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

Fulvio, Castellacci

2007

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

Fulvio Castellacci

Department of International Economics,
Norwegian Institute of International Affairs (NUPI),
POB 8159, Dep. 0033 Oslo, Norway
E-mail address: fc@nupi.no

NUPI Working Paper 719, 2007

Abstract

The paper presents a new sectoral taxonomy that combines manufacturing and service industries within the same general framework. This exercise is relevant because it seeks to achieve a greater integration between the study of sectoral patterns of innovation in manufacturing and services, and to point out the increasing importance of vertical linkages and inter-sectoral knowledge exchanges between these interrelated branches of the economy. The empirical 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.

Keywords: Technological paradigms, regimes, trajectories; vertical linkages; service innovation; CIS data

1. Introduction

The study of sectoral patterns of innovation has increasingly attracted the attention of academic scholars in the last couple of decades. The seminal contributions in the field have pointed out some major features of the innovative process and the great variety of patterns this takes 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 in recent years focused on different 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 that tie together 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 last few years, however, motivated by the rapid growth of the service sectors and the increased pace of innovation that some advanced service providers have experienced, a new body of research has shifted the attention towards this unexplored branch of the innovation system.

The literature on service innovation represents by now an increasingly important field of research, which has opened up new questions and shed new light on the process of knowledge creation in the service sectors (Drejer, 2004; Miles, 2005). This literature has pointed out, in particular, some major peculiarities that make the innovation process in services markedly different from that of manufacturing, and emphasized the increasing interdependence between the manufacturing and service branches of the economy (Evangelista, 2000; Miozzo and Soete, 2001; Guerrieri and Meliciani, 2005).

Despite of the recent advances achieved by this recent body of research, the service innovation literature seems to be developing, to some extent, as a separate field of investigation within innovation studies, without much interaction with, and relation to, the well-established paradigm-regime-trajectory model that was previously developed for the study of innovation in manufacturing industries. One major challenge ahead in the field 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 parts of the economy (Gallouj and Weinstein, 1997).

Motivated by this need to achieve a greater integration between the study of manufacturing and service innovation, this paper presents a new sectoral taxonomy that combines manufacturing and service industries within the same general 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 (i.e. their sectoral regime and trajectory). By 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 some descriptive evidence. The empirical analysis presents fresh results from the *Fourth Community Innovation Survey* (CIS4, 2002-2004) on the innovative activities of manufacturing and service industries in a large sample of 24 European countries, and combines them with informations 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 showing the great variety of sectoral patterns of innovation in European industries.

The paper 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 in favour of a greater integration between the research on manufacturing and on service innovation. Section 4 presents the new taxonomy and points out the main implications of this theoretical view for the understanding of the process of growth and structural change. Section 5 shows 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 end of the 1970s and the beginning of the 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. The new perspective focused on some of the major characteristics of the process of technological change, and 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)

> A "technological paradigm" defines contextually the needs that are meant to be fulfilled, the scientific principles utilized for the task, the material technology to be used. A technological paradigm is both an *exemplar* – an artifact that is to be developed and improved (such as a car, an integrated circuit, a lathe, each with its particular technoeconomic characteristics) – and a set of *heuristics* (e.g. Where do we go from here? Where should we search? What sort of knowledge should we draw on?). (Dosi, 1988, p.1127)

The idea of technological paradigms is closely related to the perspective originally proposed by Schumpeter in his book *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 it is inherently related to the dynamic behaviour of the system, i.e. the growth potential that any given set of interrelated and

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

pervasive radical technologies entails. The exploitation of such technological and economic potential proceeds along well-established directions, so-called *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, p.152-154)

In some of the seminal contributions, the intrinsic paradigm-trajectory relationship was expressed by using a slightly different terminology, namely the concepts of *technological regimes* and *natural trajectories*.

> The sense of potential, of constraints, and of not yet exploited opportunities, implicit in a regime focuses the attention of engineers on certain directions in which progress is possible, and provides strong guidance as to the tactics likely to be fruitful for probing in that direction. In other words, a regime not only defines boundaries, but also trajectories to those boundaries. Indeed these concepts are integral, the boundaries being defined as the limits of following various design trajectories. (Nelson and Winter, 1977, p.57)

It is apparent that, despite of the somewhat different formulation, the underlying idea of these seminal contributions is closely related to each other, namely that the paradigmatic and cumulative nature of technological change implies an inherent relationship between structure and performance, context and path, static and dynamics of the innovation system.

Relatedly, the third pillar in this theoretical construction is 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 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, p.59-60)

In any given historical era, industrial sectors whose knowledge base and capabilities set are closely related to the constellation of emerging radical innovations face a greater set of opportunities and tend therefore to follow dynamic trajectories, while industries which are 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 rapidly 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, pointing out 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. Marsili and Verspagen, 2002; Malerba, 2002; Van de Poel, 2003; Dosi et al., 2006). These works have pointed out the existence of an empirical relationship between sector-specific technological regimes and the corresponding patterns of market structure and industrial dynamics, so-called Schumpeter Mark I and Mark II regimes (Malerba and Orsenigo, 1995 and 1996; Breschi and Malerba, 1997; Breschi et al., 2000).

Another set of 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 a variety of 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,

> the basic unit of analysis is the innovating firm. Since patterns of innovation are cumulative, its technological trajectories will be largely determined by what it has done in the past in other words, by its principal activities. Different principal activities generate different technological trajectories. […] These different trajectories can in turn be explained by sectoral differences in three characteristics: sources of technology, users' needs, and means of appropriating benefits (Pavitt, 1984: 353).

Focusing on these three sector-specific characteristics of innovative firms in Britain in the period 1945-1979, 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 last 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. By making use of CIS data for selected countries, different empirical analyses have focused on a number of different aspects, such as the distinction between product and process innovation, the relevance of organizational innovation, the type and composition of innovative expenditures (R&D, acquisition of machineries, training activities, etc.), and the patterns of cooperation and interactions of innovative firms with other actors in the sectoral system of innovation (Evangelista et al., 1997; Evangelista, 1999; Veugelers and Cassiman, 1999; Mairesse and Mohnen, 2002; Reichstein and Salter, 2006).

A crucial aspect of Pavitt taxonomy and of the related set of later empirical studies is the focus on *vertical linkages*, that is 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 calls in fact the attention to the set of interactions, cooperations and exchanges between producers, suppliers and users of new technologies. These inter-sectoral exchanges, i.e. the set of input-output relationships in terms of advanced knowledge, material inputs and demand, constitute a crucial factor to enhance the competitiveness of the whole national system. According to the *home market hypothesis*, in fact, the strength of interactions between suppliers, producers and users of advanced technologies and the existence of an established and well-functioning set of vertical linkages represents one major factor of competitive advantage (Porter, 1990; Lundvall, 1992).

A recent strand of empirical research has investigated the relevance of vertical linkages to explain the patterns of international competitiveness of different industries. These econometric studies have analysed the role of intersectoral knowledge flows to explain the dynamics of export market shares and specialization patterns, and have shown, in particular, the importance of user-producer interactions and of upstream linkages between suppliers and producers (Kaiser, 2002; Laursen and Meliciani, 2002). Furthermore, using Pavitt's taxonomy as a framework, the home market hypothesis literature has shown that vertical linkages are not equally supportive of foreign competitiveness for all different groups of manufacturing industries. Upstream linkages, in fact, are more important factors

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

for scale intensive sectors, downstream linkages are more relevant to shape the competitive position of specialised suppliers, whereas University-industry links constitute a more crucial factor for science-based industries (Laursen and Drejer, 1999; Laursen and Meliciani, 2000; Castellacci, 2006).

On the whole, despite of the fact that different strands of recent empirical research have focused on distinct aspects, it is apparent that 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 in fact conceived – refers to the Fordist age (Freeman et al., 1982; Freeman and Louça, 2001). The set of radical technologies that brought a strong growth potential in the post-War era was initially based on the petrochemical technology to produce oil (‘cracking’) as well as the internal combustion engine. These radical innovations gave a great push to the mass-producing sectors that were employing these technologies on a large-scale, and in particular the automobile, plastic and chemical industries, that followed very 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, given that the general-purpose technologies sectors fostered the demand of specialised 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, namely supplier-dominated firms as well as final consumers. Pavitt’s model of the linkages between science-based, specialised suppliers, scale-intensive and supplier-dominated industries provides in fact a stylised 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 branch of the economy, given that this represented the major growth engine and the most innovative part of the economic system during the post-War era. In recent decades, however, the service sectors have experienced a rapid growth and they now account for a large share of value added, employment and trade in most industrialized countries.

The traditional explanation for the expansion of the service sectors is related to the *cost-disease* argument originally proposed by Baumol (1967). According to this, the service sectors tend to increase their employment share due to their lower productivity levels and sluggish dynamics as compared to manufacturing. This traditional view of services as productivity laggards and employment sponges, though, has more recently 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 new set 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, and has started to diffused more rapidly since the beginning of 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 the 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 represents by now one of the most rapidly growing areas within innovation studies (Drejer, 2004; Miles, 2005). Some scholars approach the study of service innovation by making use of the same concepts and methodological tools previously developed for the study of innovation in manufacturing industries, while many others emphasize the existence of some important peculiarities associated with service innovation. Four important features, in particular, characterize the process of knowledge creation in services.

First, the provision of services is frequently characterized by the *co-terminality* between production and consumption (Hill, 1999). This means that the provision of a service cannot be spatially and temporally disentagled from its consumption, i.e. the service must be consumed at the same time and in the same place as it is produced. This implies that the distinction between product and process innovation, an important conceptual pillar of studies of innovation in manufacturing, cannot easily be applied in the context of the service sectors.

Secondly, the intangible and information-based characteristics of services inherently give a predominant role to *the use and production of ICTs* (Barras, 1986; Evangelista, 2000). The emergence of the ICT-based technological paradigm, as pointed out above, is closely associated with the creation of new advanced service activities, and the co-evolution between the latter and the diffusion of the ICT-based general purpose technologies constitutes a major source of structural change in the knowledge-based economy.

Thirdly, the close relationship between service providers and consumers and the great flexibility of services associated with ICTs lead to an intense process of *customisation* and to a great relevance of *interactivity* (Miles, 2005). User-producer interactions are certainly relevant in several manufacturing activities, but assume an even more crucial role to shape innovative activities in services. Relatedly, as a consequence of their intangible nature and of the close proximity between users and producers, service innovations are frequently difficult to appropriate, at least through conventional means such as patenting.

Fourthly, human resources and the skills of the firms' employees are very important strategic assets for innovative activities in services, because the latter are predominantly based on the creation and diffusion of advanced knowledge in intangible activities, rather than on the accumulation of physical capital and tangible assetts (Gallouj and Weinstein, 1997). Innovative strategies must take this into account, and this implies, in particular, that training activities and organisational changes become central aspects of the innovative process, while formalised R&D activities are relatively less important than it is the case for manufacturing industries.

Besides pointing out these major aspects of service innovation, this recent literature emphasizes the existence of a great variety of innovative strategies and patterns within services (Evangelista, 2000; Tether, 2003). The service branch of the economy consists in fact of a very heterogenous set of activities, and the study of innovation in different service industries must take these sectoral specificities into account. Thus, similarly to what previously done for the study of manufacturing industries, innovation scholars have recently started to analyse the technological trajectories followed by different types of service industries and, relatedly, have proposed taxonomies of service innovation with the purpose of 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 the one 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 function that various groups of service sectors perform within the economic system, i.e. 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 intersectoral exchanges of knowledge among different groups of industries, Miozzo and Soete (2001) have more recently 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 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 pattern of outsourcing has two main implications. On the one hand, it suggests that (at least part of) the shift from manufacturing to services that we observe in national statistics may be accounted for by a re-allocation of existing activities, rather than by a real process of structural change and creation of entirely new services. On the other hand, however, several works point out that outsourcing is inherently related to the increasing complexity of the knowledge-based productive process, and that it therefore constitutes one major aspect of the greater technological and economic specialization that characterizes modern production (Fixler and Siegel, 1999). Thus, far from being a mere

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

statistical artefact, outsourcing reflects an intense process of structural change and a radical reorganization of the division of labour among technologically advanced sectors.

What this process is leading to is 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 specialised service providers, thus sustaining their growth by demanding a new range of intermediate products and services, technological advances in the latter sustain the dynamics of the whole manufacturing branch (Park and Chan, 1989; Franke and Kalmbach, 2005). 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 (Antonelli, 1998; Windrum and Tomlinson, 1999; Di Cagno and Meliciani, 2005; Guerrieri and Meliciani, 2005). Such an extension of the home market hypothesis is a fascinating direction for future research, although at present a full understanding of the interactions and co-evolutionary process linking together manufacturing and services is still lacking.

In summary, despite of the recent advances in the study of service innovation, one easily gets the impression that this literature is still fragmented and not clearly related to the paradigm-regime-trajectory model that was previously developed for the study of innovation in manufacturing industries (see previous section). The service innovation literature has shed much new light on a variety of peculiar aspects that characterize the process of knowledge creation in the provision of services, but it has so far been less successful to integrate these new insights into the previous well-established research on paradigms, regimes, trajectories and vertical linkages.

One major challenge ahead in the field 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), which 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 a greater integration between the study of manufacturing and service innovation constitutes an important challenge ahead for research in the field, but, 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 differs from the standard approaches adopted in the economics and in the innovation studies literatures in two main respects. On the one hand, it provides a more precise characterization of sectoral patterns of innovation than what is commonly offered by endogenous growth models in the economics literature. The new growth literature does in fact provide a rather stylised representation of sectoral groups, which mainly differ in terms of the function they have 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 to investigate in details the industry-specific nature of innovation and the great variety of sectoral patterns of innovation that characterize the knowledge-based economy.

On the other hand, our taxonomic model also differs from previous approaches 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 from each other, the taxonomic model proposed in this paper 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.

Figure 1 presents a stylized representation of this taxonomic model. 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* that each industry takes 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 figure 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 second dimension is thus defined by the technological regimes and trajectories that characterize sectoral systems, and the extent to which industrial sectors are able to create new technologies internally or rather rely on the external acquisition of machinery, equipment and knowledge from their suppliers. Technologically advanced sectors, which are 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 figure 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.

The typology is built up by making use of these dimensions in a two-step conceptual exercise. First, sectors are divided according to the main function they take in the economic system (Y-axis). This leads to 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 does not only point out the function of each sector as provider and/or recipient of goods, services and knowledge to other industries, but it also acknowledges the presence of a great deal of heterogeneity within each industrial block, in line with previous related exercises in the innovation literature (Pavitt, 1984; Miozzo and Soete, 2001).

On the whole, the manufacturing and business services branches of the economy are thus represented as a system of vertically integrated sectoral groups. 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.[4]

< Figure 1 and table 1 here >

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

Advanced knowledge providers (AKP) are characterized by a 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 the manufacturing branch, specialised suppliers of machineries, equipments and precision instruments; (2) within services, providers of specialised knowledge and technical solutions such as software, R&D, engineering and consultancy, so-called knowledge intensive business services. What these industries have in common is that, in addition to being characterized by a 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 it. Firms in these industries are typically small, and tend to develop their technological activities in close cooperation with their 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 specialised 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 and, consequently, have led to the emergence and rapid growth of knowledge intensive business services, which now play the important role of providers of specialised 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, given that they mostly produce intermediate products and services rather than items for personal consumption. However, they differ from advanced knowledge providers in terms of their technological capability, and particularly in terms of their more limited ability to internally develop new knowledge. Their innovative trajectory is in fact typically based on the acquisition of machineries, equipments and other types of advanced technological knowledge created elsewhere in the economic system. To be more precise, 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 a significantly smaller capability in this respect. Regardless of these differences, what these sectoral groups have in common is the function they take in the economic system, namely 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 intersectoral knowledge diffusion within the domestic economy, and the more efficient and productive the national system will be.

Sectors producing *mass production goods* (MPG) constitute a key part of the manufacturing branch. They may be located at an intermediate stage of the vertical chain, given that they produce both final goods and intermediate products that are used in other stages of the production process. In terms of their technological content, they are characterized by a great capability to internally develop new products and processes, although two distinct sub-groups may be distinguished (Pavitt, 1984): (1) scale-intensive industries (e.g. motor vehicles and other transport equipments) frequently have their own in-house R&D facilities, and their innovative activities also develop in close cooperation with the specialised suppliers of precision instruments and machineries; (2) science-based sectors (such as electronics) are characterized by a greater ability to internally create new technological knowledge, and their innovation process is close to the scientific advances continuously achieved by Universities and other public research institutes. Different as they may be, these sectoral groups have a great deal of common characteristics. Firms are typically large, and their profitability depends to a great extent on the exploitation of scale economies that the mass production of standardized goods makes it possible to obtain. Further, they all assume a central position in the knowledge chain, given that they receive technological inputs from advanced knowledge providers and, in turn, they provide 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 of specialised solutions from advanced knowledge providers, this group of industrial sectors thus plays a pivotal role in the economic system.

The fourth sectoral block is represented by the producers of *personal goods and services* (PGS). 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 internally new products and processes. Their dominant innovation strategy is in fact typically based on the acquisition of machineries, equipments and other types of external knowledge produced by their suppliers, while they commonly lack the capability and resources to organize and mantain their own R&D labs. This explains the term *supplier-dominated* industries that is frequently adopted in the innovation literature – and that describes well both sub-groups of industries included in this category, namely (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 thus mostly recipients of advanced knowledge and, 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 lead to lengthen the industry-life cycle of these mature industrial sectors and recreate new technological opportunities (Von Tunzelmann and Acha, 2005; Robertson and Patel, 2007).

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 driving growth and structural change in national systems of innovation. When a new technological paradigm emerges and diffuses throughout the economy, industrial sectors greatly differ in terms of the technological opportunities, capabilities and constraints they face. High-opportunity technological regimes are those that 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 and, by demanding new infrastructural services as well as advanced specialised knowledge and technical solutions to their suppliers, they transmit part of this growth potential to some of the other industrial groups.

To illustrate, during the Fordist paradigm the typical high-opportunity mass production sectors were, say, chemical, plastics and the car industries (Freeman et al., 1982). In order to follow their dynamic trajectories, these branches fostered the growth of specialised suppliers (e.g. producers of precision instruments) and of infrastructural services (in particular physical infrastructural services such as 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.

In a more recent period, due to 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 considered 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 differ in any given historical age, but the overall causation mechanism that drives the dynamics of the system is, by and large, the same. A new set of general purpose technologies need, at the same time, to be produced on a large scale, to be supported by an efficient infrastructure and to be sustained by the provision of an advanced knowledge base. Our four-group typology provides therefore a comprehensive and general framework that accounts for the dynamics of a national system within each paradigmatic phase, as well as for the transformations occuring when a regime shift changes the locus of technological opportunities and of the related growth potential.[5]

This theoretical view has one important implication for the competitiveness of national systems. Given the existence of a web of vertical linkages among industries, a specialization pattern in advanced manufacturing industries fosters the development of new services, and the latter does in turn 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-opportunities manufacturing and service industries; secondly, the intensity of inter-sectoral linkages between different types of sectoral groups within the domestic economy. The policy implication of this perspective would thus be to emphasize

[5] This is an aspect where the new taxonomy differs substantially from related works in this field. The main purpose of previous taxonomic exercises was in fact 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.

the creation of new competitive advantages in the most progressive industries of each sectoral group, instead of relying on the existing set of comparative advantages, which will eventually turn out to be obsolete when a new set of general-purpose technologies will change the locus of the growth potential.

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), which refers to the period 2002-2004 and whose results have just been released by Eurostat. CIS4 data are here used at the industry-level for a large sample of 24 European countries.[6] This cross-industry dataset provides relevant and up-to-date information on a variety of different characteristics of innovative activities in Europe, thus making it possible to analyse some major features of sectoral innovation systems. The analysis focuses, in particular, 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 (see previous section), 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 instead a set of variables that describe some of the features of sectoral trajectories, such as the dominant type of innovation produced (process, product, organisational 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 and definition of the indicators is reported in Appendix 2.

[6] The 24 European 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 1.

As discussed in section 2, the conceptual distinction between regimes and trajectories is indeed difficult to draw, and 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 make use of indicators that try to measure and empirically distinguish the characteristics of regimes from those of trajectories must be interpreted with caution. With this caveat in mind, it is however interesting to make use of these indicators in order to get to a more precise description of the dominant innovative mode that characterizes the various sectoral groups of our taxonomy.[7]

Besides presenting this descriptive evidence, we also report in tables 4 and 5 the results of a statistical exercise that aims at testing the significance of differences in technological regimes and trajectories between the two sub-groups of industries that have been pointed out in each of the four sectoral blocks of the taxonomy. The ANOVA is a standard parametric test to compare 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. 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 are rather different from each other at conventional statistical levels for a number of important dimensions. The overall evidence reported in tables 2 to 5 is presented as follows.

< Tables 2, 3, 4 and 5 here >

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 great share of innovative expenditures devoted to intramural R&D). Behind this general pattern, however, the two sub-categories within this sectoral group have a quite different

[7] 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 of 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 and 2000), Veugelers and Cassiman (1999), Kaiser (2002), Mairesse and Mohnen (2002), Marsili and Verspagen (2002), Castellacci (2006) and Reichstein and Salter (2006).

innovative mode. Innovative activities in knowledge-intensive business services are closer to the technological core of the ICT-based paradigm than the corresponding group of specialised suppliers manufacturing sectors, and this is one major factor explaining their different regimes and trajectories. Knowledge intensive business services are in fact characterized by a much higher level of technological opportunities than specialised 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% *vis-a-vis* 6%), a higher share of innovative expenditures devoted to intramural R&D and a corresponding 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, similarly to the previous group, closely related to the users and to the science system as external sources of knowledge. The two sub-groups of industries belonging to this block, despite of sharing a similar function in the economic system, do however show important differences in their innovative patterns. Science-based sectors, when compared to scale-intensive industries, are characterized by higher opportunity levels (see innovativeness variable, 57% versus 43%), higher cumulativeness conditions (48% against 29%), a greater reliance on formal appropriability means (e.g. patents, design, copyright), a 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 corresponding lower percentage invested for the acquisition of machinery and software from their suppliers (37% versus 60%).

Industries in the bunch of *supporting infrastructural services* do also 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 group are characterized by rather different regimes and trajectories. Network infrastructural services are, as previously said, closer to the new core of general-purpose technologies that provides the bulk of the growth potential in the current ICT-based paradigm, whereas the corresponding group of pysical infrastructural services represented a more dynamic area of industrial development during the Fordist age. In fact, 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% *vis-a-vis* 14%), a closer tie to the users of new technologies (29% versus 25%), a greater propensity to introduce service, organisational 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*, on average experience a less dynamic technological environment and trajectories characterized by a greater orientation towards the introduction of process innovations and, relatedly, by a higher investment share for the acquisition of advanced machineries and equipments from their suppliers. Even for this group, despite of 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 in fact reflected in the indicators presented in our tables, which indicate that supplier-dominated manufacturing industries have a 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%), more intensively acquire other external types of knowledge (e.g. from consultancy firms, 5% *vis-a-vis* 2.7%), and more frequently organize training activities (57% instead of 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 variety of innovation modes in European industries and, relatedly, a close relationship between technological paradigms, regimes and trajectories. On the one hand, there is a bunch 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 leads to a regime characterized by high technological opportunities and to 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.

On the other hand, another set of industrial sectors appear 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 industries, which represented the most dynamic part of the economy during the Fordist paradigm (or in previous paradigmatic phases), are in our taxonomy the mass-production scale-intensive industries, physical infrastructure services and 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 machineries, equipments and software from the suppliers. These sectoral systems are therefore mostly *recipients* of advanced knowledge, products and infrastructures that are created by other more technologically advanced industries.

Admittedly, CIS4 data provide rich empirical evidence on the charatcteristics of European industries at the present time (period 2002-2004), although their mainly static nature does not enable to properly analyse the process of structural change and industrial transformation over a longer period of time. 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 in the longer period 1970-2003.

Figure 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. The 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 economy. From the various graphs, it is apparent 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 last few decades, while those related to the Fordist industrial core are characterized by a stagnant or decreasing RLP trend. This is particularly evident when we compare science-based industries to the scale-intensive group, and the network infrastructure to the physical infrastructure bunches of service sectors (see the second and third panels of figure 2, respectively). The former (more technologically advanced) groups have significantly increased their contribution to aggregate labour productivity since the early 1980s, and their productivity level is now much above the economy's average (i.e. much above 100), whereas the latter (less technologically dynamic groups) are characterized by a stable or decreasing trends of relative labour productivity.

< Figure 2 here >

Taken together, this empirical evidence on the innovative and economic characteristics of the major sectoral groups of our taxonomy shows 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 advanced knowledge providers. However, behind this general mechanism, the specific set of high-opportunity industries differs 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.

6. Conclusions and policy implications

The 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 technological activities in the manufacturing branch, and extends it further in order 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 mantain 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, as well 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 however a long-run committment and a great amount of resources that it may sometimes be hard to find in a short-time horizon. Such a long-run 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, and target the specific characteristics, obstacles and opportunities that characterize technological activities in different 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 calls the 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 fostering their overall level of innovation intensity and strengthening the intensity of interactions with the advanced users of new technologies and with the public S&T system. On the other hand, the competitiveness of sectors that face lower opportunities and less dynamic trajectories in the new ICT-based age (scale-intensive, physical infrastructure services, supplier-dominated) can also be sustained. The crucial challenge for this type of industries is to strengthen their linkages with more technologically advanced branches of the economy, so to enable the process of inter-sectoral knowledge diffusion that may lead to generate new opportunities and lengthen the industry-life cycles of these mature sectors (Von Tunzelmann and Acha, 2005; Robertson and Patel, 2007). Public policies can accelerate this process, for instance, by supporting the acquisition of advanced machineries, equipments, software and external knowledge from specialised suppliers, and by increasing the intensity of supplier-producers interactions.

While the main intention of this paper has been to combine manufacturing and services within the same comprehensive framework, the work has also pointed out, in line with the literature, the existence of important peculiarities in the process of knowledge creation in services. These peculiarities are indeed important, and innovation policies must therefore take them into due account. Three of them appear to be particularly relevant in the light of the empirical evidence presented in the paper. First, the great importance of customisation and interactivity emphasizes the role of user-producer interactions and of policies that may strengthen this type of linkages. Secondly, the relevance of human resources and capabilities for the performance of service firms calls the attention of policy makers to the role played by training activities and organisational changes – that may turn out to be a more crucial factor of competitive advantage in services than the amount of resources spent by them for 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.

Acknowledgements

The current (revised) draft of the paper has been presented at the workshop on *Innovation and the International Competitiveness of Nordic Services*, Oslo, March 2007, at the *Micro-Dyn* Workshop in Vienna, April 2007, and it will be presented at the DRUID Conference on *Appropriability, Proximity, Routines and Innovation*, Copenhagen, June 2007. Bjørn Terje Asheim, Rinaldo Evangelista, Jan Fagerberg, Staffan Laestadius, Keld Laursen and Mario Pianta have read and commented the previous draft of the paper. Rinaldo Evangelista, Keld Laursen and Valentina Meliciani have read and discussed the revised version. I wish to thank all of them for the insightful comments and useful suggestions. The usual disclaimers apply.

Appendix 1: 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 – *Specialised 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*:
Sale, mantainance and repair of motor vehicles; retail trade and repair of personal and household goods; hotels and restaurants

Appendix 2: Definition and source of the 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 equipments, 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 higher education 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

- **Organisational innovation:** firms introducing organisational 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

References

Antonelli, C. 1998. Localized technological change, new information technology and the knowledge-based economy: the European evidence. Journal of Evolutionary Economics, 8: 177-198.

Archibugi, D. 2001. Pavitt's taxonomy sixteen years on: A review article. Economics of Innovation and New Technology 10, 415-425,

Barras, R. 1986. Towards a theory of innovation in services. Research Policy 15, 161-173.

Baumol, W. 1967. Macroeconomics of unbalanced growth: the anatomy of urban crisis. American Economic Review, 57: 415-426.

Breschi, S., Malerba, F. 1997. Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries, in: Edquist, C. (Ed.), Systems of Innovation: Technologies, Institutions and Organisations. Pinter, London and Washington.

Breschi, S., Malerba, F., Orsenigo, L. 2000. Technological regimes and Schumpeterian patterns of innovation. Economic Journal 110, 388-410.

Castellacci, F. 2006. Technological regimes and sectoral differences in productivity growth. Revised and resubmitted.

Castellacci, F. 2007. Evolutionary and new growth theories. Are they converging? Journal of Economic Surveys, 21 (3), in press.

Di Cagno, D., Meliciani, V. 2005. Do inter-sectoral flows of services matter for productivity growth? An input/output analysis of OECD countries. Economics of Innovation and New Technology, 14 (3): 149-171.

Dosi, G. 1982. Technological paradigms and technological trajectories. Research Policy, 11: 147-162.

Dosi, G. 1988. Sources, procedures, and microeconomic effects of innovation. Journal of Economic Literature XXVI, 1120-1171.

Dosi, G., Marengo, L., Pasquali, C. 2006. How much should society fuel the greed of innovators? On the relations between appropriability, opportunities and rates of innovation. Research Policy, forthcoming.

Drejer, I. 2004. Identifying innovation in surveys of services: a Schumpeterian perspective. Research Policy, 33 (2004): 551-562.

Evangelista, R. 1999. Knowledge and Investment. The Sources of Innovation in Industry. Edward Elgar, Cheltenham.

Evangelista, R. 2000. Sectoral patterns of technological change in services. Economics of Innovation and New Technologies 9, 183-221.

Evangelista, R., Perani, G., Rapiti, F., Archibugi, D. 1997. Nature and impact of innovation in manufacturing industries: some evidence from the Italian innovation survey. Research Policy 26, 521-536.

Fixler, D., Siegel, D. 1999. Outsourcing and productivity growth in services. Structural Change and Economic Dynamics, 10: 177-194.

Franke, R., Kalmbach, P. 2005. Structural change in the manufacturing sector and its impact on business-related services: an input-output study for Germany. Structural Change and Economic Dynamics, 16: 467-488.

Freeman, C., Clark, J., Soete, L. 1982. Unemployment and Technical Innovation. Pinter, London.

Freeman, C., Louça F. 2001. As Time Goes by: From the Industrial Revolutions to the Information Revolution. Oxford University Press, Oxford.

Gallouj, F., Weinstein, O. 1997. Innovation in services. Research Policy, 26: 537-556.

Gershuny, J., Miles, I. 1983. The New Service Economy. The Transformation of Employment in Industrial Societies. Frances Pinter, London.

Grossman, G.M., Helpman, E. 1991. Innovation and Growth in the Global Economy. MIT Press, Cambridge, USA.

Guerrieri, P., Meliciani, V. 2005. Technology and international competitiveness: the interdependence between manufacturing and producer services. Structural Change and Economic Dynamics. 16: 489-502.

Hill, P. 1999. Tangibles, intangibles and services: a new taxonomy for the classification of output. The Canadian Journal of Economics, 32 (2): 426-446.

Hipp, C., Grupp, H. 2005. Innovation in the service sector: the demand for service-specific innovation measurement, concepts and typologies. Research Policy, 34: 517-535.

Kaiser, U. 2002. Measuring knowledge spillovers in manufacturing and services: an empirical assessment of alternative approaches. Research Policy, 31, 125-144.

Laursen, K., Drejer, I. 1999. Do inter-sectoral linkages matter for international export specialisation? Economics of Innovation and New Technology, 8: 311-330.

Laursen, K., Meliciani, V. 2000. The importance of technology based inter-sectoral linkages for market share dynamics. Weltwirtscaftliches Archiv, 136 (4).

Laursen, K., Meliciani, V. 2002. The relative importance of international *vis-à-vis* national technological spillovers for market share dynamics. Industrial and Corporate Change, 11 (4): 875-894.

Lundvall, B-Å. 1992. National Systems of Innovation: Towards a theory of Innovation and Interactive Learning. Pinter Publishers, London.

Mairesse, J., Mohnen, P. 2002. Accounting for Innovation and Measuring Innovativeness: An Illustrative Framework and an Application. American Economic Review, 92 (2), 226-230.

Malerba, F. 2002. Sectoral systems of innovation and production. Research Policy 31 (2), 247-264.

Malerba, F., Orsenigo, L. 1995. Schumpeterian patterns of innovation. Cambridge Journal of Economics 19, 47-65.

Malerba, F., Orsenigo, L. 1996. Schumpeterian patterns of innovation are technology-specific. Research Policy 25, 451-478.

Marsili, O., Verspagen, B. 2002. Technology and the dynamics of industrial structure: an empirical mapping of Dutch manufacturing. Industrial and Corporate Change 11 (4), 791-815.

Miles, I. 2005. Innovation in services. In J. Fagerberg, D. C. Mowery and R. R. Nelson (Eds.), The Oxford Handbook of Innovation. Oxford University Press, Oxford.

Miozzo, M., Soete, L. 2001. Internationalization of services: a technological perspective. Technological Forecasting and Social Change, 67: 159-185.

Nelson, R., Winter, S. 1977. In search of a useful theory of innovation. Research Policy 6, 36-76.

Park, S., Chan, K. 1989. A cross-country input-output analysis of intersectoral relationships between manufacturing and services and their employment implications. World Development, 17 (2): 199-212.

Pavitt, K. 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. Research Policy 13, 343-373.

Porter, M. 1990. The Competitive Advantage of Nations. Macmillan, London.

Reichstein, T., Salter, A. 2006. Investigating the sources of process innovation among UK manufacturing firms. Industrial and Corporate Change, 15 (4), 653-682.

Robertson, P., Patel, P. 2007. New wine in old bottles: Technological diffusion in developed economies. Research Policy, forthcoming.

Romer, P. 1990. Endogenous technological change. Journal of Political Economy, 98: 71-102.

Schumpeter, J. 1939. Business Cycles. Porcupine Press, Philadelphia.

Tether, B. 2003. The sources and aims of innovation in services: variety between and within sectors. Economics of Innovation and New Technology, 12 (6): 481-505.

Tether, B., Hipp, C. 2002. Knowledge intensive, technical and other services: patterns of competitiveness and innovation compared. Technology Analysis and Strategic Management 14 (2): 163-182.

Van de Poel, I. 2003. The transformation of technological regimes. Research Policy 32, 49-68.

Veugelers, R., Cassiman, B. 1999. Make and buy in innovation strategies: evidence from Belgian manufacturing firms. Research Policy 28, 63-80.

Von Tunzelmann, N., Acha, V. 2005. Innovation in ‘low-tech’ industries, in: Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), The Oxford Handbook of Innovation, Oxford University Press, Oxford.

Windrum, P., Tomlinson, M. 1999. Knowledge-intensive services and international competitiveness: a four country comparison. Technology Analysis and Strategic Management, 11 (3): 391-408.

Figure 1: A new taxonomy of sectoral patterns of innovation in manufacturing and service industries

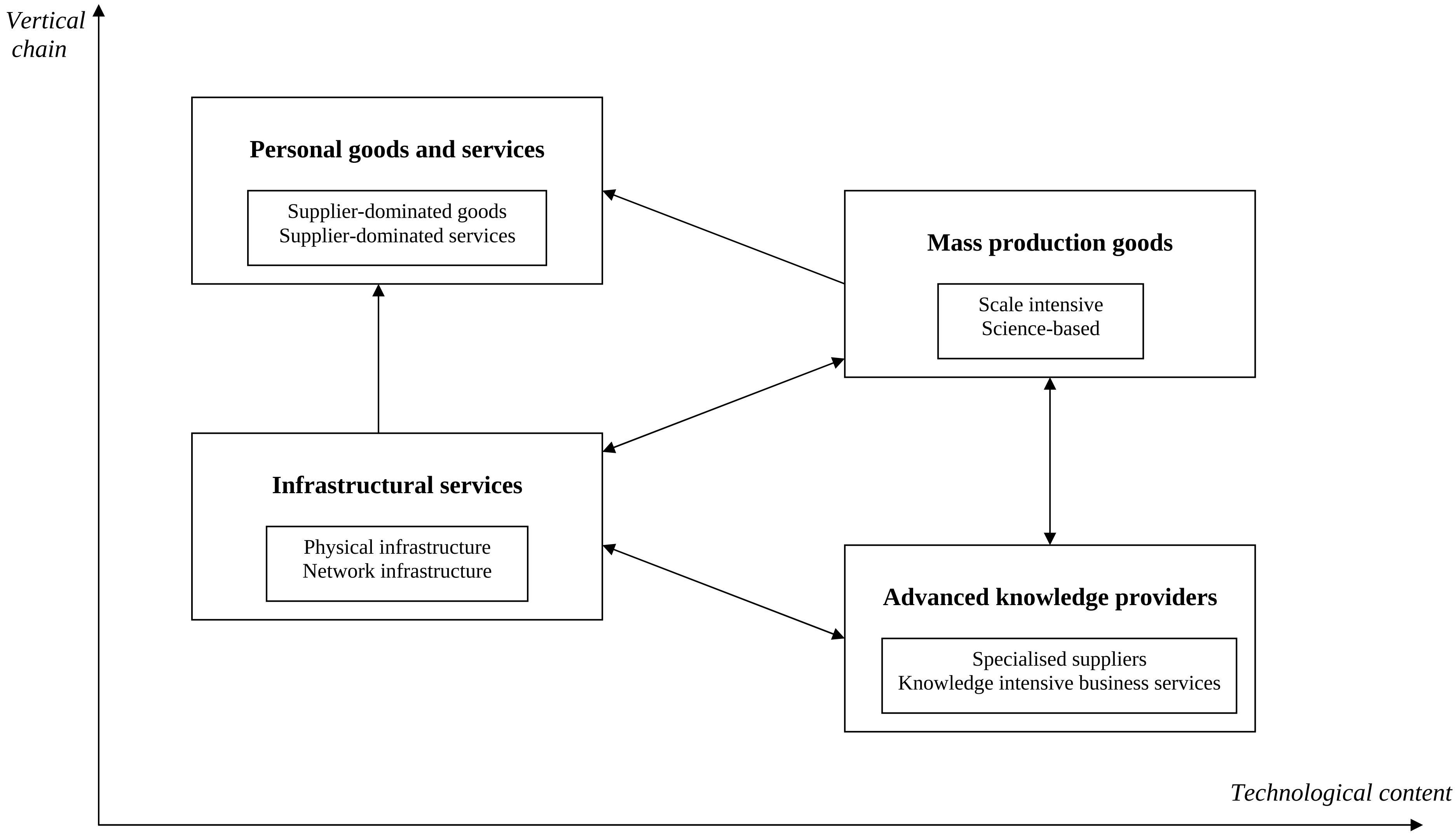


Table 1: The main characteristics of the various sectoral groups in the new taxonomy

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
	Specialised 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; processy 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
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

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	**Specialised 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.

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	**Specialised 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
Organisational 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.

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**	
Test	**ANOVA**	**Mann-Whitney**	**ANOVA**	**Mann-Whitney**	**ANOVA**	**Mann-Whitney**	**ANOVA**	**Mann-Whitney**
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**

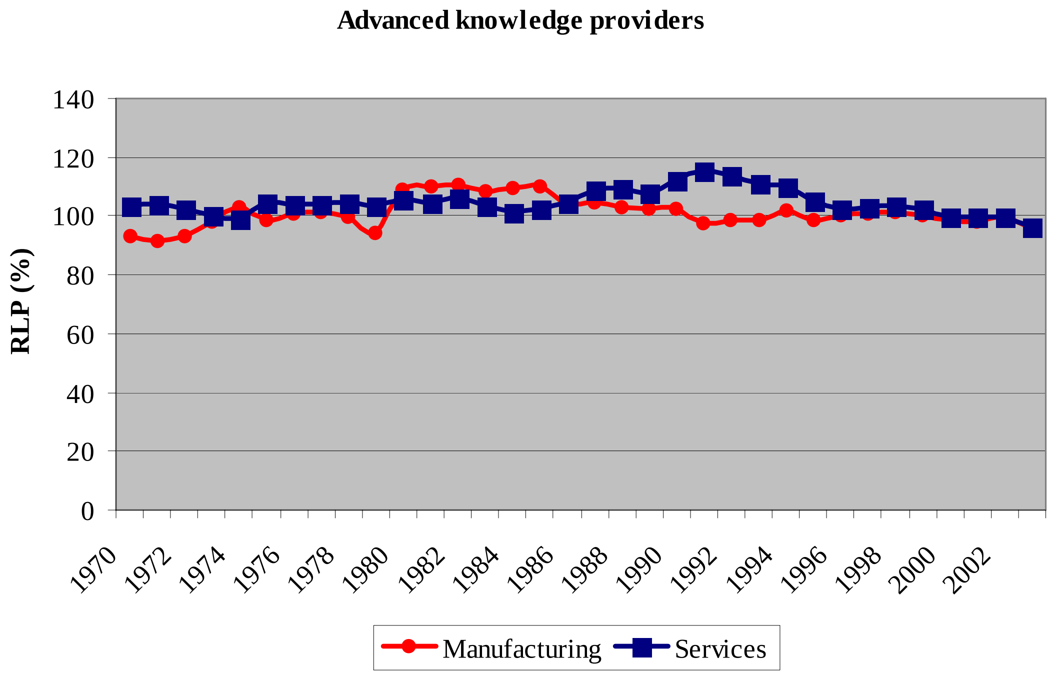
[a] AKP: advanced knowledge providers; MPG: mass production goods; SIS: supporting infrastructure services; PGS: personal goods and services.
*** Significance at 1% level; ** Significance at 5% level; * Significance at 10% level.

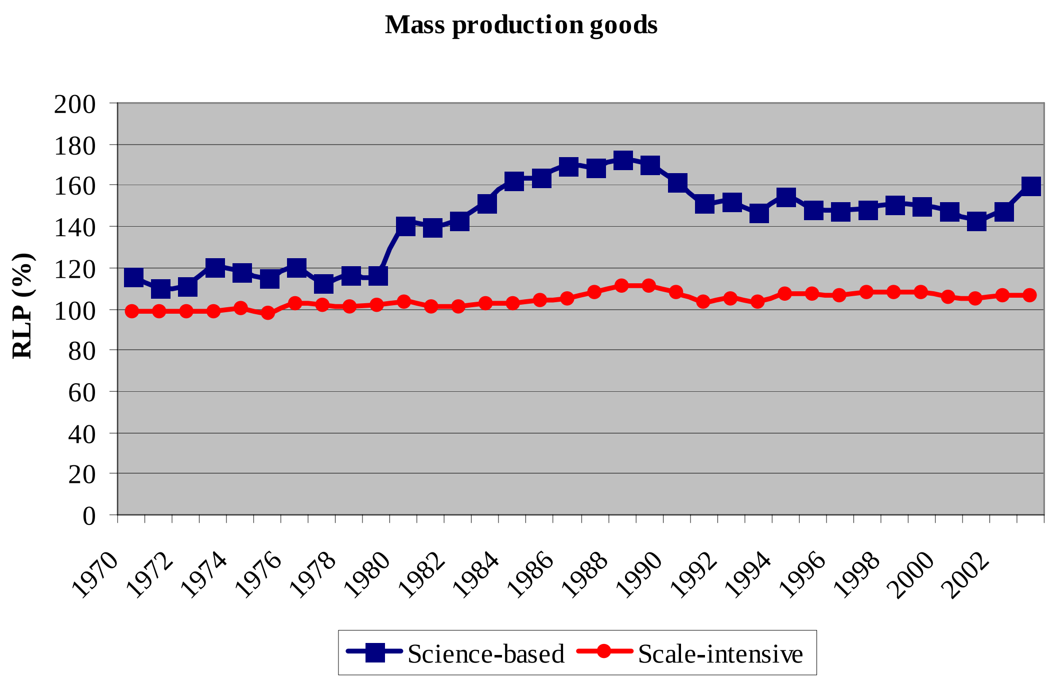
Table 5: Testing for the significance of differences within each of the four sectoral blocks: ANOVA and Mann-Whiney U test – *Technological trajectories*[a]

	AKP		**MPG**		**SIS**		**PGS**	
Test	**ANOVA**	**Mann-Whitney**	**ANOVA**	**Mann-Whitney**	**ANOVA**	**Mann-Whitney**	**ANOVA**	**Mann-Whitney**
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**
Organisational 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

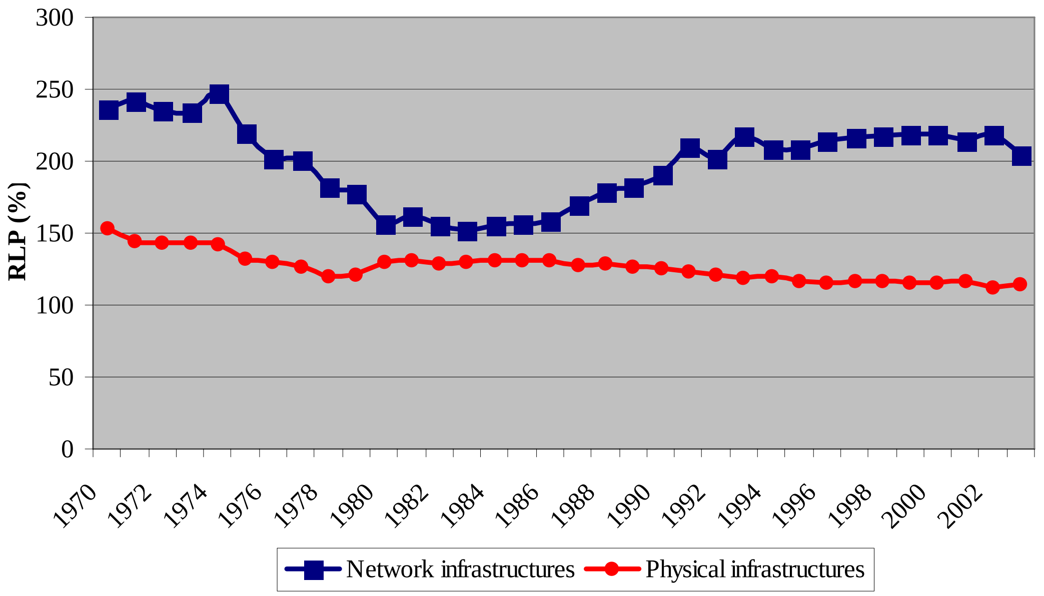
[a] AKP: advanced knowledge providers; MPG: mass production goods; SIS: supporting infrastructure services; PGS: personal goods and services.
*** Significance at 1% level; ** Significance at 5% level; * Significance at 10% level.

Figure 2: The dynamics of relative labour productivity (RLP) in the various sectoral groups, 1970-2003, EU24 average





Supporting infrastructure services



Personal goods and services