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Technological paradigms, regimes and trajectories: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation

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ABSTRACT

This article presents a new sectoral taxonomy that combines manufacturing and service industries within the same framework. This exercise is relevant because it aims at greater integration between the study of sectoral patterns of innovation in manufacturing and services, stressing the increasing importance of vertical linkages and inter-sectoral knowledge exchanges between these interrelated branches of the economy. The relevance of the new taxonomy is illustrated with reference to the innovative activities and economic performance of manufacturing and service industries in Europe. This empirical evidence, which presents fresh results from the *Fourth Community Innovation Survey*, supports the relevance of the taxonomy by showing the great variety of sectoral patterns of innovation in European industries.

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1. Introduction

The study of sectoral patterns of innovation has attracted increasing academic attention in recent decades. Seminal contributions have pointed out some major features of the innovative process and the great variety of patterns in different historical periods and industrial settings (Nelson and Winter, 1977; Dosi, 1982; Freeman et al., 1982; Pavitt, 1984).

Inspired by these original insights, a substantial amount of empirical research has focused on various aspects of sectoral patterns of innovation. Several contributions have investigated the emergence and diffusion of technological paradigms that characterize any given historical era, the set of opportunities and constraints that these create for different types of sectoral regimes, the distinct trajectories followed by industrial sectors, and the related web of vertical linkages between sector-specific regimes and trajectories in the national system of innovation (Archibugi, 2001; Laursen and Meliciani, 2002; Marsili and Verspagen, 2002; Malerba, 2002).

For a long time, most of the empirical literature in this field, and the underlying theoretical framework, focused on innovative activities and performance in manufacturing industries. In the past few years, however, with the rapid growth in the service sectors and the increased pace of innovation experienced by some advanced service providers, a new body of research has turned to this hitherto unexplored branch of the innovation system.

The literature on service innovation represents an increasingly important field of research, which has formulated new questions and shed new light on the process of knowledge creation in the service sectors (Drejer, 2004; Miles, 2005). In particular, this literature has identified certain features that make the innovation process in services markedly different from that of manufacturing, and emphasized the growing interdependence between the manufacturing and service branches of the economy (Evangelista, 2000; Miozzo and Soete, 2001; Guerrieri and Meliciani, 2005).

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However, the service innovation literature seems to be developing, to some extent, into a separate field of investigation within innovation studies, without much interaction with or relation to the well-established paradigm–regime–trajectory model already developed for the study of innovation in manufacturing industries. One major challenge is therefore to provide a more integrated view of the characteristics that innovation takes in manufacturing *and* in service industries alike, and to shed new light on the relationships between these interrelated parts of the economy (Gallouj and Weinstein, 1997).

Motivated by this need for greater integration between the study of manufacturing and service innovation, this article presents a new sectoral taxonomy that combines manufacturing and service industries within the same overall framework. The taxonomy is built up by focusing on two main characteristics of industrial sectors: the function they assume in the economic system as providers and/or recipients of advanced products, services and knowledge; and the dominant innovative mode that characterizes their technological activities (their sectoral regime and trajectory). Using these two conceptual dimensions, the new taxonomy identifies four major sectoral groups, points out their characteristic features, and focuses on the vertical linkages that tie them together.

The empirical relevance of the taxonomy is then illustrated by means of descriptive evidence. The analysis presents fresh results from the *Fourth Community Innovation Survey* (CIS4, 2002–2004) on the innovative activities of manufacturing and service industries in a sample of 24 European countries, and combines them with information on the economic performance of these industrial sectors in the longer period 1970–2003 from the OECD-STAN database. The descriptive evidence supports the relevance of the taxonomy by demonstrating the great variety of sectoral patterns of innovation in European industries.

The article is organized as follows. Section 2 briefly reviews the literature on paradigms, regimes and trajectories in manufacturing industries. Section 3 describes the state of the art in the study of service innovation and argues for greater integration between the research on manufacturing and on service innovation. Section 4 presents the new taxonomy, pointing out the main implications of this theoretical view for understanding the process of growth and structural change. Section 5 illustrates the empirical relevance of the taxonomic model. Section 6 concludes and discusses the policy implications of the analysis.

2. Paradigms, regimes and trajectories in manufacturing industries

The study of innovation in manufacturing industries received a significant push between the late 1970s and the early 1980s, when the seminal contributions of, among others, Dosi, Freeman, Pavitt, Nelson and Winter opened up a new direction of research and a new set of questions. This perspective focused on some of the major characteristics of the process of technological change, in particular on its paradigmatic, cumulative and sector-specific nature.[1]

The paradigmatic nature refers to the existence of major technologies that create, in any given historical era, a set of opportunities and constraints for the innovative activities and business strategies of economic agents. The seminal concept is that of *technological paradigm*.

> In broad analogy with the Kuhnian definition of a "scientific paradigm", we shall define a "technological paradigm" as "model" and a "pattern" of solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on *selected* material technologies [. . .] It would perhaps be better to talk of "cluster of technologies", e.g. nuclear technologies, semiconductor technologies, organic chemistry technologies, etc. (Dosi, 1982, p. 152)

The idea of technological paradigms is closely related to the perspective originally proposed by Schumpeter in *Business Cycles* (1939), which emphasized the discontinuities associated with the introduction of radical technologies and the disruptive effects that these may have on the dynamics of the whole economy. Historically, the emergence and diffusion of new technological paradigms have been closely associated with the rise of interrelated and pervasive radical innovations which had the potential to be used in many sectors of the economy and to drive their long-run performance for several decades (Freeman et al., 1982; Freeman and Louça, 2001).

Thus, the concept of technological paradigm does not simply describe a set of structural techno-economic features in a static sense, but is inherently related to the dynamic behaviour of the system, i.e. the growth potential that any given set of interrelated and pervasive radical technologies entails. The exploitation of such technological and economic potential proceeds along well-established directions, the *technological trajectories*.

> We will define a *technological trajectory* as the pattern of "normal" problem solving activity (i.e. of "progress") on the ground of a technological paradigm. [. . .] Once a path has been selected and established, it shows a momentum of its own [. . .], which contributes to define the directions towards which the "problem solving activity" moves. A technological trajectory, i.e. to repeat, the "normal" problem solving activity determined by a paradigm, can be represented by the movement of multi-dimensional trade-offs among the technological variables which the paradigm defines as relevant. Progress can be defined as the improvement of these trade-offs. (Dosi, 1982, pp. 152–154)

The third pillar in this theoretical construction is then the *sector-specific* nature of innovation. This is a direct consequence of this Schumpeterian perspective and of the paradigm-bounded and path-dependent nature of the process of technological accumulation. In fact, when a new

[1] For a more extensive survey of this literature and a comparison of various theoretical approaches to the study of innovation and economic growth, see Castellacci (2007a).

technological paradigm emerges and starts to diffuse in the economic system

> industries differ significantly in the extent to which they can exploit the prevailing general natural trajectories, and these differences influence the rise and fall of different industries and technologies. (Nelson and Winter, 1977, pp. 59–60)

In any given historical era, industrial sectors whose knowledge base and capabilities are closely related to the constellation of emerging radical innovations face a broader set of opportunities and tend therefore to follow dynamic trajectories. By contrast, industries less directly involved in the production and use of the new general-purpose technologies experience a lack of opportunities and are therefore forced to move along less dynamic paths.

Inspired by these theoretical insights, empirical research on sectoral patterns of innovation has flourished in the last few years, investigating both the characteristics of the innovative process in particular industries as well as cross-sectoral differences in technological activities and performance. Different strands of research have focused on different elements of the original theoretical framework.

One group of studies has focused on sector-specific technological regimes, identifying the various features that distinguish innovative activities and industrial dynamics in different sectors, particularly in terms of technological opportunities, properties of the knowledge base, cumulativeness and appropriability conditions (e.g. Breschi et al., 2000; Marsili and Verspagen, 2002; Malerba, 2002; Van de Poel, 2003; Dosi et al., 2006). Other studies, instead of focusing on the patterns of industrial dynamics and the related process of competition and selection within each industrial sector, have more closely analysed the innovative strategies that firms follow in different sectors of the economy. Here, the emphasis is more on the notion of technological trajectories, and on the relationships between sector-specific paths and the various characteristics of firms' innovative strategies.

It was Pavitt (1984) who originally applied the idea of technological trajectories to the investigation of sectoral patterns of innovation. In his well-known taxonomy, Pavitt identified four major patterns of innovation (i.e. four dominant technological trajectories): supplier-dominated, scale-intensive, specialized suppliers, and science-based industries. Pavitt's taxonomy inspired a great amount of research in this field.[2] In particular, this empirical work has been fostered by the rapid diffusion of Community Innovation Survey (CIS) data in Europe in the past decade, which has made it possible to enlarge the set of factors used to describe the dominant technological trajectories followed by innovating firms in different industries of the economy (Evangelista et al., 1997; Evangelista, 1999; Veugelers and Cassiman, 1999; Mairesse and Mohnen, 2002; Reichstein and Salter, 2006).

A crucial aspect of the Pavitt taxonomy and the related set of later empirical studies is the focus on *vertical linkages*, i.e. the set of relationships and interactions that innovative firms have with enterprises in other sectors of the economy. The systemic nature of the innovative process in fact calls attention to the interactions, cooperations and exchanges involving producers, suppliers and users of new technologies. These inter-sectoral exchanges, the set of input–output relationships in terms of advanced knowledge, material inputs and demand, constitute a factor crucial to enhance the competitiveness of the whole national system. According to the *home market hypothesis*, in fact, the strength of interactions among suppliers, producers and users of advanced technologies and the existence of an established and well-functioning set of vertical linkages represent one major factor of competitive advantage (Porter, 1990; Lundvall, 1992; Laursen and Meliciani, 2002).

Even though various strands of recent empirical research have focused on distinct aspects, all of them are founded upon the original Schumpeterian framework briefly outlined in this section. In sum, this story is based on the emergence and diffusion of technological paradigms that characterize any given historical era, the set of opportunities and constraints that these create for different types of sectoral regimes, the distinct trajectories followed by industrial sectors, and the related web of vertical linkages that tie together sector-specific regimes and trajectories in the national system of innovation.

The ideal-type example of this paradigm–regime–trajectory–linkages model – and the very same historical context where this framework was conceived – dates from the Fordist age (Freeman et al., 1982; Freeman and Louça, 2001). The radical technologies that brought a strong growth potential in the post-war era were initially based on the petrochemical technology for producing oil ('cracking') as well as the internal combustion engine. These radical innovations gave a major push to the mass-producing sectors that employed these technologies on a large scale, especially the automobile, plastic and chemical industries, which came to follow highly dynamic trajectories during the post-war decades.

This growth potential diffused rapidly throughout the economic system by means of the set of vertical linkages and inter-sectoral relationships within the home market. The general-purpose technologies sectors fostered the demand for specialized inputs from their suppliers (e.g. precision instruments and advanced components), while at the same time providing a set of advanced knowledge outputs to the users of new technologies, supplier-dominated firms as well as final consumers. Pavitt's model of the linkages between science-based, specialized suppliers, scale-intensive and supplier-dominated industries provides a stylized and powerful description of the core set of industrial sectors that sustained the growth of advanced economies during the Fordist age.

3. Structural change, innovation and the growth of services

The literature on technological regimes, trajectories and vertical linkages is mostly focused on the manufacturing

[2] For a critical discussion of this literature, see Archibugi (2001).

branch of the economy, since this represented the major growth engine and the most innovative part of the economic system throughout most of the post-war era. In recent decades, however, the service sectors have experienced rapid growth, and they now account for a large share of value added, employment and trade in most industrialized countries.

The traditional view of services as productivity laggards and employment sponges (Baumol, 1967) has been called into question by the great dynamism that some advanced service sectors have shown in relation to the emergence and diffusion of information and communication technologies (ICTs). In the last few decades, a range of interrelated radical innovations has progressively been introduced in the economic system, first in the semiconductor industry and later in the software and telecommunications sectors, diffusing rapidly since the early 1990s (Freeman and Louça, 2001). As part of the diffusion of the new general-purpose technologies, a related set of innovations has spread, based on multimedia and the Internet, closely linked to publishing and entertainment activities and to a whole range of new services (voice networks, cable, mobile and satellite communications, data transmission, networks, etc.). The growth of advanced services is thus closely related to the emergence of a new technological paradigm characterized by the pervasiveness and growth potential brought by ICTs.

Motivated by these recent transformations, an emerging body of literature points to the increasingly important role of innovation for the creation of entirely new ICT-based services as well as for the growth of existing ones. The literature on innovation in services now represents one of the most rapidly growing areas within innovation studies (Drejer, 2004; Miles, 2005). This recent literature emphasizes the existence of a great variety of innovative strategies and patterns within services (Evangelista, 2000; Tether, 2003). In fact, the service branch of the economy consists of a very heterogeneous set of activities, and the study of innovation in different service industries must take these sectoral specificities into account. Thus, similarly to what was done in the study of manufacturing industries, innovation scholars have recently started to analyse the technological trajectories followed by different types of service industries and have proposed taxonomies of service innovation aimed at identifying some major sectoral patterns of innovation that characterize different groups of service industries.

In the economics literature, a traditional and well-known distinction is that between *producer*, *distributive* and *personal* services (Gershuny and Miles, 1983; Park and Chan, 1989). This simple taxonomy is not explicitly focused on innovation, but it is important because it points out the different functions that various groups of service sectors perform within the economic system as providers of intermediate, distributive or final services, respectively. Building upon this original distinction, but focusing more explicitly on the role of innovation and of inter-sectoral exchanges of knowledge among different groups of industries, Miozzo and Soete (2001) have proposed an interesting taxonomy of sectoral patterns of innovation in services. This taxonomy is inspired by Pavitt's (1984) conceptualization, and it uses a similar approach to examine the innovative patterns of different types of service industries.[3]

The study of the sectoral variety of innovation within services is closely related to the analysis of the relationships among different types of service industries, namely the extent and intensity of vertical linkages that tie together producers, suppliers and users of new technologies. This aspect becomes even more relevant in the light of the fact that an intense process of outsourcing has taken place in recent decades, where many activities previously performed within manufacturing firms are now carried out by specialized business services. This process is leading to an increasing interdependence and a more intense knowledge exchange between manufacturing and service activities. While the former outsource part of the technological and productive activities to specialized service providers, thus sustaining their growth by demanding a new range of intermediate products and services, technological advances in the latter serve to sustain the dynamics of the whole manufacturing branch (Park and Chan, 1989; Franke and Kalmbach, 2005).

Two examples can illustrate the relevance of this argument. The first concerns infrastructural and distributive services, such as transport, financial and telecommunication services. Innovative activities for service providers of this type are heavily dependent on the acquisition of advanced capital equipment (ICT-related devices in particular) from manufacturing industries, whose application yields increases in efficiency and quality improvements of the infrastructure of the economy. In turn, advances in the latter have a pervasive effect on the whole system of innovation by bringing cost reductions and productivity gains in all other industries. In addition, an advanced communication infrastructure favours the process of technological and economic specialization: hence, it enables the deepening of the division of labour and the outsourcing of activities that the process of structural change entails (Antonelli, 1998).

The second example refers to knowledge-intensive business services, such as software, R&D, engineering and consultancy firms. These produce specialized knowledge and act as problem-solvers for advanced manufacturing firms, as well as for ICT-based infrastructural services. This is for instance the case for the interactions between hardware and software in the computer industry, and for the increasingly important role played by R&D and engineering services for the innovative activities carried out by science-based and specialized manufacturing industries.

Therefore, a crucial factor of competitive advantage in the new ICT-based technological paradigm is represented by the interdependence and vertical linkages that tie together different groups of manufacturing and service sectors (Windrum and Tomlinson, 1999; Di Cagno and Meliciani, 2005; Guerrieri and Meliciani, 2005). Such an extension of the home market hypothesis is a fascinating subject for further study, although at present a full understanding of the interactions and co-evolutionary process linking together manufacturing and services is still lacking.

[3] See also the related works of Evangelista (2000) and Hipp and Grupp (2005).

In summary, despite the recent advances in the study of service innovation, this literature still seems fragmented and not clearly related to the paradigm–regime–trajectory model earlier developed for the study of innovation in manufacturing industries. The service innovation literature has shed much new light on a range of specific aspects that characterize the process of knowledge creation in the provision of services, but it has so far been less successful in integrating these new insights into the previous well-established research on paradigms, regimes, trajectories and vertical linkages.

One major challenge is therefore to build up a more integrated view of the characteristics that innovation takes in manufacturing *and* in service industries, and to shed new light on the relationships between these interrelated branches of the economy. One previous important attempt in this direction was presented by Gallouj and Weinstein (1997), who argued in favour of a *synthesis* approach to innovation and presented an integrated microeconomic model encompassing both manufacturing and service characteristics.

> The construction of a general description of innovation is essential for an understanding of what the notion of innovation might encompass, in both services and manufacturing industry, and the basic forms it might take. (Gallouj and Weinstein, 1997, p. 538)

This paper agrees that greater integration between the study of manufacturing and service innovation constitutes an important challenge for research in the field; however, instead of focusing on the microeconomic characteristics of goods and services, it approaches the issue at a more aggregate level of analysis, and presents a sectoral taxonomy that integrates manufacturing and service industries within the same general framework.

4. Manufacturing and service industries in a new taxonomy

The new taxonomy of sectoral patterns of innovation presented in this section builds upon and combines elements of sectoral classifications previously pointed out in the economics and innovation studies literatures.

On the one hand, the economics literature has frequently adopted a product-related type of classification, where industrial sectors are identified according to the kind of item that firms predominantly produce and commercialize. The product-related classification naturally leads to an emphasis on the function that each industry assumes in the economic system as provider (recipient) of goods and services to (from) other industries, i.e. its stage in the vertical chain. One well-known example of this type of *product- and function-related classification scheme* can be seen in the "new growth" literature. New growth models admittedly provide a rather stylized representation of sectoral groups, which mainly differ in terms of their function in the economic system as producers of blueprints (the R&D sector), intermediate or final goods (e.g. Romer, 1990; Grossman and Helpman, 1991). This standard type of three-sector model presents a useful stylized representation of the economy, but it does not enable detailed investigation of the industry-specific nature of innovation and the great variety of sectoral patterns of technological change characteristic of the knowledge-based economy. While recognizing the analytical appeal of this simple type of classification, our typology aims to provide a more precise characterization of sectoral patterns of innovation than what is commonly offered by endogenous growth models in the economics literature.

On the other hand, the innovation studies literature has frequently adopted sectoral classifications that point out more explicitly the characteristics of the process of technological change, rather than the types of items produced by firms in various sectors. *Technological systems of classification* focus on the innovative modes and strategies that are adopted by firms in different parts of the economic system, i.e. the characteristics of their technological regimes and trajectories. As pointed out in Section 2, the focus on technological regimes and trajectories naturally leads to an emphasis on the vertical linkages and knowledge exchanges that firms in different sectors of the economy have with their suppliers and/or with the users of new technologies. A familiar example of this type of classification scheme is the taxonomy of Pavitt (1984), where the main focus is on the innovative mode adopted by different sectoral groups and the related inter-sectoral knowledge flows.[4] Our taxonomic model also builds upon this type of classification scheme, but it differs from previous sectoral taxonomies in the innovation studies literature in one important aspect. While typologies of manufacturing and service innovation have so far been carried out separately and independently of each other, the taxonomic model proposed here combines manufacturing and services within the same framework, and points out the fundamental role played by vertical linkages and inter-sectoral knowledge exchanges between them.

Fig. 1 presents a stylized representation of this taxonomic model. In an attempt to consider product- and technology-related characteristics simultaneously, the typology is constructed by dividing industrial sectors along two main dimensions. The first focuses, in analogy with the endogenous growth literature, on the *function* assumed by each industry in the economic system as provider and/or recipient of goods and services, i.e. its position in the vertical chain. Industries that provide final (intermediate) goods and services to other sectors are therefore positioned at a higher (lower) level on the *Y*-axis in the diagram in Fig. 1.

The second dimension represents, in analogy with previous taxonomic exercises in the innovation literature, the *technological content* of an industry, i.e. the overall level of technological capabilities of innovative firms in the sectoral system. This dimension is thus defined by the technological regimes and trajectories that characterize sectoral systems,

[4] To be more precise, Pavitt's taxonomy does not only focus on innovative activities and knowledge flows, but also incorporates elements of a *process-related type of classification*, e.g. by emphasizing the relevance of scale economies for his group of scale-intensive producers. For a more detailed discussion of product-, technology- and process-related sectoral classification schemes, see Von Tunzelmann and Acha (2005).

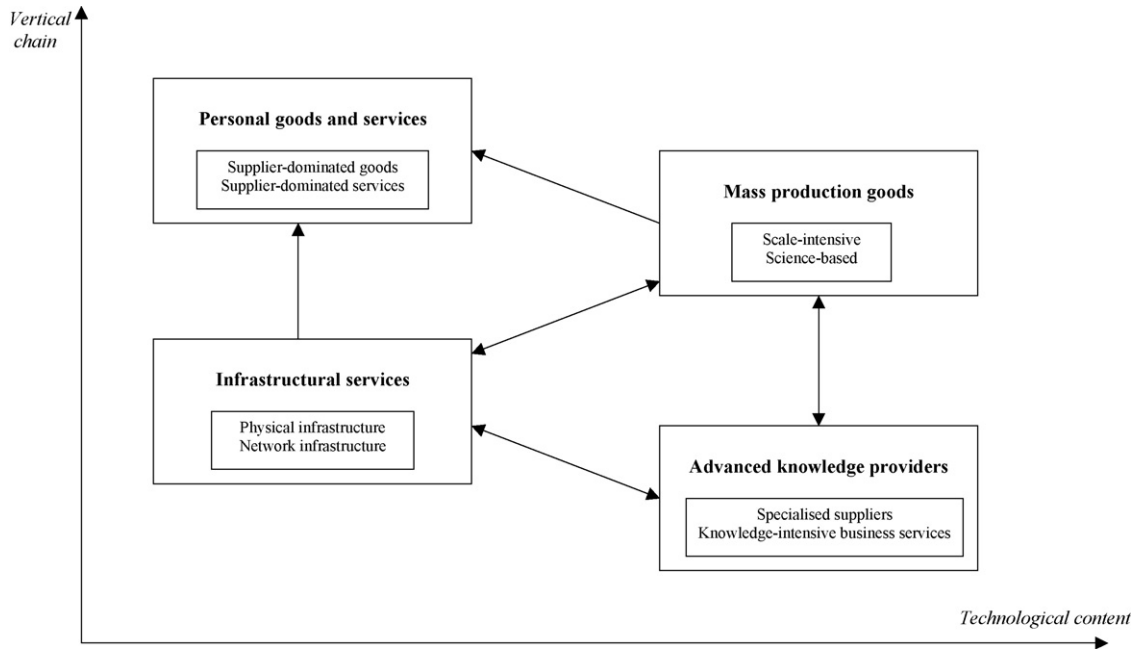


Fig. 1. A new taxonomy of sectoral patterns of innovation in manufacturing and service industries.

and the extent to which industrial sectors are able to create new technologies internally or must rely on the external acquisition of machinery, equipment and knowledge from their suppliers. Technologically advanced sectors, able to develop new technologies internally and provide them to the rest of the economy, are positioned on the right-hand side of the *X*-axis in Fig. 1, whereas industries that mostly acquire advanced knowledge from other sectors rather than creating them internally are positioned on the left-hand side of the *X*-axis.[5]

The typology is built up by applying these dimensions in a two-step conceptual exercise. First, sectors are divided according to the main function they assume in the economic system (*Y*-axis). This yields the identification of *four major sectoral groups*. Secondly, each of these four blocks is subsequently divided into two distinct sub-groups on the basis of the technological content that characterizes them (*X*-axis). By using these two layers of analysis, the taxonomy not only points out the function of each sector as provider and/or recipient of goods and services to other industries, but also acknowledges the presence of considerable heterogeneity within each industrial block, in line with previous related exercises in the innovation literature (Pavitt, 1984; Miozzo and Soete, 2001).

Table 1 presents a summary of the main features of these various industrial blocks, pointing out their relationship to the dominant technological paradigm and some of the characteristics of their technological regimes and trajectories.[6]

Advanced knowledge providers (AKP) are characterized by great technological capability and a significant ability to manage and create complex technological knowledge. Two sub-groups of industries belong to this category: (1) within manufacturing, specialized suppliers of machinery, equipment and precision instruments; (2) within services, providers of specialized knowledge and technical solutions like software, R&D, engineering and consultancy (so-called knowledge-intensive business services). What these industries have in common is that, in addition to their high level of technological capability, they perform the same function in the innovation system as providers of advanced technological knowledge to other industrial sectors. They represent *the supporting knowledge base* upon which innovative activities in all other sectors are built, and they continuously upgrade and renew this base. Firms in these industries are typically small, and tend to develop their technological activities in close cooperation with their

[5] One important caveat needs to be noted. The two dimensions pointed out here and graphically presented in Fig. 1 admittedly provide a rather stylized and simplified representation of concepts that are indeed multi-dimensional in nature. First, the vertical chain represented on the *Y*-axis of Fig. 1 refers to the product chain, and the related set of input–output sectoral exchanges. The chain would, however, look different if structured in terms of, e.g., knowledge or financial flows. Furthermore, the degree of vertical integration in the industrial system changes over time, so that different sectors, and firms within sectors, may indeed shift their relative position on the vertical chain in the long run (Von Tunzelmann and Acha, 2005). Secondly, the technological content dimension represented on the *X*-axis in the figure also represents a convenient linearization of the concept of innovative mode (regimes, trajectories, etc.), which is actually complex and difficult to summarize by means of a single uni-dimensional construct, as discussed in Section 2. Thus, this taxonomic model provides a rather stylized and simplified representation of the economic system, and it is important to acknowledge and emphasize the sense of multi-dimensionality that underlies these two conceptual dimensions.

[6] The table can be directly compared to the corresponding tables in Pavitt (1984, p. 354) and Miozzo and Soete (2001, p. 161), which, as pointed out, represent two major previous taxonomic exercises for the study of sectoral patterns of innovation in manufacturing and service industries, respectively.

Table 1
The main characteristics of the various sectoral groups in the new taxonomy

Sectoral category	Sub-groups within each category	Typical core sectors	Major function and relationship to technological paradigms	Technological regimes	Technological trajectories
Advanced knowledge providers	Knowledge-intensive business services	Software; R&D; engineering; consultancy	The supporting knowledge base of the ICT paradigm	*Opportunity levels*: very high *External sources*: users and universities *Appropriability*: know-how; copyright *Dominant firm size*: SMEs	*Type of innovation*: new services; organizational innovation *Innovation expenditures and strategy*: R&D; training; cooperations
	Specialized suppliers manufacturing	Machinery; instruments	The supporting knowledge base of the Fordist paradigm	*Opportunity levels*: high *External sources*: users *Appropriability*: patents; design know-how *Dominant firm size*: SMEs	*Type of innovation*: new products *Innovation expenditures and strategy*: R&D; acquisition of machinery; software purchase
Mass production goods	Science-based manufacturing	Electronics	The carrier industries of the ICT paradigm	*Opportunity levels*: high *External sources*: universities and users *Appropriability*: patents; design; copyright *Dominant firm size*: large	*Type of innovation*: new products; organizational innovation *Innovation expenditures and strategy*: R&D; cooperations
	Scale-intensive manufacturing	Motor vehicles	The carrier industries of the Fordist paradigm	*Opportunity levels*: medium *External sources*: suppliers and users *Appropriability*: design; process secrecy *Dominant firm size*: large	*Type of innovation*: mixed products and process innovation *Innovation expenditures and strategy*: R&D; acquisition of machinery
Supporting infrastructure services	Network infrastructure services	Telecommunications; finance	The supporting infrastructure of the ICT paradigm	*Opportunity levels*: medium *External sources*: suppliers and users *Appropriability*: standards; norms; design *Dominant firm size*: large	*Type of innovation*: mixed process, service and organizational innovation *Innovation expenditures and strategy*: R&D; acquisition of software; training
	Physical infrastructure services	Transport; wholesale trade	The supporting infrastructure of the Fordist paradigm	*Opportunity levels*: low *External sources*: suppliers *Appropriability*: standards; norms; design *Dominant firm size*: large	*Type of innovation*: process *Innovation expenditures and strategy*: acquisition of machinery and software

Table 1 (*Continued*)

Sectoral category	Sub-groups within each category	Typical core sectors	Major function and relationship to technological paradigms	Technological regimes	Technological trajectories
Personal goods and services	Supplier-dominated goods	Textiles and wearing	They enhance the quality of final products and services by acquiring and embodying technologies related to different paradigms	*Opportunity levels*: medium *External sources*: suppliers and end users *Appropriability*: trademarks; design know-how *Dominant firm size*: SMEs	*Type of innovation*: process *Innovation expenditures and strategy*: acquisition of machinery
	Supplier-dominated services	Hotels and restaurants		*Opportunity levels*: low *External sources*: suppliers *Appropriability*: non-technical means *Dominant firm size*: SMEs	*Type of innovation*: process *Innovation expenditures and strategy*: acquisition of machinery; training

clients and with the users of the new products and services they create. In the Fordist model, the typical example of this kind of user–producer interactions was Pavitt's illustration of the close ties between specialized suppliers and car producers in the automotive industry. In more recent times, the greater technological specialization and deeper division of labour have increased the demand for complex innovative capabilities, leading to the emergence and rapid growth of knowledge-intensive business services, which now act as providers of specialized knowledge and technical solutions for the other advanced branches of the economic system.

Supporting infrastructural services (SIS) may be located, similarly to the previous category, at an early stage of the vertical chain, since they mostly produce intermediate products and services rather than items for personal consumption. Where they differ from advanced knowledge providers is in terms of their technological capability, especially their more limited ability to develop new knowledge internally. Their innovative trajectory tends to be based on the acquisition of machinery, equipment and various types of advanced technological knowledge created elsewhere in the economic system. Two sub-groups of sectors can be distinguished here, each characterized by a different level of technological sophistication (Miozzo and Soete, 2001): (1) providers of distributive and physical infrastructure services (e.g. transport and wholesale trade); (2) providers of network infrastructure services (such as finance and telecommunications). Firms in the latter group typically make heavy use of ICTs developed by other advanced sectors in order to increase the efficiency of the productive process and the quality of their services, whereas the former group of industries has significantly less capability in this respect. Regardless of these differences, what these sectoral groups have in common is the function they assume in the economic system: they represent *the supporting infrastructure* upon which business and innovative activities carried out by firms in the whole economy are based. The more advanced this infrastructure is, the easier the process of inter-sectoral knowledge diffusion within the domestic economy, and the more efficient and productive the national system will be.

Sectors producing *mass-production goods* (MPGs) constitute a key part of the manufacturing branch. They may be located at an intermediate stage of the vertical chain, since they produce both final goods and intermediate products used in other stages of the production process. In terms of their technological content, they are characterized by their considerable capability to develop new products and processes internally, although two distinct sub-groups may be distinguished (Pavitt, 1984): (1) scale-intensive industries (e.g. motor vehicles and other transport equipment) frequently have their own in-house R&D facilities, and their innovative activities also develop in close cooperation with the specialized suppliers of precision instruments and machinery; (2) science-based sectors (such as electronics) are characterized by a greater ability to create new technological knowledge internally, and their innovation processes stay close to the scientific advances continuously achieved by universities and other public research institutes. Different as they may be, these sectoral groups share several common characteristics. Firms are typically

large, and their profitability depends on the exploitation of scale economies that can be obtained through the mass production of standardized goods. Further, they all assume a central position in the knowledge chain, as they receive technological inputs from advanced knowledge providers, while in turn providing technological outputs (new products) that are used by infrastructural services as well as by producers of final goods. They are, in a nutshell, *the carrier industries* of a new technological paradigm (Freeman and Louça, 2001). By producing technologically advanced products on a large scale, by fostering the efficiency and quality of the production process of infrastructural and final goods and services, and by increasing the demand for specialized solutions from advanced knowledge providers, this group of industrial sectors plays a pivotal role in the economic system.

In the fourth sectoral block we find the producers of *personal goods and services* (PGSs). Located at the final stage of the vertical chain, these manufacturing and service industries are characterized by a lower technological content and a more limited ability to develop new products and processes internally. Their dominant innovation strategy is typically based on the acquisition of machinery, equipment and other types of external knowledge produced by their suppliers, while they commonly lack the capability and resources to organize and maintain their own R&D labs. This explains the term *supplier-dominated* industries that is frequently adopted in the innovation literature—and that describes well the two sub-groups of industries included in this category: (1) the producers of personal goods and (2) the providers of personal services (Pavitt, 1984; Miozzo and Soete, 2001). Firms in these manufacturing and service branches, typically small enterprises, are mostly recipients of advanced knowledge. To the extent that they are able to implement new technologies created elsewhere in the economy, they may use them to increase the efficiency of the production process as well as to improve the quality of the final goods and services they commercialize. This type of strategy may help to lengthen the industry-life cycle of these mature industrial sectors and recreate new technological opportunities.[7]

In a nutshell, this sectoral typology presents a stylized view of some of the main vertical linkages between manufacturing and business services within a national system of innovation. One relevant aspect of this neo-Schumpeterian taxonomic model is the explanation it provides of the mechanisms that drive growth and structural change in national systems of innovation. When a new technological paradigm emerges and diffuses throughout the economy, industrial sectors differ greatly in terms of the technological opportunities, capabilities and constraints they face. High-opportunity technological regimes are in a better position to exploit the advantages of the new general-purpose technologies, and have a greater growth potential. Some of these industries belong to our *mass-production goods* sectoral group. By demanding new infrastructural services as well as advanced specialized knowledge and technical solutions to their suppliers, they transmit part of this growth potential to some of the other industrial groups.

To illustrate, under the Fordist paradigm, the typical high-opportunity mass-production sectors included the chemical, plastics and automobile industries (Freeman et al., 1982). In order to follow their dynamic trajectories, these branches fostered the growth of specialized suppliers (e.g. producers of precision instruments) and of infrastructural services (in particular, physical infrastructural services like transport). It was the set of mutual interactions between these vertically integrated branches of the economy that sustained the dynamics of national systems in many advanced countries in the post-war era.

More recently, with the emergence and rapid diffusion of the ICT-based paradigm, greater technological opportunities can instead be found in other sectors. Electronics and hardware producers may be seen as the high-opportunity mass production manufacturers of the present age. In their dynamic trajectory, these sectors have, however, also sustained the rise of advanced knowledge providers (such as software and technical consultancy) and of network infrastructure services (e.g. telecommunications). It is the exchange of advanced knowledge, goods and services among these high-opportunity manufacturing and service sectors that accounts for the bulk of the growth potential of the current era.

In short, the specific key industries will differ in any given historical age, but the overall causation mechanism that drives the dynamics of the system remains, by and large, the same. A new set of general-purpose technologies will need to be produced on a large scale, supported by an efficient infrastructure and sustained by the provision of an advanced knowledge base. Our four-group typology provides a comprehensive and general framework that accounts for the dynamics of a national system within each paradigmatic phase, as well as for the transformations that occur when a regime shift changes the locus of technological opportunities and of the related growth potential.[8]

This theoretical view has one important implication for the competitiveness of national systems. Given the exis-

[7] It is important to emphasize the multifaceted nature of the concept of *opportunity* that is so frequently used in the innovation literature. Table 1 and the related discussion in this section focus on *technological opportunities*, in line with the emphasis on technological paradigms, regimes and trajectories that inspires the new taxonomic model. However, for some industrial sectors, *market opportunities* may frequently be an equally important driver of structural change and competitiveness. For instance, in some medium- and low-tech industries, demand differentiation plays a relevant role, as firms progressively seek to improve the quality of traditional products and to produce new items in keeping with new tastes and demand changes (Von Tunzelmann and Acha, 2005). By focusing on technological rather than market opportunities, our taxonomic model emphasizes the supply-side determinants of structural change, while neglecting some important demand-side drivers.

[8] This is an aspect where the new taxonomy differs substantially from related works in this field. The main purpose of previous taxonomic exercises was more to point out the existence of industries characterized by distinct innovative modes in a given historical period (e.g. in the post-war era, as in Pavitt's taxonomy), rather than exploring the implications of a given industrial structure for the dynamics of the economic system. The taxonomy presented here, by making explicit the link between paradigms, regimes and trajectories, tries to link the identification of sectoral patterns in a static sense with the study of structural change and economic dynamics in the long run.

Table 2
The characteristics of the categories of the new taxonomy [*Technological regimes*—CIS4 data (2002–2004), EU24 average[a]]

	AKP		MPG		SIS		PGS	
	Knowledge-intensive business services	Specialized suppliers manufacturing	Science-based manufacturing	Scale-intensive manufacturing	Network infrastructure services	Physical infrastructure services	Supplier-dominated goods	Supplier-dominated services
Level of innovativeness (%)	56.76	53.27	56.59	42.71	46.49	29.96	37.59	22.15
Level of opportunities (%)	19.24	5.37	5.28	4.15	2.66	2.69	4.27	0.67
Cumulativeness conditions (%)	48.11	43.24	48.45	28.77	24.07	13.96	22.52	16.69
Appropriability through patents (%)	14.61	20.92	20.14	14.40	4.89	6.59	10.03	3.13
Appropriability through design (%)	11.75	14.90	21.46	13.53	12.17	9.12	13.96	8.73
Appropriability through copyright (%)	14.15	5.89	13.00	3.49	3.74	3.97	5.23	2.04
Sources of opportunities: suppliers (%)	21.00	21.97	22.10	23.92	26.34	25.86	24.37	31.99
Sources of opportunities: users (%)	28.13	31.62	30.65	26.65	29.02	25.14	27.26	17.82
Sources of opportunities: universities (%)	12.60	6.30	7.98	7.08	4.60	3.79	4.44	2.49

[a] AKP: advanced knowledge providers; MPG: mass production goods; SIS: supporting infrastructure services; PGS: personal goods and services.

tence of a web of vertical linkages among industries, a specialization pattern in advanced manufacturing industries fosters the development of new services, and the latter in turn acts to enhance the growth of the former. The key mechanism of competitiveness of a national system is thus related to two major factors: first, the ability of a country to undertake a process of structural change from traditional to GPT-related high-opportunity manufacturing and service industries; secondly, the intensity of inter-sectoral linkages between different types of sectoral groups within the domestic economy.

5. Empirical evidence: regimes, trajectories and performance in Europe

This section presents some descriptive evidence to illustrate the empirical relevance of the new sectoral taxonomy. The empirical evidence is based on the *Fourth Community Innovation Survey* (CIS4, 2002–2004). CIS4 data are here used at the industry-level for a sample of 24 European countries.[9] This cross-industry dataset provides relevant and up-to-date information on a range of characteristics of innovative activities in Europe, thus making it possible to analyse some major features of sectoral innovation systems. The analysis here focuses on a set of important aspects that characterize the technological regimes and trajectories of the various sectoral groups. The main purpose of the exercise is to provide empirical support for the sectoral properties outlined in Table 1, and to show the close relationship between paradigms, regimes and sectoral trajectories.

Tables 2 and 3 present some main descriptive results from the CIS4 Survey. Table 2 reports a set of indicators measuring various characteristics of sectoral technological regimes, such as their innovativeness and opportunity levels, cumulativeness conditions, appropriability means, and external sources of opportunities (e.g. suppliers, users and Universities). Table 3 presents a set of variables that describe some of the features of sectoral trajectories, such as the dominant type of innovation produced (process, product, organizational and marketing innovation) and the type of expenditures and strategies typically adopted in the innovative process (intramural R&D, acquisition of machinery, software and other external knowledge, training and cooperation activities). A complete list, with definitions of the indicators, is given in Appendix B.

As discussed in Section 2, the conceptual distinction between regimes and trajectories is indeed difficult to determine. There exists a close relationship between these two concepts, due to the inherent link between the structural characteristics of an industry in a static sense and its dynamic trajectory over time. Consequently, any attempt to employ indicators that try to measure and empirically distinguish the characteristics of regimes from those of

[9] The 24 countries in the CIS dataset used in this section are listed as follows: Sweden, Denmark, Norway, Finland, Germany, UK, Netherlands, Belgium, Austria, Italy, France, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Spain, Portugal and Greece. For a list of industries included in each sectoral category of the taxonomy, see Appendix A.

Table 3
The characteristics of the categories of the new taxonomy [*Technological trajectories*—CIS4 data (2002–2004), EU24 average[a]]

	AKP		MPG		SIS		PGS	
	Knowledge-intensive business services	Specialized suppliers manufacturing	Science-based manufacturing	Scale-intensive manufacturing	Network infrastructure services	Physical infrastructure services	Supplier-dominated goods	Supplier-dominated services
Process-product orientation (+1/−1)	−0.21	−0.27	−0.32	0.07	0.02	0.29	0.17	0.45
Turnover from new or improved products (%)	13.09	17.59	15.72	13.21	10.52	10.33	12.88	6.91
Organizational innovation (%)	35.39	28.23	29.81	22.99	33.26	18.64	18.92	12.08
Marketing innovation (%)	18.45	15.37	19.58	10.74	23.13	9.40	12.39	7.83
Intramural R&D (%)	59.81	49.26	51.75	29.37	29.22	17.45	21.68	26.45
Acquisition of machinery and software (%)	24.44	41.14	37.12	60.01	47.46	68.36	68.63	61.84
Acquisition of other external knowledge (%)	5.58	2.67	2.75	2.29	10.40	5.46	2.70	5.17
Training activities (%)	65.22	57.45	59.98	52.16	64.12	54.44	45.08	56.65
Cooperation in innovative activities (%)	45.05	40.01	44.62	38.01	40.66	31.96	28.56	28.23

[a] AKP: advanced knowledge providers; MPG: mass production goods; SIS: supporting infrastructure services; PGS: personal goods and services.

trajectories must be interpreted with caution. With this caveat in mind, it is interesting to make use of these indicators in order to achieve a more precise description of the dominant innovative modes that characterize the various sectoral groups of our taxonomy.[10]

In addition to this descriptive evidence, Tables 4 and 5 present the results of a statistical exercise aimed at testing the significance of differences in technological regimes and trajectories between the two sub-groups of industries indicated in each of the four sectoral blocks of the taxonomy.[11] The results of the two tests are basically the same, and indicate that the cross-country distributions of the sub-groups of industries belonging to each of the four sectoral groups differ from each other at conventional statistical levels on several important dimensions.

The *advanced knowledge providers* group is characterized, on average, by a dynamic technological regime (high levels of opportunities, high cumulativeness conditions, close relationship to the users as a major external source of opportunities) as well as a dynamic trajectory (based on the creation of advanced products and services, and on a considerable share of innovative expenditures devoted to intramural R&D). Behind this overall pattern, however, the two sub-categories within this sectoral group have quite different innovative modes. Innovative activities in knowledge-intensive business services are closer to the technological core of the ICT-based paradigm than the corresponding group of specialized suppliers manufacturing sectors, and this is one major factor explaining their different regimes and trajectories. Knowledge-intensive business services are characterized by a much higher level of technological opportunities than specialized suppliers manufacturing (19% against 5%), lower reliance on patents as an appropriability mechanism (15% versus 21%), a greater use of protection through copyright claims (14% against 6%), a much closer connection to the scientific knowledge produced by universities (12% as against 6%), a higher share of innovative expenditures devoted to intramural R&D and a correspondingly lower investment share for the acquisition of machinery and software.

Sectors producing *mass-production goods* are also characterized, on average, by dynamic technological regimes and trajectories, and are, similar to the previous group, closely related to the users and to the science system as external sources of knowledge. However, although the two sub-groups of industries in this block share similar functions in the economic system, they show important differences in their innovative patterns. Science-based sec-

[10] The CIS-based indicators used here have frequently been used in the recent applied innovation literature to measure various aspects of sectors' regimes and trajectories. They therefore constitute, despite the obvious limitations, a relevant and widely diffused source of knowledge on the innovative activities of European firms. For previous studies using some of these indicators, see e.g. Evangelista (1999, 2000), Veugelers and Cassiman (1999), Kaiser (2002), Mairesse and Mohnen (2002), Marsili and Verspagen (2002), Reichstein and Salter (2006) and Castellacci (2007b).

[11] The ANOVA is a standard parametric test for comparing the mean of different statistical distributions, whereas the Mann–Whitney *U*-test is a corresponding non-parametric procedure based on the rank of the variables, which has the advantage of being robust to violations of the standard assumptions of normality and homoschedasticity.

Table 4
Testing for the significance of differences within each of the four sectoral blocks [ANOVA and Mann–Whiney *U*-test—*Technological regimes*[a]]

	AKP		MPG		SIS		PGS	
	ANOVA[b]	Mann–Whitney[b]	ANOVA[b]	Mann–Whitney[b]	ANOVA[b]	Mann–Whitney[b]	ANOVA[b]	Mann–Whitney[b]
Level of innovativeness	0.69	−0.74	10.68***	2.70***	15.56***	3.55***	8.21***	2.79***
Level of opportunities	21.11***	−4.13***	2.52	0.62	0.00	0.26	16.09***	3.84***
Cumulativeness conditions	1.14	−1.15	14.89***	3.19***	6.53**	2.34**	1.41	1.36
Appropriability through patents	2.95*	1.46	2.54	1.64*	0.64	−1.94*	6.02**	2.74***
Appropriability through design	1.35	1.25	5.83**	1.99**	0.91	0.20	2.20	1.41
Appropriability through copyright	7.11**	−2.53**	7.60***	2.95***	0.03	−0.45	5.08**	2.46**
Sources of opportunities: suppliers	0.08	0.47	0.19	−1.06	0.02	0.21	2.00	−0.61
Sources of opportunities: users	0.85	0.73	1.25	0.82	1.47	1.17	6.66**	2.05**
Sources of opportunities: universities	7.48***	−2.40**	0.12	0.73	0.13	−0.50	0.55	2.02**

***Significance at 1% level; **significance at 5% level; *significance at 10% level.

[a] AKP: advanced knowledge providers; MPG: mass production goods; SIS: supporting infrastructure services; PGS: personal goods and services.

[b] Test.

Table 5
Testing for the significance of differences within each of the four sectoral blocks [ANOVA and Mann–Whiney *U*-test—*Technological trajectories*[a]]

	AKP		MPG		SIS		PGS	
	ANOVA[b]	Mann–Whitney[b]	ANOVA[b]	Mann–Whitney[b]	ANOVA[b]	Mann–Whitney[b]	ANOVA[b]	Mann–Whitney[b]
Process-product orientation	0.27	−0.54	18.79***	−3.99***	4.09*	−1.98**	4.42**	−1.83*
Turnover from new or improved products	5.52**	2.00**	1.33	1.38	0.01	0.04	5.26**	1.96**
Organizational innovation	2.18	−1.33	1.98	1.29	5.81**	2.41**	2.59	1.74*
Marketing innovation	0.87	−1.03	11.42***	2.95***	13.59***	3.33***	2.23	1.36
Intramural R&D	2.62	−1.56	10.86***	3.01***	3.62*	1.87*	0.40	−0.97
Acquisition of machinery and software	5.52**	1.83*	7.27**	−2.49**	7.50***	−2.39**	0.57	1.09
Acquisition of other external knowledge	5.49**	−2.39**	0.49	0.54	7.03**	2.07**	4.26*	−1.18
Training activities	2.19	−1.33	2.14	1.40	3.56*	1.61*	3.51*	−1.80*
Cooperation in innovative activities	1.78	−1.54	2.53	1.64*	3.66*	1.96**	0.00	0.12

***Significance at 1% level; **significance at 5% level; *significance at 10% level.

[a] AKP: advanced knowledge providers; MPG: mass production goods; SIS: supporting infrastructure services; PGS: personal goods and services.

[b] Test.

tors, when compared to scale-intensive industries, are characterized by higher opportunity levels (innovativeness variable: 57% versus 43%), higher cumulativeness conditions (48% against 29%), greater reliance on formal appropriability means (e.g. patents, design, copyright), stronger orientation to the creation of new products, a much higher share of innovative expenditures devoted to intramural R&D activities (52% instead of 29%), and a correspondingly lower percentage invested for the acquisition of machinery and software from their suppliers (37% versus 60%).

Industries in the *supporting infrastructural services* block share the same broad function in the economic system as providers of infrastructural and distributive services, although the two sub-groups of industries belonging to this category are characterized by rather different regimes and trajectories. Network infrastructural services are, as previously noted, closer to the new core of general-purpose technologies that provide the bulk of the growth potential in the current ICT-based paradigm, whereas the corresponding group of physical infrastructural services represented a more dynamic area of industrial development during the Fordist age. A comparison between network and physical infrastructure services indicates that the former is characterized by a higher opportunity level than the latter group (innovativeness variable: 46% against 30%), greater cumulativeness conditions (24% and 14%), a closer tie to the users of new technologies (29% against 25%), a greater propensity to introduce service, organizational and marketing innovations, a greater effort for investments in intramural R&D activities, acquisition of other external knowledge and training of personnel, and a higher cooperation intensity (40% against 32%).

Industries in the fourth sectoral group of the taxonomy, the producers of *personal goods and services*, tend to experience a less dynamic technological environment, with trajectories characterized by a greater orientation towards the introduction of process innovations and, likewise, by a higher investment share for the acquisition of advanced machinery and equipment from their suppliers. Even for this group, despite the common function and similar technological environment, some important intra-group differences emerge between the innovative mode of manufacturing producers and that of service providers. Supplier-dominated manufacturing firms have in general a greater capability to acquire advanced technologies produced in other sectors of the economy and to use this type of embodied technological change strategy to recreate new opportunities and lengthen their industry-life cycle (Von Tunzelmann and Acha, 2005; Robertson and Patel, 2007). This is reflected in the indicators presented in our tables, which show that supplier-dominated manufacturing industries have much greater opportunity levels than the corresponding group of services, stronger cumulativeness conditions, greater reliance on formal appropriability means, closer ties with the end users, higher turnover from the commercialization of new products, and a higher investment intensity for the acquisition of machinery and software from their suppliers. Personal services, in turn, have a closer link to their suppliers (32% against 24%); they more intensively acquire other external types of knowledge (e.g. from consultancy firms, 5% versus 2.7%), and more frequently organize training activities (57% as against 45%).

Summing up, the descriptive evidence presented in Tables 2 and 3, and the corresponding statistical tests reported in Tables 4 and 5, indicate the existence of a considerable range of innovation modes in European industries and, relatedly, a close relationship between technological paradigms, regimes and trajectories. On the one hand, there is a cluster of industries whose knowledge base and innovative activities are close to the emerging set of general-purpose technologies based on ICTs. In our taxonomy, these are the groups of knowledge-intensive business services, mass-production science-based industries and network infrastructure services. In these industries, the close relationship to the emerging technological paradigm results in a regime characterized by high technological opportunities and a dynamic technological trajectory oriented towards the creation of advanced products and services and R&D-related investments. These sectoral groups are thus active *providers* of advanced knowledge, products and infrastructures to the rest of the economic system.

Another set of industrial sectors appears to be less close to the core of the new technological paradigm, in the sense that they are less directly involved in the production of ICT-related technologies, although they may of course make intensive use of them in order to improve the efficiency of their production process and/or the quality of the final good and service they provide. These are the industries that represented the most dynamic part of the economy during the Fordist paradigm (or in previous paradigmatic phases). In our taxonomy, they are the mass-production scale-intensive industries, the physical infrastructure services and the supplier-dominated personal goods and services. These sectors, on average, are characterized by lower-opportunity technological regimes, and a less dynamic trajectory oriented towards the introduction of labour-saving process innovations and predominantly based on the acquisition of machinery, equipment and software from the suppliers. These sectoral systems are therefore mostly *recipients* of the advanced knowledge, products and infrastructures created by other more technologically advanced industries.

CIS4 data provide rich empirical evidence on the characteristics of European industries at the present time, although their mainly static nature does not permit proper analysis of the process of structural change and industrial transformation over a longer period. For this reason, it is useful to support our descriptive analysis with a different type of data source referring to a longer time span. This is provided by OECD-STAN data on the economic performance of industrial sectors in Europe for the longer period 1970–2003.

Fig. 2 reports the evolution of the *relative labour productivity* (RLP) of the various sectoral groups of our taxonomy over this three-decade period in Europe. RLP is defined as the labour productivity of a sectoral group divided by the labour productivity of the whole economy. The RLP is measured on the *Y*-axis of the various graphs, where a value greater (lower) than 100 means that an industrial group is more (less) productive than the average sector of the

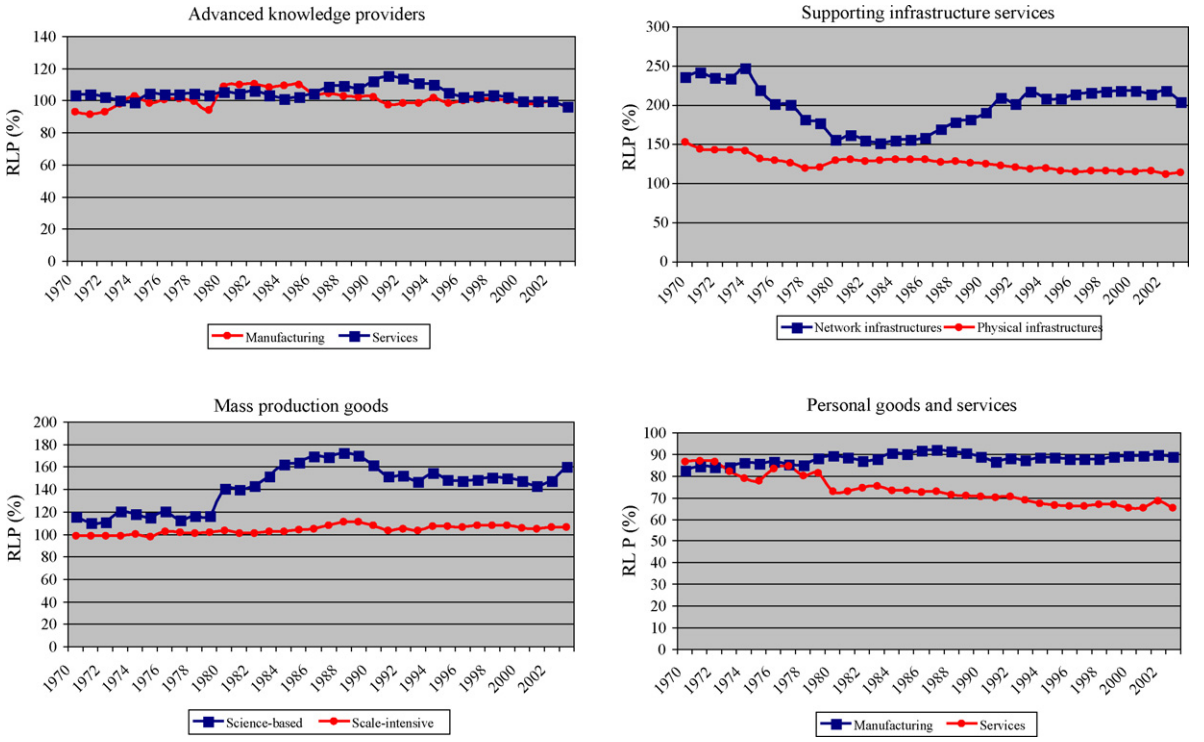


Fig. 2. The dynamics of relative labour productivity (RLP) in the various sectoral groups, 1970–2003, EU24 average.

economy. From the various graphs, it is evident that, for each of the four sectoral groups in our taxonomy, industries related to the new GPT have progressively increased their contribution to the growth of the European economy in the past few decades, while those related to the Fordist industrial core are characterized by a stagnant or decreasing RLP trend. This becomes particularly clear when we compare science-based industries with the scale-intensive group, and the network infrastructure with the physical infrastructure service sectors (second and third panels of Fig. 2, respectively). The former (more technologically advanced) groups have significantly increased their contribution to aggregate labour productivity since the early 1980s. Today their productivity level is now far above the average for the economy (considerably higher than 100). By contrast, the latter (less technologically dynamic) groups are characterized by stable or decreasing trends in relative labour productivity.

Taken together, this empirical evidence on the innovative and economic characteristics of the major sectoral groups of our taxonomy illustrates the empirical relevance of the theoretical view presented in the previous section. The four-group taxonomic model provides a general and stylized view of the basic growth mechanism within each long-run paradigmatic phase based on the interactions between mass-production manufacturers, infrastructural services and providers of advanced knowledge. However, behind this general mechanism, the specific set of high-opportunity industries will differ in any given historical age. In the long run, the emergence of a new paradigm may determine a shift in the locus of the growth potential, so that the high-opportunity sectors of one age may become lower-opportunity industries in the next paradigmatic phase. The evidence presented here – on the variety of technological regimes, trajectories and economic performance within each of the four sectoral groups of our taxonomy – provides basic support for this view.[12]

6. Conclusions and policy implications

This paper has put forward a new taxonomy of sectoral patterns of innovation that combines manufacturing and service industries within the same framework. The taxonomy is based on the paradigm–regime–trajectory model, originated and commonly used for the study of technologi-

[12] One limitation of this empirical analysis is that it focuses on the sectoral (two-digit) level of analysis, and is therefore unable to investigate the extent of firm-level heterogeneity within each industry. Leiponen and Drejer (2007) have recently presented an empirical study based on CIS2 firm-level data for Finland and Denmark, which points out the existence of a great variety of innovative modes and strategies within each sector. Their findings challenge the well-established view that technological regimes and trajectories are mostly determined by sector-specific characteristics of industries, and show instead the relevance of firm-specific capabilities and strategies. Leiponen and Drejer's argument is indeed important, and it is likely to be investigated and supported further in future research, given the current great availability and interest in the use of firm-level innovation data. However, while firm-level research is certainly necessary for investigating the nature and extent of within-industry heterogeneity, industry-level analyses such as the one reported in this paper may still be important for obtaining a more aggregate and synthetic picture of the innovation system as a whole. Ideally, firm- and industry-level innovation studies should complement (rather than compete with) each other.

cal activities in the manufacturing branch. Here it is further extended to include the service sectors in the Schumpeterian growth framework.

The taxonomic model, in a nutshell, suggests that it is the interaction between technologically advanced manufacturing and service industries that sustains the dynamics of national systems in each long-run paradigmatic phase. In order to sustain their international competitiveness, national systems should ideally build up and maintain a sophisticated branch of advanced knowledge providers, an efficient set of supporting infrastructure services and a strong mass-producing manufacturing base. In this ideal scheme, the dynamics of the latter supports, and is supported by, the growth of the former groups of industrial sectors. Each national economy should therefore make an active effort to transform its industrial structure towards the most progressive industries of a given historical age, so to make it more congruent with the requirements and opportunities provided by the emergence and diffusion of a new set of general-purpose technologies.

This broad policy implication, although reasonable and widely shared, requires a long-run commitment and considerable resources that may be hard to find in a short time-horizon. Such a long-term strategy should therefore be complemented by other types of shorter-term and more specific policies that may have a more immediate effect on the dynamics of a national system. These policy measures should be based on the sector-specific nature of innovative activities, targeting the specific characteristics, obstacles and opportunities that characterize technological activities in various industries of the economy—instead of implementing a generic scheme of R&D support for all industrial sectors.

The focus on industry-specific regimes, trajectories and vertical linkages draws attention to the variety of innovative patterns that have been pointed out in this paper. On the one hand, the performance of the group of high-opportunity industries that are more closely related to the new technological paradigm (advanced knowledge providers, science-based and network infrastructure services) can be enhanced by policies designed to foster their overall level of innovation intensity and strengthen the intensity of interactions with the advanced users of new technologies and with the public S&T system. On the other hand, it is also possible to sustain the competitiveness of sectors that face lower opportunities and less dynamic trajectories in the new ICT-based age (scale-intensive, physical infrastructure services, and supplier-dominated). The crucial challenge for industries of this type is to strengthen their linkages with more technologically advanced branches of the economy, so as to enable the process of inter-sectoral knowledge diffusion that may generate new opportunities and lengthen the industry-life cycles of these mature sectors. Public policies can accelerate this process, for instance, by supporting the acquisition of advanced machinery, equipment, software and external knowledge from specialized suppliers, and by increasing the intensity of supplier–producer interactions.

While the main intention of this paper has been to combine manufacturing and services within the same comprehensive framework, we have also noted, in line with the literature, the existence of several peculiarities in the process of knowledge creation in services. These peculiarities are indeed important, and innovation policies must take them into due account. Three of them appear particularly relevant in light of the empirical evidence presented here. First, the great importance of customization and interactivity emphasizes the role of user–producer interactions and of policies that may strengthen linkages of this type. Secondly, the relevance of human resources and capabilities for the performance of service firms should draw the attention of policy-makers to the role played by training activities and organizational changes—that may prove to be a more crucial factor of competitive advantage in services than the amount of resources spent on R&D investments, as suggested by the CIS4 evidence presented in this paper. Finally, the lower reliance on formal means of appropriability (e.g. patents) in services requires a rethinking of the policy rationale that is commonly adopted for the protection of innovative results.

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Appendix A. List of industries in each sectoral group

Advanced knowledge providers—Knowledge-intensive business services:
Computer and related activities; research and development; other business activities

Advanced knowledge providers—Specialized suppliers manufacturing:
Machinery and equipment; medical, precision and optical instruments

Mass production goods—Science-based manufacturing:
Chemicals; office machinery and computers; electrical machinery and apparatus; radio, TV and communication equipment

Mass production goods—Scale-intensive manufacturing:
Rubber and plastic products; other non-metallic mineral products; basic metals; fabricated metal products; motor vehicles; other transport equipment

Supporting infrastructure services—Network infrastructure:
Post and telecommunications; financial intermediation; insurance and pension funding; activities auxiliary to financial intermediation

Supporting infrastructure services—Physical infrastructure:
Wholesale trade and commission trade; land, water and air transport; supporting and auxiliary transport activities

Personal goods and services—Supplier-dominated goods:
Food and beverages; textiles; wearing; leather; wood and related; pulp and paper; printing and publishing; furniture; recycling

Personal goods and services—Supplier-dominated services:
Sales, maintenance and repair of motor vehicles; retail trade and repair of personal and household goods; hotels and restaurants

Appendix B. Definitions and source of indicators used [*Source*: Fourth Community Innovation Survey (2002–2004)]

- *Level of innovativeness*: innovative firms, share of total population of firms.
- *Level of opportunities*: total innovation expenditures, share of total turnover.
- *Cumulativeness conditions*: firms engaged continuously in R&D, share of innovative firms.
- *Appropriability through patents*: firms with patent applications, share of innovative firms.
- *Appropriability through design*: firms with industrial designs registration, share of innovative firms.
- *Appropriability through copyright*: firms with copyright claims, share of innovative firms.
- *Sources of opportunities—Suppliers*: firms considering their suppliers of equipment, materials, components or software as a very important source of information for their technological activities, share of innovative firms.
- *Sources of opportunities—Users*: firms considering their clients or customers as a very important source of information for their technological activities, share of innovative firms.
- *Sources of opportunities—Universities*: firms considering the universities or other public research institutes as a very important source of information for their technological activities, share of innovative firms.
- *Process-product orientation*: [(number of process innovators − number of new product innovators)/(number of process innovators + number of new product innovators)]. The indicator varies between +1 (only process innovation) and −1 (only product innovation).
- *Turnover from new or improved products*: turnover of new or improved products, share of total turnover.
- *Organizational innovation*: firms introducing organizational innovations, share of total population of firms.
- *Marketing innovation*: firms introducing marketing innovations, share of total population of firms.
- *Intramural R&D*: intramural R&D expenditures, share of innovative costs.
- *Acquisition of machinery and software*: expenditures for the acquisition of machinery and software, share of innovative costs.
- *Acquisition of other external knowledge*: expenditures for the acquisition of other external knowledge, share of innovative costs.
- *Training activities*: firms engaged in training activities, share of innovative firms.
- *Cooperation in innovative activities*: firms engaged in all types of cooperation in technological activities, share of innovative firms.

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