and demand. An enormous literature on technologies and technological change has clearly shown how much sectors differ in their basic technologies and how these technologies affect the nature, boundaries and organizations of sectors (see, e.g. Rosenberg, 1976, 1982; Grandstand, 1994). This literature has shown that often in a sectoral system more than one technology may be relevant. Thus, for each sectoral system, in principle, one would build a technology-product matrix that links the products of the sectoral system to a range of technologies. This matrix differs from one sectoral system to another. Moreover, it has been found that in most sectors even firms specialized in one product often have to master several technologies: they are labeled multitechnology corporations (Grandstand et al., 1997). However, within the same sectoral system, the profile of technological diversification among large firms is rather similar (Patel and Pavitt, 1994).

Also differences in demand conditions play a major role in affecting sectoral differences in firms' competencies, behavior and organization. Porter's (1977) broad sectoral taxonomy of demand conditions and its effect on firms' organizations and strategies clearly illustrate this point. And, when demand conditions are coupled with some basic features of knowledge and technology, the effect on firms' behavior and organization could be significant. For example, empirical and theoretical analysis of the evolution of the computer industry show complex and relevant relationships between demand, technology, knowledge base and the boundaries of firms (Bresnahan and Malerba, 1999; Malerba et al., 1999b).

Basic technologies and demand constitute major constraints on the full range of diversity in the behavior and organization of firms active in a sectoral system. And obviously these constraints differ from sector to sector in relations to the basic technologies and demand. A given technological environment or demand defines the nature of the problems firms have to solve in their innovative and production activities and the types of incentives and constraints to particular behavior and organizations. As it will be discussed later, however, within these constraints great and persistent heterogeneity in firms' innovative and productive behavior and organization is present.

In addition to technologies and demand, links and complementarities among artifacts and activities play a major role in defining the real boundaries of a sectoral system. These links and complementarities are first of all of the static type, as input–output links are. Then there are dynamic complementarities which take into account interdependencies and feed-backs, both at the demand and at the production levels. As mentioned in Section 2, dynamic complementarities among artifacts and activities are a major source of transformation and growth of sectoral systems, and may set in motion virtuous cycles of innovation and change. This could be related to the concept of filiere and the notion of development blocks (Dahmen, 1989). Of course, links and complementarities change over time and differ among sectoral systems. They greatly affect a wide variety of variables of a sectoral system: firms' strategies, organization and performance, the rate and direction of technological change, the type of competition and the networks among agents.

Two examples may show that links and complementarities have to be taken into account for an understanding of the working and dynamics of sectoral systems. In multimedia, the convergence of different types of demand and technologies has originated a new sector with continuously expanding boundaries and in which the main actors coming from various industries constituting the new multimedia sector, but have to use new strategies more in tune with the new features of multimedia. In computers until the 1980s dynamic complementarities and key linkages have kept hardware and software highly interdependent and have consequently affected the vertical organization and strategies of several computer firms. Later on, some of these dynamic complementarities have become less strong and standard interfaces have emerged, thus, leading to the creation of strategies of specialization in computers hardware and in software.

4.3. Types and structure of interactions among heterogeneous firms and non-firms organizations

What are the major types of agents in a sectoral system? *Firms* are the key actors in a sectoral system. They are involved in the innovation, production and sale of sectoral products, and in the generation, adoption and use of new technologies. As our previous discussion of evolutionary theory has stressed, they are characterized by specific beliefs, expectations, competencies, and organization and are engaged in processes of learning and knowledge accumulation. (Nelson and Winter, 1982; Dosi et al., 1998; Malerba, 1992; Teece and Pisano, 1994; Metcalfe, 1998).

Firms include also *users* and *suppliers* who have different types of relationships with the innovating, producing or selling firms. The role of users is extremely important in several sectors, such as agro-food or instrumentation (Lundvall, 1993; Von and Hippel, 1998). The focus on users puts a different emphasis on the role of demand. In a sectoral system demand is not seen as an aggregate set of similar buyers, but as composed by heterogeneous agents with specific attributes, knowledge and competencies who interact in various ways with producers (Devetag, 1999). Similarly, also suppliers of components and subsystems play a major role in affecting innovation, productivity increases and competitiveness of downstream sectors. Suppliers are characterized by specific attributes, knowledge and competencies, with more or less close relationships with producers. The role of suppliers varies across sectors. It is enough to mention the wide range of relations between microelectronics suppliers and information technology producers or the close links between producers of advanced machinery and downstream user industries in the Italian industrial districts (Pavitt, 1984; Malerba, 1993).

Firm heterogeneity is a key feature of a sectoral system. A higher or lower degree of agents heterogeneity in terms of types, beliefs, competencies, behavior and organizations may stem out of differences in a set of factors: the characteristics of the knowledge base, experience and learning processes, firms specific interaction with demand, the working of dynamic complementarities, firms' histories and differential rates and trajectories of innovation and growth. Moreover, sectoral systems greatly differ in the extent and type of agent heterogeneity.

Other types of agents in a sectoral system are *non-firm organizations* such as universities, financial institutions, government agencies, local authorities, and so on. In various ways, they support innovation, technological diffusion and production by firms, but again their role greatly differs among sectoral systems. Think of venture capital and universities in biotechnology, the local government in machine tools, the military in the early days of the semiconductors and computers, and venture capital in software, biotechnology and multimedia.

As mentioned earlier, often the most appropriate units of analysis in specific sectoral systems are not necessarily firms, but *individuals*, *firms' sub-units* (such as the R&D or the production department) and *groups of firms* (such as industry consortia). For example, in sectoral systems such as biotechnology or software, inventors, scientists, or specific engineers are key players. In biotechnology, a key unit of analysis is also the university department and the research laboratory. In electronics, R&D consortia or alliances for standards are often a more appropriate unit of analysis for the competitive process.

Within sectoral systems, heterogeneous agents are connected in various ways through market and non-market relationships. On this issue, it is possible to identify different types of relations, linked to different analytical cuts. First, traditional analyses of industrial organizations have examined agents as involved in processes of exchange, competition and command (such as vertical integration). Second, in more recent analyses processes of formal co-operation or informal interaction among firms or between firms and non-firm organizations have been examined in-depth, as one may see from the literature on tacit or explicit collusion, hybrid governance forms or formal R&D co-operation. This literature has analyzed either and firms with certain market power, suppliers and users facing opportunistic behavior asset specificity in transaction, or firms with similar knowledge and facing appropriability and indivisibility problems in the R&D process. Finally, the evolutionary approach and the innovation systems literature have paid a lot of attention to formal and informal co-operation and interaction among firms: according to this perspective, in uncertain and changing environments networks emerge not because agents are similar, but because they are different. In this way, networks may integrate complementarities in knowledge, capabilities and specialization (see Lundvall, 1993; Edquist, 1997; Nelson, 1995; Teubal et al., 1991). In addition, the role of the relationships between firms and non-firm organizations (such as universities and public research centers) as a source of innovation and change in several sectors, (such as pharmaceuticals and biotechnology, information technology and telecommunications) has been enphasized (Nelson and Rosenberg, 1993).

The types and structures of relationships and networks differ from sectoral system to sectoral system, as a consequence of the features of the knowledge base, the relevant learning processes, the basic technologies, the characteristics of demand, the key links and the dynamic complementarities. For example, in pharmaceuticals think of the change in the underlying knowledge base in the switch from random screening to modern biotechnology. This change has created new types of networks and relations among firms (large pharmaceutical companies and new biotech firms), and among firms, non-firms organizations (such as universities and venture capitalists) and institutions (such as regulations) (Henderson et al., 1999; Orsenigo et al., 2001). And compare it with the knowledge base of machinery related to completely different types of networks and relationships between firms (users and suppliers), non-firm organizations (such as local banks and industry associations and government) and institutions (local trust). Or relate it to the type of knowledge and networks in complex system industries such as flight simulation (Miller et al., 1995).

One final remark has to be advanced. The key role played by networks in a sectoral system leads to a meaning of the term "sectoral structure" different from the one used in industrial economics. In industrial economics, structure is related mainly to the concept of market structure and of vertical integration and diversification. In a sectoral system perspective, on the contrary, structure refers to links among artifacts and to relationships among agents: it is, therefore, far broader than the one based on exchange–competition–command. Thus, we can say that a sectoral system is composed by webs of relationships among heterogeneous agents with different beliefs, competencies and behavior, and that these relationships affect agents' actions. They are rather stable over time. [4]

[4] A business scholar such as Porter has clearly understood these problems and issues. In his analysis of business strategies, Porter has quite early abandoned the traditional concept of industry and market. It has attempted to enlarge it in various ways. In "Competitive Strategy" (Porter, 1980), he discusses firm strategies in industries and provides a description of industry boundaries that move away from similarity of technical processes or substitutability in demand, by considering also suppliers and buyers, and the threat of products or services substitutes. In "Competitive Advantage" (Porter, 1985), he discusses the value chain and the collection of activities that are performed to design, produce and market a product. Later on, in discussing how nations can affect the way industries compete on the international scene he stresses the role of factor conditions (skilled labor, infrastructure and so on), demand conditions and related and supporting industries (in addition to firm strategy, structure and rivalry) ("The Competitive Advantage of Nations", Porter, 1990). Finally, in his last work, "Clusters and the new economics of competition" (Porter, 1998), Porter focuses on local knowledge, trust relationships and culture as the basis of competition (better access to employees and suppliers; access to specialized information; complementarities of various kinds; co-ordination with local companies; better motivation and access to institutions and public goods such as pool of skills, reputation and technology).

4.4. Institutions

Finally, sectoral systems may greatly differ with respect to their typical institutions. Institutions include norms, routines, common habits, established practices, rules, laws, standards and so on, that shape agents cognition and action and affect the interactions among agents (Edquist and Johnson, 1997; Coriat and Dosi, 1994; Nelson and Sampat, 1998). Institutions and the related organizations differ greatly in terms of types. They may range from the ones that bind or impose enforcements on agents to the ones that are created by the interaction among agents (such as contracts); from more binding to less binding; from formal to informal (such as patent laws or specific regulations vs. traditions and conventions) (Edquist and Johnson, 1997; Coriat and Weinstein, 1999). In addition, a lot of institutions are national (such as the patent system), while others are specific to sectoral systems, such as sectoral labor markets or sector-specific financial institutions. Other examples of sectoral institutions are disclosure agreements and standards in software or the regulations in the modern pharmaceutical sector.

A key issue to be address by current research refers to the emergence of sectoral institutions. They may either come into being as a result of deliberated planned decision by firms or other organizations, or they may emerge as the unpredicted consequence of agents interaction. This is an issue to be analyze in-depth and requires a careful examination of specific cases of sectoral system evolution.

Another major topic to be examined in-depth is the relationship between national institutions and sectoral systems. The most obvious aspect to be analyzed is the effect that national institutions have on specific sectoral systems. For example, the patent system, property rights or antitrust regulations have different effects on different sectoral systems as a consequence of the different features of the systems, as surveys and empirical analyses have shown (Levin et al., 1987). However, the same institution may take different features in different countries, and thus, may affect the same sectoral system differently in different countries. The well-known diversity between the first-to-invent and the first-to-file rules in the patent system in the United States and in Japan had major consequences on the behavior of firms in the two countries.

Often the characteristics of national institutions favor specific sectors that fit better with their specificities. Thus, in certain cases, some sectoral systems become predominant in a country because the existing institutions of that country provide an environment more suitable for certain types of sectors and not for others. For example, in France sectors related to public demand have grown considerably (Chesnais in Nelson, 1993). In other cases, national institutions may constraint the development or innovation in specific sectors or mismatches between national and sectoral institutions and agents may take place. The examples of the different types of interaction between national institutions and sector evolution in various advanced countries in Dosi and Malerba (1996) are cases in point.

The relationship between national institutions and sectoral systems is not always one-way, as it is in the case of the effects of national institutions on sectoral variables. Sometimes the direction is opposite, and goes from the sectoral to the national level. In fact, it may occur that the institutions of a sector, which is extremely important for a country in terms of employment, competitiveness or strategic relevance, end up emerging as national, thus becoming relevant also for other sectors. But in the process of becoming national, they may change some of their original distinctive features.

In conclusion, the analysis of the role of institutions in sectoral systems is only at the beginning. Just to reiterate what has been said above, a lot of work needs to be done in this respect, and it has to be done in various directions. This will present a formidable analytical challenge, because the relevance and balance of various types of institutions may not only differ across sectoral systems. They may also differ across countries for the same sectoral system, and involve a range of related organizations. (Edquist and Johnson, 1997). [5]

4.5. Processes of selection and variety generation

At the base of the extent of firms' heterogeneity within sectoral systems lies the interplay between two

[5] One could also claim that the macroeconomic environment may exert major effects on specific sectoral systems. Sectoral systems in fact evolve within specific macro context. This aspect is quite relevant, but it is not going to be discussed at length here.

key evolutionary processes that differ from sector to sector: the process of variety creation and the process of selection (Nelson, 1995; Metcalfe, 1998). These two processes affect industrial dynamics and greatly account for its differences across sectoral systems.

Processes of variety creation refer to products, technologies, firms, institutions as well as strategies and behavior. They are related to several mechanisms: entry, R&D, innovation and so on. These mechanisms interact at various levels. For example, the emergence and growth of new sectoral institutions and organizations such as new specialized departments within universities and new scientific, technological and educational fields increase variety and can be associated to the emergence of new technologies and new knowledge. See, for example, the general discussion by Nelson and Rosenberg (1993) on the role of universities in several fields of science and technology and the case of the emergence in the chemical industry of new departments and engineering degrees in universities in response to new technological developments in industry (Arora et al., 1999). Sectoral systems differ extensively in the processes of variety creation and of heterogeneity among agents.

The creation of new agents—both new firms and non-firms organizations—is particularly important for the dynamics of sectoral systems. For example, new firms bring a variety of approaches, specialization and knowledge in the innovation and production processes, and contribute to the major changes in the population of agents and in the transformation of technologies and products in a sector. As examined by Audretsch (1996) and Geroski (1995) among others, the role of new firms differs drastically from sector to sector (in terms of entry rates, composition and origin), and thus has quite different effects on the features of sectoral systems and their degree of change. Sectoral differences in the level and type of entry seem to be closely related to differences in the knowledge base, level, diffusion and distribution of competencies, presence of non-firms organizations (such as universities and venture capital) and working of sectoral institutions (such as regulations or labor markets) (Audretsch, 1996; Malerba and Orsenigo, 1999; Geroski, 1994).

Processes of selection play the key role of reducing heterogeneity, and may refer to different environments: firms, products, activities, technologies, and so on. In addition to market selection, in several sectoral systems also non-market selection processes are at work, as in the cases of the involvement of the military, the health system and so on. In general selection affects the growth and decline of the various groups of agents and the range of viable behaviors and organizations in a sectoral system. Selection may be more or less intense and frequent. It greatly differs across sectoral systems. However, while theoretical work on selection has been done at a very general level (see Metcalfe, 1998), a finer grained analysis of selection and the factors affecting it at the sectoral level has still to be developed.

5. The dynamics and transformation of sectoral systems

Change is a distinctive feature of sectoral systems. However, change does not mean simply a quantitative growth of the variables of a sectoral systems. It means also transformation and evolution.

During the evolution of sectoral systems change may occur in the technological and learning regimes and in the patterns of innovations. As mentioned before over time, a change in regimes may transform a Schumpeter Mark I pattern of innovative activities to a Schumpeter Mark II. Or, in the presence of major knowledge, technological or market discontinuities, a Schumpeter Mark II pattern of innovative activities may be replaced by a Schumpeter Mark I. Moreover, the knowledge base of innovative activities may change in two different ways: an evolution towards a dominant design or a drastic change. In the first case, a growth of concentration and the rise of large dominant firms may take place (Utterback, 1994). In the second case, new types of competencies may be required for innovation, with major industrial turbulence, entry of new firms and turnover in industrial leadership (Jovanovich-McDonald, 1984; Tushman-Anderson, 1986; Henderson and Clark, 1990). Finally, changes in demand, users and applications represent another major modification in the context in which firms operate and may favor the entry of new firms rather than the success of established ones (Christensen and Rosenbloom, 1996; Langlois and Robertson, 1995).

This brief discussion highlights the need to take into account major sectoral differences in the change of sectoral systems and to assess the factors causing these changes. In particular, some key questions that need to be explored in-depth could be the following. First, how do new agents come into being and what are the main sectoral differences in the rate, type and determinants of entry? Second, do new competencies, organizational forms and strategies radically differ from the old ones or do they emerge from the old ones (i.e. do we have adaptation or drastic change)? How is the balance between the two affected by sectoral features? Third, do relationships among agents and networks show a great stability or do they change over time, and if so, in which direction? Fourth and more generally, how do new sectoral systems emerge, and what is the link with previous sectoral systems?

From the previous claim that the elements of a sectoral system are closely connected, it follows that their change over time results in a co-evolutionary process of its various elements. This process involves technology, demand, knowledge base, learning processes, firms, non-firm organizations and institutions. Nelson (1994) and Metcalfe (1998) have discussed these processes at the general level by focusing on the interaction between technology, industrial structure, institutions and demand.

In this paper, the claim is that these processes are sector-specific. For example, just looking at three elements such as technology, demand and firms, in sectors characterized by a system product and consumers with a rather homogeneous demand, co-evolution leads to the emergence of a dominant design and industrial concentration (Klepper, 1996). However, in sectors with either a heterogeneous demand, or competing technologies with lock ins, or network externalities and standards, specialized products and a more fragmented market structure may emerge.

Often co-evolution is related to path-dependent processes (Arthur, 1988; David, 1985). Here, local learning, interactions among agents and networks may generate increasing returns and irreversibilities that may lock sectoral systems into inferior technologies. The cases of sectors with competing technologies such as nuclear energy (Cowan, 1990), cars (and their power sources—Foreman-Peck, 1996), metallurgy (ferrous casting—Foray and Grubler, 1990) and multimedia (VCR—Cusumano et al., 1992) are interesting examples of path-dependent processes.

In sum, a lot of empirical and theoretical work has to be done in order to understand the dynamics of sectoral systems and their basic co-evolutionary processes. Recent work such as Mowery and Nelson (1999) on the long-term evolution of sectors such as semiconductors, computers, software, pharmaceuticals and biotechnology, chemicals, medical devices and machine tools has started to shed new light on co-evolutionary processes over time and across countries. In Mowery and Nelson (1999), it has been shown that these co-evolutionary processes clearly differ among sectors. An example is given by the computer industry, whose long-term development cannot just be described in terms of sales' growth and the introduction over time of radically new products (such as the minicomputer, the microcomputer and the computer networks) with different features and demand. Rather, in this sector complementarities between changes in components and changes in computer systems have affected the strategies of firms. And a co-evolutionary process involving technology, demand, institutions and firms' organization and strategies has characterized the whole history of the industry (Bresnahan and Malerba, 1999).

Even more work is necessary when the transformation of sectors involves not just traditionally defined sectors as in Mowery and Nelson (1999), but the emergence of new clusters that span over several sectors, such as Internet–software–telecom, biotechnology–pharmaceutical and new materials. Here, the analysis of sectoral systems has to consider the integration and fusion of previously separated knowledge and technologies and the new relations and overall dynamics among different types of users and consumers, firms with different specialization and competencies, and non-firms organizations and institutions grounded in previously separated sectors.

At the modeling level, one way to represent in a stylized form aspects of co-evolution in different sectoral systems is through history friendly models (Malerba et al., 1999a). Two of this type of models refer to the computer industry. One refers to the dynamics of technology, firms' competencies, market structure and demand. During the long-term evolution of an industry major technological and demand discontinuities may take place, thus greatly affecting market structure and the survival of established firms. In general, technological discontinuities have been absorbed successfully by industry leaders much more than demand discontinuities. When a technological discontinuity takes place within an existing demand, incumbents are able to shelter the major change in the technology through the lock-in of existing customers. On the other hand, a major change in demand is often associated to changes in the related technologies, so that established firms have to pass through several shifts in terms of knowledge, with major consequences for the entry and growth of new entrants. These results emphasize the need to examine the possible tradeoffs and complementarities between knowledge about technologies and knowledge about demand (Malerba et al., 1999a). A second model examines the organization of innovative and production activities in computers when knowledge complementarities among components and systems are present as a the result of the dynamic interplay of knowledge, competencies and market structure, and more broadly of the co-evolution of the upstream and downstream industries (Malerba et al., 1999b). Once developed for several sectoral systems, history friendly models will allow comparative analyzes of the patterns of structural evolution and industrial dynamics, identify commonalties across sectors and enrich our understanding of the factors behind structural evolution. In addition to firms, these models may focus on several elements of sectoral systems: non-firms organizations, suppliers, users and public policy. In this way, they could prove quite useful in the analysis of the interaction among several elements of a sectoral system.

6. The regional and national dimensions

Geographical boundaries are an important element to be considered in most analyses of sectoral systems. Not always national boundaries are the most appropriate ones for an examination of the structure, agents and dynamics of these systems. Often a sectoral system is highly localized and frequently defines the specialization of the whole local area (as in the case of machinery, some traditional industries, and even information technology). For example, machinery is concentrated in specialized regional areas. Similarly, sectoral specialization and local agglomeration has overlapped in Route 128 (for minicomputers) and in Silicon Valley (for personal computers, software and microelectronics) (Saxenian, 1994).

Breschi and Malerba (1997) have provided some very simple examples of the geographical boundaries of sectoral systems by considering the relevant dimensions of technological regimes. Traditional sectoral systems composed by many innovators, geographically dispersed with no specific knowledge spatial boundaries are associated to technological regimes with low degrees of opportunities, appropriabilities and firms' cumulativeness with a knowledge base partly embodied in equipment and materials. Machinery, located in industrial districts with many innovators geographically concentrated with local knowledge boundaries, is associated to technological regimes of medium opportunities, and high firms' cumulativeness and a tacit and specific knowledge base. Automobiles, with few innovators, geographically concentrated with local knowledge boundaries are associated to technological regimes characterized by high cumulativeness at the firm level and a system type of knowledge with some tacit components. Finally, modern microelectronics, software and micro computers with many innovators, geographically concentrated with both local and global knowledge boundaries are associated with very high opportunity conditions and a wide variety of potential technological approaches (Breschi and Malerba, 1997).

What do we know about the interplay between sectoral systems and national (or local) systems? In the previous pages, the effects of national institutions on sectoral systems have been discussed extensively. Some similarities among the sectoral systems of a country may emerge and these may differ from the ones that characterize the sectoral systems of another country. Much more research is needed on this issue. One useful starting point is to assess how much the features and dynamics of the same sectoral system is similar and how much is different across countries or regions. As mentioned before, empirical research on the sectoral patterns of innovative activities in terms of innovative concentration, technological entry and innovative turbulence has confirmed that major differences exist across sectors, but, for the same sector, these patterns are rather similar across countries. This similarity in the sectoral patterns has been associated to features of technological regimes, knowledge base and learning processes that are somewhat invariant across countries. In these analyses based on patents, however national innovation systems play a major role in affecting the sectoral patterns of innovation. For example, on average technological entry is lower in Germany and Japan than in the United States and the UK (Malerba and Orsenigo, 1996). This type of analysis has to be greatly expanded in order to study the role of national (regional) institutions in affecting some basic cross-country (cross-regional) "invariant" features of the structure and dynamics of a sectoral system.

A different, but somewhat related issue regards the relationship between sectoral systems and countries (regions) international performance. Again, this issue may be tackled from different angles. As previously mentioned the relationship between the features of a sectoral system and countries (regions) international performance in that sector is mediated by the national (regional) institutions and non-firms organizations that form a national (regional) system of innovation and production. The identification of the link between specific elements (or the structure and dynamics) of a sectoral system and countries (regions) international performance is still ground to be covered by empirical research. The most interesting attempt in this regard is the book by Mowery and Nelson (1999). By examining six sectors in the United States, Europe and Japan, they claim that countries' international competitiveness is closely related the presence of competent firms, interactions among firms (such as with users and suppliers) and advanced non-firm organizations and institutions. These are factors that could be related to sectoral systems and that differ from sectoral system to sectoral system.

Finally, one last remark refers to multinational corporations. These firms may be active in a specific sectoral system, but span over different regions and countries. Therefore, the analysis of how these companies are able to profit form the specificities of a sectoral system in various countries is a matter of relevant empirical scrutiny. For example, a multinational firm operating in a specific sectoral system may locate its research laboratories in a country, have co-operation with a top university in another one, produce and have links with key suppliers in still another and so on.

7. The challenges ahead

In this paper, the concepts and the methodology regarding the analysis of sectoral systems of innovation and production have been discussed. A definition of sectoral system of innovation and production as a set of new and established products for specific uses and the set of agents carrying out interactions for the creation, production and sale of those products has been provided. According to this definition, sectoral systems have a knowledge base, demand technologies, and inputs. The agents composing a sectoral system are individuals and organizations, are characterized by specific learning processes, competencies, beliefs, objectives, organizational structure and behaviors, and interact through processes of communication, exchange, co-operation, competition and command processes, which are shaped by institutions. Finally, it has been claimed that over time sectoral systems undergo change and transformation through the co-evolution of its various elements.

A methodological remark comes from the above definition and should be stressed here as a way of conclusion. In a sectoral system, there are different levels for the analysis of agents: the individual, firms' sub-units, groups of firms and non-firms organizations. Flexibility has to be used in the choice of the unit of analysis, the variables to be examined and the fine grained analysis that has to be conducted. The same holds for products. Sometimes it is necessary to analyze very broad sectoral systems, such as computer hardware and software. Other times not, as in the case of software. Particularly, with respect to the emergence of new clusters such as software–internet–telecommunication, new materials or pharmaceutical–biotechnology, a high level of aggregation is important. In any case, the goal and the objectives of the analysis should dictate the appropriate level of disaggregation.

Sectoral systems may prove a useful tool in various respects: for a descriptive analysis of sectors, for a full understanding of their working, dynamics and transformation, for the identification of the factors affecting the performance and competitiveness of firms and countries and finally for the development of new public policy proposals.

One remark has to be advanced about the impossibility of identifying "optimal" structures and working for sectoral systems. In reality, some coherence among the various elements of a sectoral system does occur and develops over time as a result of both conscious design and unplanned processes. And mismatches among the various parts and variables of sectoral systems could be identified and eventually eliminated. But the actual coherence is far from being “optimal”. The same is true for the working of sectoral systems. Sectoral systems may take different features in different countries, and in different times. And in continuously changing environments, with historical processes going on and embedded in different countries, there is no way to identify an “optimal” sectoral system.

Future research on sectoral system should move along four lines. The first (and the most urgent one) regards analyses of sectoral systems along similar dimensions. While relevant progress has been done in identifying sectoral differences in the types of innovation and production, the kinds of agents, the sources of knowledge, the key dimensions of demand, the geographical boundaries and the presence of non-firm organizations, less advancement has concerned the extent and features of within-sector firms heterogeneity and the structure and change in the relationships among agents. Even less progress has been reached in understanding differences in the role of sectoral institutions, the processes of variety creation and selection, and co-evolution. Albeit these issues present quite different levels of analytical and empirical difficulty, all of them have to be studied in-depth and understood in order to have a full comprehension of the differences in the features, working and dynamics of sectoral systems.

Second, on the basis of the results obtained from the analyses mentioned above, taxonomies of sectoral systems have to be constructed. Here, comparative work is particularly relevant. These taxonomies should group sectoral systems in terms of elements, structure and dynamics, so that regularities could be identified among sectors and a general description of the features could be proposed. Pavitt’s taxonomy (Pavitt, 1984) is a useful starting point as far as the sources of innovation, the appropriability means and the industrial structure are concerned. The same holds for the Schumpeter Mark I and Schumpeter Mark II distinction, with the related types of technological regimes (Malerba and Orsenigo, 1996).

Third, conceptual and theoretical work has to be carried out on the basic relationships among the elements of a sectoral system, the emergence and persistence of firms heterogeneity, the basic processes of variety creation, selection, and co-evolution. Here, both of industry dynamics and history friendly models can be useful. In the best evolutionary (and innovation system) tradition, this work should go hand in hand, and be continuously confronted with, empirical work.

Finally, public policy proposals may be developed on how to affect the transformation of sectoral systems, the innovation and diffusion processes, and the competitiveness of firms and countries. A sectoral system perspective may help in identifying mismatches and blocks that parts of the system exert on the rest. And may help overcome vicious cycles that block systems in their growth, development and transformation.

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