Innovation and the International Competitiveness of Manufacturing and Service Industries: a Survey

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Abstract

The paper presents a survey of the empirical literature studying the impacts of innovation on the international competitiveness of industries. Different strands of applied research, namely the R&D spillovers literature and the evolutionary economic approach, have pointed out that the international competitiveness of manufacturing industries is greatly affected by their own innovative activities as well as by the intersectoral exchange of advanced knowledge among suppliers, producers and users of new technologies. In an attempt to extend this literature to the study of the service sectors, the paper puts forward a new taxonomy that combines manufacturing and services within the same framework. This taxonomy focuses on the vertical linkages that tie together these interrelated branches of the economy, and points out their relevance to sustain the competitiveness of domestic industries in international markets.

Keywords: International competitiveness; Innovation; Vertical linkages; Services

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1. Introduction

International competitiveness has for a long time been a relevant issue for policy and an engaging topic of academic research. This may be thought of as the ability of an industry to compete with its foreign counterparts. Behind the apparent simplicity of this definition, the concept of international competitiveness is indeed a complex one, and it is closely related to a number of different aspects (Krugman, 1994; Fagerberg, 1996; Cantwell, 2005). The ability of an industry to compete with foreign competitors does in fact refer to its trade performance and specialization patterns, as well as to the dynamics of its productivity. These aspects are closely interwined. Productivity growth is in fact an important factor to improve the terms of trade of an industry, and its trade performance, in turn, is a relevant engine of growth of value added and productivity.

Academic research on the subject has achieved great progress in the last two decades. Since the second half of the 1980s, the attention has shifted from the analysis of price- and cost-related factors of competitiveness to the important role played by technological change. The greater attention to technology and non-price factors of competitiveness corresponds to a shift of focus from short-run patterns to long-run dynamics, which has been greatly inspired by the classical contribution of Schumpeter (1934 and 1939) on the role of innovation and technology diffusion in the process of growth and structural change. Different strands of empirical research have recently flourished within the Schumpeterian tradition, providing new insights on the relationships between innovation and international competitiveness.

On the one hand, new growth models have pointed to the existence of increasing returns and spillovers effects related to R&D activities, and have thus provided the theoretical foundation for the flourishing of a huge applied literature on R&D and

intersectoral spillovers (Nadiri, 1993; Los and Verspagen, 2004). On the other hand, a heterogenous set of empirical studies within the evolutionary economics tradition have emphasized the sector-specific nature of innovation and extensively investigated its impact on the competitiveness of different systems of innovation (Fagerberg, 2002; Laursen and Meliciani, 2002). These two Schumpeterian strands of research, different as they may be, both indicate that, in a long-run perspective, the international competitiveness of industries is robustly related to two major factors, namely their own innovative activities and the intersectoral diffusion of advanced knowledge.

Notwithstanding the great progress achieved by research in this field, a clear understanding of the various channels through which innovation sustains the competitiveness of domestic industries in foreign markets is still lacking. Behind a general agreement on the fact that sectoral innovation and intersectoral knowledge spillovers are important for the dynamics of the economic system, applied research has not yet reached conclusive results on the effectiveness of different spillover mechanisms, and on the geographical scope of the latter. Knowledge flows are easy to refer to in theoretical discussions, but difficult to measure in empirical analyses.

A second area where academic research has not yet achieved significant progress refers to the study of the relationship between innovation and the international competitiveness of the service sectors. As a matter of fact, most of the applied studies in this field have so far focused on manufacturing industries and commonly neglected services. The latter now constitute, however, an increasingly important and dynamic branch of the economy, whose development proceeds in close connection with the process of structural change in manufacturing. In the modern knowledge-based economy, manufacturing and services are strictly interwined, and both of them needs

to be taken into account in order to understand the competitiveness of innovation systems.

Motivated by these considerations, this paper presents a comprehensive and up-to-date overview of the relationships between innovation and the international competitivenss of manufacturing and service industries. The purpose of the study is twofold: first, to present the major results and challenges ahead of the huge empirical research focusing on innovation and competitiveness of manufacturing industries; secondly, to discuss a possible extension of this literature to the analysis of the service sectors. This second task will be carried out by presenting a new taxonomy of sectoral patterns of innovation that combines manufacturing and services within the same general framework. This taxonomy, which builds upon the seminal works of Pavitt (1984) and Miozzo and Soete (2001), points out that the international competitiveness of innovation systems depends on the intersectoral flow of advanced knowledge that ties together manufacturing and service industries.

The amount of applied research that it is relevant to consider in our discussion is substantial. The survey will focus on the major empirical results emerging from the different strands of Schumpeterian literature, and will try to provide a comprehensive view of the links between them. On the contrary, the paper will not be able to describe in details neither the methods used to obtain given empirical results nor the analytical models that provide the theoretical foundation of the different types of econometric exercises. The discussion will however briefly refer to them, and indicate, whenever possible, additional references on the subject.

The paper is organized as follows. Section 2 will present the main insights of the R&D spillovers literature, which represents the mainstream state-of-the-art approach to study the impact of sectoral innovation on growth and competitiveness. Section 3

will shift the focus to a different research tradition, rooted in evolutionary economics, which emphasizes the sector- and context-specific nature of innovation and investigates its impacts on the international competitiveness of sectoral systems. Section 4 will then point to the need of extending this literature to the study of the service sectors, and will discuss the theoretical and methodological difficulties that this extension may possibly entail. This section will focus on the relationships between manufacturing and services, and propose a new taxonomy that conceives these linkages as a major determinant of international competitiveness. Finally, section 5 will conclude the paper by summing up the main points of the discussion.

2. The mainstream view: R&D and knowledge spillovers

About two decades ago, the first contributions within the new growth theory tradition pointed out the important role of increasing returns for the growth process, and introduced this idea into a formal endogenous growth framework. The first models argued that investments in physical and human capital may generate externalities, increasing returns and, hence, persistent growth differences across countries (Romer, 1986; Lucas, 1988; Azariadis and Drazen, 1990). Subsequently, a second generation of models focused on the role of the R&D sector and the endogenous nature of the growth process. In the models of Romer (1990) and Aghion and Howitt (1992), the R&D sector produces new blueprints for the intermediate goods sector, and the expansion of the range of intermediate goods determines increasing returns and a scale effect on aggregate growth.

The idea that sectoral R&D and knowledge spillovers are important for growth and competitiveness originates therefore from these innovation-based new growth models.

The main underlying assumption is that knowledge is a non-rival and (partly) non-excludable good, and that its public good characteristics lead to the existence of spillovers, increasing returns and endogenous growth.

These theoretical ideas raised new interesting questions for applied research. Do R&D and knowledge spillovers effectively lead to productivity growth, and how do industries differ in this respect? The empirical literature investigating the impact of R&D activities on sectoral differences in productivity growth is now huge.[1] Typically, these contributions consist of econometric studies where the stock of (direct and indirect) R&D is included as a production factor together with capital and labour in an extended Cobb-Douglas specification. Thus, the growth of total factor productivity (TFP) in each sector is commonly regressed on its stock of sectoral R&D expenditures (measuring innovation) and on its indirect R&D stock (measuring R&D spillovers from other industries).

A large part of this literature focuses on this latter aspect, namely the indirect contribution that R&D expenditures in a sector have on the growth of productivity in other industries, so-called R&D spillovers (Griliches, 1992). From a conceptual point of view, it is possible to distinguish between two different types of spillover effects (Grilliches, 1979). *Rent spillovers* are those where there is a pecuniary exchange between the provider and the recipient of technology, such as in the case of a supplier that sells an intermediate input to a user. *Knowledge spillovers*, on the other hand, do not entail any contractual agreement or pecuniary exchange between provider and recipient, and arise because of the public good nature of knowledge. It is therefore this

[1] There exist several overviews of this empirical literature. Nadiri (1993) summarizes the main results of the major econometric works; Los and Verspagen (2004) review the various methodologies used in different strands of empirical analysis; David et al. (2000) focus on the relationships between private and public R&D; finally, Bartelsman and Doms (2000) and Wieser (2005) review the large set of micro-level studies on R&D and TFP growth.

second type of spillovers that more closely corresponds to the idea underlying new growth models. The major channels through which knowledge spillovers affect the growth of productivity are all related to innovating firms' R&D capabilities: reverse engineering, the mobility of R&D employees, their participation to technical meetings and scientific conferences, and the exploitation of codified information available in the form of scientific journals and patents (Levin et al., 1987).

The conceptual distinction between rent and knowledge spillovers is important, although it is frequently not possible to separate the two categories in empirical analyses. The strategy followed by most contributions in this field is to weight the stock of R&D of other sectors and to use it as a measure of inter-sectoral R&D spillovers. This is typically done in two ways. The first is to use transaction-based weights, such as inter-industry sales or investment flows, while the second is to construct measures of technological distance between industries. The former method closely corresponds to the concept of rent spillovers, whereas the latter implicitly focuses on knowledge spillovers.

The latter way to build up a measure of R&D spillovers has been followed by Jaffe (1986), who used as weights the distribution of patents across patent classes, and by Verspagen (1997a, 1997b), who used patent classifications and patent citations. These contributions, as well as several others in this field, have generally found evidence of a positive influence of R&D spillovers on sectoral productivity growth. Using a different methodology, based on a growth accounting type of sectoral decomposition of TFP, ten Raa and Wolff (2000) found a similar result, and showed the importance of technological spillovers from high-tech sectors (e.g. computers and electronics) for the growth of TFP of the whole economy.

A second strand of research in the R&D spillovers literature has extended the analysis to the investigation of the nature, extent and impact of *international* knowledge spillovers. This empirical research is inspired by a class of new growth models where sectoral R&D activities do not only sustain the dynamics of the domestic economy, but do also have positive effects for the competitiveness of foreign countries.[2] In the models of Riviera-Batiz and Romer (1991) and Grossman and Helpman (1991), in particular, the R&D sector produces new blueprints that increase the variety of available intermediate inputs, and the latter positively affect the growth of foreign countries through cross-border trade and knowledge flows (representing channels of rent and knowledge spillovers respectively).

The major questions that these analytical models raise are therefore whether spillovers are really global, rather than national, in scope, and which the most effective channels of international diffusion are. Considering these issues, a set of recent empirical works have weighted R&D in other countries with imports, so to obtain a measure of foreign R&D acquired through imports of goods and services (see overview by Barba-Navaretti and Tarr, 2000). In particular, Coe and Helpman (1995), Coe et al. (1997) and Eaton and Kortum (1996) found that both domestic and international R&D spillovers have a positive effect on the growth of TFP at the aggregate level, and that the international diffusion of knowledge is a more relevant growth engine for small open economies than for large countries.

Verspagen (1997b), Dalum, Laursen and Verspagen (1999), Fagerberg and Verspagen (2000) and Keller (2000) performed a similar analysis at the sectoral level, and showed that both kinds of spillovers contribute to explain differences in productivity growth across industries. However, these works also pointed out that the relative

[2] For an overview of this type of new growth and new trade models, see Chui et al. (2002) and Darity and Davis (2005).

importance of domestic vs. foreign R&D spillovers depends to a great extent on the econometric framework in which the analysis is undertaken. Foreign spillovers appear relatively more important when panel data are used, but much less relevant when the sample is cross-sectional in nature (Gittleman and Wolff, 1995).

This debate on the geographical scope of R&D spillovers is also related to a third stream of applied research, which focuses more closely on the regional clustering of innovative activities, and investigates the extent to which spillovers are local, rather than national or international, in scope. This is the recent empirical literature on the so-called *localised knowledge spillovers* (LKS).[3]

The main theoretical idea underlying these studies originates from analytical models in the *new economic geography* tradition. These models share with new growth and new trade theory the main idea that increasing returns, economies of scale and imperfect competition determine trade, specialization patterns and the growth paths of different countries. However, they additionally point out that the externalities underpinning these cumulative causation patterns are based on regional and local economies of agglomeration, rather than on country-specific factors. The microeconomic foundation of these economies of agglomeration refers to the tacit nature of knowledge, which, the LKS literature argues, has indeed the characteristics of a *local* public good (Krugman, 1991, 1995 and 1996; Krugman and Venables (1995).[4]

This means that spillovers effects exist and are important for the dynamics of the system, but also that they have a limited geographical scope. Two main types of

[3] Critical discussions of this strand of research have been presented by Baptista (1998), Feldman (1999) and Breschi and Lissoni (2001a and 2001b).

[4] Martin (1999) and Martin and Sunley (1996) present critical surveys of models within the new economic geography tradition.

spillovers are relevant here. The first is a *Marshallian* type of externality, which is related to exchanges of intermediate inputs and the mobility of skilled employees among firms located in the same region. The second mechanism is commonly defined as *urbanization* externality, and suggests that the diffusion of knowledge is enabled and fostered by the co-location of firms in innovative clusters. Both types of externalities, corresponding by and large to rent and knowledge spillovers respectively, point to the local nature of knowledge flows and the relevance of regional clustering for sustaining the international competitiveness of innovation systems.

The econometric literature investigating this idea is relatively recent and rapidly flourishing. The common empirical strategy is to use a "knowledge production function" (Grilliches, 1979) to estimate the relationships between R&D and innovative output, measured in terms of patents or innovation counts (Jaffe, 1989; Acs et al., 1992 and 1994; Feldman and Florida, 1994; Audretsch and Feldman, 1996; Feldman and Audretsch, 1999). Other studies are not explicitly based on a production function approach, and make use of different methodologies based on the analysis of patent citations or new product announcements (Jaffe et al., 1993; Almeida and Kogut, 1997; Brouwer et al., 1999; Kelly and Hageman, 1999; Maurseth and Verspagen, 2002).

In a nutshell, the main result from this type of econometric studies on LKS is that innovation inputs (from private R&D or University research) lead to a greater innovation output when they originate from local sources, i.e. from firms or public institutes that are located in the same region. This stylised fact is usually interpreted as evidence of the existence of knowledge spillovers (urbanization externalities),

although this may also indicate that rent spillovers (Marshallian externalities) are at work (Breschi and Lissoni, 2001a).

These empirical insights on the local nature of spillover mechanisms are interesting, although they appear to be in sharp contrast with the emphasis on the international scope of spillovers that other econometric studies suggest. On the whole, it seems fair to argue that the applied literature on the geographical scope of different channels of knowledge diffusion is far from having achieved conclusive results, and presents interesting challenges for future research.

In particular, this literature raises one major question. Given that R&D activities constitute a major factor to sustain the international competitiveness of industries, what does, in turn, determine sectoral differences in R&D intensity? A large number of studies in industrial organization and, more recently, in the economics of innovation have in fact pointed out that R&D activities differ markedly across sectors, and that these differences may be explained as the outcome of the interplay of a complex set of sector-specific characteristics (e.g. Levin et al., 1987). Hence, the competitiveness of domestic sectors in foreign markets does not merely depend on their R&D intensity, but rather on the structural characteristics that define the industry-specific opportunities, strategies and obstacles of innovative activities in different sectors. For instance, it has been shown that some low-tech and traditional industries do not innovate by undertaking formal R&D activities, but rather by acquiring advanced capital equipments from other sectors (Pavitt, 1984; Evangelista, 1999). In this case, the econometric strategy based on the estimation of R&D spillovers is likely to underestimate the innovative activities carried out by these sectors.

A different research tradition, rooted in evolutionary economics, emphasises the sectoral specificities of the innovative process, and it approaches the study of the international competitiveness of industries in a rather different way. To the discussion of this evolutionary literature we now turn.

3. The evolutionary view: technology-gap, vertical linkages and innovation systems

The general proposition that innovation and intersectoral knowledge spillovers are important for the international competitiveness of manufacturing industries is a major point of agreement between new growth theories and evolutionary economics. The two approaches, however, differ substantially in terms of the conceptualization of the innovative process and the analysis of its economic impacts.[5]

Evolutionary economics conceives innovation as a paradigm-bounded, sector-specific and context-dependent activity. The paradigmatic nature refers to the existence of dominant technological paradigms that create, in any given historical era, a set of opportunities and constraints for innovative activities (Nelson and Winter, 1982; Dosi, 1982; Freeman et al., 1982).

Industries, however, "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: 59). Thus, the paradigmatic nature of technological knowledge does not only explain the relatively ordered patterns that may be observed in each phase of long run growth at the

[5] For a general discussion of the theoretical, philosophical and methodological differences between evolutionary and new growth theories, see Castellacci (2006a).

aggregate level (Dosi, 1988), but also the inherent tendency towards qualitative change and transformations at the sectoral level. This accounts for the industry-specific nature of innovation, which naturally leads, in turn, to give emphasis to the systemic context in which the innovative process unfolds. In the evolutionary view, the impact of innovation on the international competitiveness of industries must therefore be analysed within a complex framework comprising both, the broader systemic context shaping innovative activities, and the sectoral specificities that characterize the creation and diffusion of knowledge.

In the last two decades, a large body of empirical research has developed within this tradition, and has extensively investigated the role of innovation for international competitiveness. This empirical literature is rich, and it has achieved considerable results. However, the different strands of research within evolutionary economics have not yet agreed on a standard set of models, methodology and stylized facts. This makes the task of surveying and summarizing this heterogenous literature rather complex.

Figure 1 presents an attempt to organize this vast body of empirical research. The diagram reported in the figure represents the major strands of evolutionary applied research that have investigated the relationships between sectoral innovation and international competitiveness. Each arrow in the diagram corresponds to a branch of applied literature, and the variables on which this focuses. On the whole, figure 1 may therefore be considered as a stylized representation of a general evolutionary model, yet to be written, which is based on the co-evolution and the dynamic interactions between the systemic context, the creation of knowledge within sectors, the vertical linkages among industries, and their international competitiveness. This section clarifies the different parts of this evolutionary model by referring to the major strands

of research and the main empirical results achieved by them. The evolutionary approach points out that the impact of innovation on international competitiveness depends on five major factors.

< Figure 1 here >

3.1 Sectoral innovative activity

The *technology-gap hypothesis* argues that innovation is a major determinant of the competitiveness of industries in international markets. This idea was originally inspired by the seminal contribution of Posner (1961), and was subsequently investigated by a large number of empirical studies. These econometric works typically take the form of cross-section analyses of the relationship between measures of input and/or output of innovative activities (i.e. R&D and patents, respectively) and the trade performance of different industries. This set of studies has robustly pointed out that sectoral innovative activity is indeed a major determinant of international competitiveness, and that therefore, in a long run perspective, non-price factors are significantly more important than price related variables (Soete, 1981 and 1987; Dosi and Soete, 1983; Fagerberg, 1988 and 1996; Dosi et al., 1990; Amendola et al., 1993; Verspagen and Wakelin, 1993; Magnier and Toujas-Bernate, 1994; Amable and Verspagen, 1995; Padoan, 1998; Montobbio, 2003).

A related strand of research within the technology-gap tradition focuses on the impacts of innovative activity on the dynamics of labour productivity at the macroeconomic level. Macro-oriented studies of this type have consistently shown that cross-country differences in productivity and GDP per capita levels can be explained, among several other factors, by countries' abilities to innovate as well as

their capability to exploit the international diffusion of technologies, so-called absorptive capacity (Gerschenkron, 1962; Abramovitz, 1986 and 1994). These studies have shown that imitation, far from being an automatic and easy activity, is a costly process that requires an active effort to build up a strong social capability and an advanced industrial structure (Cornwall, 1976; Verspagen, 1991; Amable, 1993; Fagerberg, 1994).

This finding points out that sectoral innovative activity does not only have a direct positive effect on international competitiveness through its impact on trade performance, but an indirect effect as well, given that the upgrading of a country's industrial structure increases its absorptive capacity and, hence, its ability to imitate foreign advanced technologies (Fagerberg and Verspagen, 2002; Castellacci, 2004). The two aspects, sectoral innovative activity and international diffusion of new technologies, are therefore closely related to each other, and both of them are important to sustain the competitiveness of national industries in the international arena.

3.2 Vertical linkages and intersectoral knowledge flows

A related strand of research within the evolutionary tradition investigates the so-called *home market hypothesis*. This was originally put forward by Linder (1961), and later developed by Porter (1990) and Lundvall (1992). The idea is that the home market constitutes a fundamental arena to develop, test and commercialise new products in the early phase of their introduction, before they are eventually exploited in foreign markets. The characteristics of the home market, and particularly the vertical linkages between suppliers, producers and users of advanced technologies, represent therefore a major factor of competitive advantage.

The focus on the importance of vertical linkages is intrinsically related to the sector-specific nature of innovation. A large set of evolutionary studies has in fact shown that innovative activities, strategies and performance greatly differ among manufacturing industries, and that different sectors tend to follow very distinct technological trajectories over time (Nelson and Winter, 1977; Malerba, 2005). Pavitt (1984), in particular, put forward a well-known taxonomy that identifies four sectoral trajectories, i.e. four groups of industries characterized by markedly different innovative modes, namely science-based, scale intensive, specialised suppliers and supplier dominated industries. The most original feature of Pavitt's taxonomy is its focus on the intersectoral flow of advanced knowledge that continuously circulates among the various industry groups, so that each of them assumes a well-distinct and specific function in the system of innovation as a provider and/or recipient of technology to/from the other groups of sectors.

Inspired by these insights on the importance of the home market and on the relevance of vertical linkages, a recent strand of empirical research has investigated their relevance to explain the international competitiveness of different industries. These econometric studies have considered, in addition to variables typical of the technology-gap approach, 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 (Fagerberg, 1995; Fagerberg and Verspagen, 2000; Laursen and Meliciani, 2002; Castellacci, 2005). 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 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, 2006b).

3.3 Technological regimes

The evolutionary applied literature presented above raises one major question. Given that sectoral innovative activity and intersectoral knowledge flows are important factors to sustain the international competitiveness of manufacturing industries, what does in turn determine them? In the investigation of the sector-specific characteristics of the innovative process, the focus of evolutionary studies is on the nature of learning processes, which are specific to a given technological environment. A *technological regime* (Nelson and Winter, 1982; Winter, 1984) defines such a technological environment, i.e. the framework conditions in which firms' innovative activities take place. In each sector of the economy, some technological characteristics affect the direction and intensity of learning processes and the knowledge accumulation by economic agents.

Extending previous empirical works in industrial organization (Cohen and Levin, 1989), recent evolutionary studies have focused on four main characteristics of sectoral technological regimes: (i) *the nature of the knowledge base*, i.e. the "properties of the knowledge upon which firms' innovative activities are based" (Breschi and Malerba, 1997, p.136); (ii) *the appropriability conditions*, i.e. the possibilities of appropriating the innovative rents by protecting innovations from imitation through a variety of means, such as patents, process secrecy and know-how, design and R&D know-how, and other non-technical means; (iii) *the cumulativeness*

conditions, which define the extent to which current innovative activity builds upon the experience and results obtained in the past; (iv) *the technological opportunities*, i.e. the "likelihood of innovating for any given amount of money invested in search". This definition focuses on the *level* of technological opportunities, that is on the relationships between input and output of the innovative process in different sectors of the economy. However, besides the level of opportunity, there are other important aspects that contribute to shape sectoral technological opportunities, such as its variety, pervasiveness and sources. The exploitation of technological opportunities is thus a complex and multifaceted process, and it is strictly linked to the existence of major dominant technological trajectories in different industries of the economy (Marsili, 2001; Marsili and Verspagen, 2002).

The investigation of the nature of technological regimes has recently led to a surge of applied research in evolutionary economics. In particular, it has been shown that the characteristics of technological regimes may shed new light on two relevant aspects of the innovative process.

First, they may explain the existence of different patterns of market structure and industrial dynamics in different sectors of the economy. Most of the recent works in this field (Malerba and Orsenigo, 1995 and 1996; Breschi and Malerba, 1997; Breschi et al., 2000) have focused on sectoral differences in terms of concentration of innovative activity, size of innovative firms, ease of entry in the market, turbulence or stability in the population of innovative firms. These studies have argued that sector-specific technological regimes may explain the existence of the two main patterns of innovation originally pointed out by Schumpeter (1934 and 1943). The first, the *Schumpeter Mark I*, is characterized by high ease of entry in the market, low concentration of innovative activity, and a turbulent population of new and old

innovators with a significant role played by small firms. Creative destruction (Schumpeter, 1934) is the main feature of this regime (also defined 'entrepreneurial' or 'widening'). The second, the *Schumpeter Mark II* pattern, is characterized by high barriers to entry for new innovators, high concentration of innovative activity, and a stable population mainly formed by large and well-established firms. Creative accumulation (Schumpeter, 1943) is the distinctive feature of such a regime, also defined 'routinized' or 'deepening'.

Secondly, a more recent branch of research has focused on the impact that sectoral technological regimes have on the international competitiveness of industries. Malerba and Orsenigo (1995 and 1996) and Malerba and Montobbio (2003) show that technological opportunities, properties of the knowledge base, appropriability and cumulativeness conditions are relevant factors to explain the patters of international technological performance, measured by the 'revealed technological advantage' in terms of patents. Relatedly, the characteristics of technological regimes have also been shown to have an impact in terms of export market share dynamics. Based on the estimation of a technology-gap trade model, other econometric studies have in fact found that sectoral trade performance is closely related to a range of industry-specific technological variables, such as technological opportunities (Laursen, 1999), cumulativeness (Lee and Lim, 2001) and appropriability conditions (Castellacci, 2005). In a nutshell, these studies provide an extension and a refinement of the technology-gap approach, as they shed new light on the links between the structural characteristics of sectoral systems of innovation, on the one hand, and their competitiveness in international markets, on the other.

3.4 The co-evolution of national and sectoral systems

Evolutionary economics emphasizes the context-specific nature of innovative activities. In the study of sectoral patterns and impacts of innovation, the context that it is relevant to look at does not simply refer to the structural characteristics defining the industry-specific technological regime, but also the broader systemic context within which the innovative process unfolds. Sectoral innovation is greatly shaped by the characteristics of the national system of innovation, and the latter, in turn, is affected by the former. The co-evolution of national and sectoral systems is therefore a major factor to drive international competitiveness.

The idea that sectoral and national systems are interwined has been recently put forward by Mowery and Nelson (1999) Murmann and Homburg (2001), Malerba (2005) and Castellacci (2006b). These studies have pointed out the existence of three channels of interactions between sectoral patterns and national systems.

The first refers to the performance of national systems. The technology-gap and home market hypotheses discussed above point out that sectoral innovative activities and intersectoral knowledge flows contribute to shape the specialization patterns, productivity dynamics and trade performance of the whole system of innovation. Several empirical studies, in addition, indicate that the specialization profile matters for the macroeconomic performance, and that countries that are able to shift their industrial structure towards areas characterized by higher technological opportunities experience a more dynamic aggregate performance in the long run (Dalum et al., 1999; Amable, 2000; Fagerberg, 2000; Landesmann and Stehrer, 2001; Montobbio, 2002; Carree, 2003; Peneder, 2003).

In turn, the country-specific patterns of scientific, technological and economic specialisation, together with the other features characterizing the home market, affect,

strengthen and reproduce over time the innovative activities of the domestic producers and the intersectoral linkages between producers, suppliers, users and the science system (Porter, 1990; Lundvall, 1992; Mowery and Nelson, 1999). Various empirical studies have in fact shown the continuity and persistence of country- and sector-specific technological trajectories and specialisation patterns over long periods of time (Archibugi and Pianta, 1994; Dalum et al., 1998; Begg et al., 1999; Laursen, 2000; Cefis and Orsenigo, 2001; Fai and Von Tunzelmann, 2001; Laursen and Salter, 2005).

Secondly, the policy level constitutes a major channel of interaction between the meso and the macro level. In fact, the existence of important industries or core industrial areas where the country is specialised, with the related set of well-established vertical linkages that they entail, may shape regulations and governmental decisions at the national level, and affect in particular (i) innovation policies, (ii) industrial policies, (iii) IPRs regulations, and (iv) University-industry links (Mowery and Nelson, 1999). If national policies actively promote core industrial areas for a prolonged period of time, and neglect others, this policy strategy will affect the entire national system of innovation, which may eventually turn out to be locked in into a specific path (Narula, 2002). Conversely, national policies may directly affect sectoral innovative activities, cooperation patterns, intersectoral linkages and University-industry collaborations through a wide variety of incentives, schemes and regulations (Lundvall and Borras, 2005; Mowery and Sampat, 2005).

Thirdly, a broad range of other country-specific factors, of a social, institutional, and cultural nature, affect, as well as are shaped by, the degree of trust and cooperation in the system and, relatedly, the intensity of intersectoral linkages and the exchange of advanced knowledge. Network interactions and systemic relationships are in fact

embedded in, and co-evolve with, a complex set of social and cultural factors that are specific to a given national framework (Powell and Grodal, 2005).

In short, the interaction between sectoral patterns and national systems of innovation tend to strengthen and reproduce a given country- and industry-specific technological trajectory over time. Sectoral innovative activities and vertical linkages, due to their persistent, enduring and context-dependent nature, are fundamental for explaining the cumulative and path-dependent dynamics that innovation systems follow over time, as well as their patterns of international competitiveness.

3.5 The co-evolution of regional and sectoral systems

In addition to the national system of innovation, a relevant context that shapes sectoral innovative activities and performance is the regional one. Regional systems co-evolve with sectoral patterns of innovation, and the competitiveness of industries in the international arena must therefore be sustained by the dynamic interaction between regional and sectoral systems. This argument comprises two distinct causal mechanisms, each of which refers to a different branch of empirical research.

The first is the so-called *geography of innovation and economic clustering* (Breschi and Malerba, 2001). This is a recent body of literature within evolutionary economics, which emphasizes the relevance of clustering of innovative activities in space, and investigates the factors that may explain these spatial patterns. The evidence that innovation clusters in successful regions, rather than spreading uniformly across the geographic space, is robust. This empirical evidence has been provided by different strands of research, ranging from the localised knowledge spillovers literature (see section 2), to the studies of industrial districts and regional success stories (e.g. Porter,

1990), to the analysis of the internationalization of MNEs' R&D activities, or lack of such (Archibugi and Iammarino, 2003; Narula and Zanfei, 2005).

A recent generalization of these previous bodies of research is constituted by the regional systems of innovation approach, which argues that innovation is a systemic process that is inherently shaped by the characteristics of the regions where innovative activities are located (Cooke, 2001; Todtling and Trippl, 2005). In a recent overview of this literature, Asheim and Gertler (2005) points to three main factors that determine the clustering of innovative activies. The first is the *tacitness of the knowledge base*, which refers to the localised and embedded nature of learning and innovation, and which implies that learning through interacting mechanisms and vertical linkages frequently require a geographical proximity of suppliers, producers and users of new technologies. The second refers to the existence of *public sources of technological opportunities*, which means that the availability of public facilities and infrastructures (e.g. R&D labs, Universities, technical schools) provides a strong incentive for innovators to locate in advanced regions. The third is a mechanism of *regional cumulativeness*, i.e. the fact that successful regions are more easily able to attract advanced resources (skilled labour, specialised suppliers, engineers, etc.) that will ensure further technological and economic success in the future.

These three factors, though, do not affect all manufacturing industries in the same manner (Asheim and Coenen, 2005). The availability of public sources of technological opportunities and close University-industry links is in fact a more relevant factor to shape the location choice of firms in science-based sectors, while specialised suppliers and scale intensive firms require geographical proximity because of the highly tacit nature of the knowledge base that they use in their interaction process. In more general terms, clustering is a more relevant factor of competitiveness

for industries characterized by high levels of technological opportunities, high appropriability and cumulativeness conditions, and a complex and tacit knowledge base (Breschi and Malerba, 1997). In other words, clustering is a particularly important aspect for technologically advanced industries, which are precisely those that constitute the major engine of growth and the most competitive branch of the system of innovation.

While the literature on the geography of innovation and economic clustering establishes a causal mechanism where regional characteristics affect the patterns and performance of innovative activities, a related branch of empirical research focuses on the opposite mechanism, namely the effect that innovation has on the economic performance and the evolution of regional systems. Inspired by the seminal contributions of Barro and Sala y Martin (1991 and 1992), various econometric studies have investigated the patterns of β-convergence across European regions, focusing on the role that innovation has to explain cross-regional differences in the dynamics of productivity and GDP per capita (Neven and Gouyette, 1995; Fagerberg and Verspagen, 1996; Fagerberg et al., 1997; Cappelen et al., 1999; 2003a; 2003b).

These studies are rooted in the technology-gap tradition presented above, and they typically take the form of cross-section estimations where regional growth is regressed on the initial level of GDP per capita, measuring the scope for diffusion, some indicators of innovative activity (e.g. patents or R&D), and a set of control variables, such as the industrial structure of the region, which measure the absorptive capacity and the ability of each region to exploit the international diffusion of technologies. The empirical evidence robustly shows that EU regions are not on a converging path and that, particularly in the last decade, advanced regions have been significantly more dynamic than backward regions. Technology-gap econometric

studies indicate that innovation is indeed a relevant factor to explain this pattern of regional divergence, and that poorer regions have frequently not been able to exploit the opportunities provided by the international diffusion of ICT-related technologies (Begg et al., 1999).

Thus, the impact of innovation on the dynamics of regional systems varies significantly across EU regions, so that we observe the existence of different *regional convergence clubs*, rather than the uniform pattern of β-convergence that neoclassical theory would predict. The dynamics of such convergence clubs is closely related to the industrial structure and the specialization patterns of different regions, where regions specialized in technologically advanced sectors tend to converge towards a more rapid growth path than regions specialized in traditional and low-tech productive activities (Giannetti, 2002; Gardiner et al., 2004; Mora et al., 2005).

Taken together, the two strands of research discussed in this section indicate that the co-evolution of sectoral and regional systems is a major factor of international competitiveness. Sectoral innovative activities and vertical linkages are greatly shaped by the characteristics of regional systems and the latter, in turn, are strengthened, reproduced and transformed over time by sectoral patterns of innovation. This co-evolution suggests the existence of cumulative causation patterns, where high-tech industries more frequently cluster in successful regions, thus contributing to make them even more successful in the future. This is a major factor of international competitiveness as well as a source of increasing regional disparities.

4. Innovation and the international competitiveness of services

One striking feature of the vast empirical literature discussed in sections 2 and 3 is that it is mostly focused on the international competitiveness of manufacturing industries, and has so far neglected the service sectors. The lack of empirical analyses on innovation and the international performance of services constitutes an important research gap in this field, given that service industries account by now for a large share of value added, employment and trade in most industrialized countries.

Different explanations have been put forward to explain the steady increase that services have experienced in recent decades (for an overview, see Schettkat and Yocarini, 2006). The first is the well-known *cost-disease* argument originally proposed by Baumol (1967), according to which the service sectors tend to increase their employment share due to their lower productivity levels and sluggish dynamics as compared to manufacturing.

The 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 connection to the emergence and diffusion of ICTs. Different theoretical explanations have therefore been put forward to explain the process of structural change and the rapid shift of economic activities from manufacturing to services. One focuses on the greater income elasticity of the consumption of services *vis-a-vis* manufacturing goods. The greater income elasticity implies that, as industrialized economies increase their levels of GDP per capita, a higher proportion of the latter is spent for the consumption of services (Gregory et al., 2006).

Another explanation, not in competition with the former, emphasizes 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 leads to a twofold interpretation. On the one hand, it suggests that (at least part of) the shift from manufacturing to services that we observe in national accounts and 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 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 (Park and Chan, 1989; Midelfart et al., 2000; Franke and Kalmbach, 2005). Innovation lies at the very core of this process of structural change and intensification of inter-sectoral linkages.

4.1 Innovation in services

Innovation studies have traditionally focused on manufacturing industries and, until recently, neglected the service sectors. In the last few years, however, an emerging body of literature has pointed 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). Studies of

service innovation emphasize the peculiarities of the innovative process in services as compared to manufacturing industries, and argue that these sectoral specificities require a set of new concepts and approaches to study innovative activities and patterns in this increasingly dynamic branch of the economy. Service innovation, in particular, is characterized by four important peculiarities that make it sharply different from innovation in manufacturing.

First, the provision of services is 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 predominat role to *the use and production of ICTs* (Evangelista, 2000). The emergence of the ICT-based technological paradigm, in fact, 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 important in several technologically advanced manufacturing activities, but assume an even more important 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 great 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 in manufacturing industries. This also suggests that the traditional approach to the study of innovation and competitiveness, based on the concept of R&D spillovers (see section 2), cannot easily be applied within the context of the service sectors, precisely due to the different modes of innovation and the minor relevance of R&D activities that characterize the latter.

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 great account. Thus, similarly to what previously done for the study of manufacturing industries, innovation scholars have recently started to propose taxonomies of service innovation with the purpose of identifying some major sectoral patterns of innovation, or technological trajectories, 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 emphasizing 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.[6]

Supplier dominated services, similarly to the corresponding category of Pavitt's taxonomy, predominantly innovate by acquiring advanced capital equipments from manufacturing sectors. These industries represent the least technologically advanced branch of the economy (e.g. restaurants and hotels, laundry, repair, barber and beauty), roughly corresponding to the traditional view of services as productivity laggards, and they provide a heterogenous set of personal services that are purchased by final consumers.

Scale intensive infrastructural services constitute the physical and the information network infrastructure of the knowledge-based economy. These industries innovate mainly by acquiring advanced capital equipments from manufacturing industries (e.g. ICTs), which lead to efficiency and quality improvements of the infrastructural and distributive services they provide to the whole economic system. Physical networks are constituted by industries such as transport, travel, trade and distribution; while

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

information networks characterize sectors heavily dependent on the use of ICTs, and in particular finance, insurance and communications.

The third category of Miozzo and Soete's taxonomy refers to the most technologically advanced and dynamic branch of the modern economy, so-called *knowledge intensive business services (KIBS)*, which correspond to Pavitt's science-based and specialised suppliers sectoral trajectories.[7] These industries innovate by interacting closely with advanced manufacturing sectors, and their knowledge base is complex and strictly related to the production of scientific knowledge by the S&T system. Their major function in the system of innovation is to produce specialized knowledge and perform problem-solving activities for manufacturing and other service sectors, thus assuming a major role for the creation and intersectoral diffusion of advanced knowledge (e.g. R&D, software and other ICT-related services, engineering, consultancy).

4.2 Innovation and economic performance in services

While the research on sectoral patterns of innovation in services has recently experienced rapid advances, the investigation of the economic performance of service innovation has been much more limited in scope, arguably due to some methodological and conceptual difficulties that will be discussed in this section. The economic performance of service innovation is investigated by two related groups of studies, one focusing on the dynamics of productivity and the other on international trade in services.

The study of the relationships between innovation, and particularly ICTs, and productivity growth in manufacturing has recently received much attention in innovation studies, but the corresponding analysis for the service sectors has been

[7] Miozzo and Soete (2001, p.162), in fact, define this category precisely as "science-based and specialised suppliers". In this paper, I will instead refer to it as *knowledge intensive business services (KIBS)*, which is an intuitevely simple and more widely used label.

rather limited (Heshmati, 2003). The diffusion of the ICT-based general purpose technology has led to the optimistic expectation of a pervasive effect of innovation on the growth of productivity in many sectors of the economy, and particularly in services, due to their intangible nature and the great use that these make of ICTs. Some applied studies have investigated this general hypothesis by making use of firm-level data for selected countries, e.g. Mairesse and Kremp (1993), Lichtenberg (1995), Licht and Moch (1999) and Cainelli et al. (2006). Others have used industry-level data or input-output tables to compare productivity levels in services across countries (e.g. Wolff, 1999; Van Ark et al., 1999).

The results from these studies are mixed and not yet conclusive. ICTs and innovative activities appear to have led to rapid productivity growth of service industries in the last decade, but such a positive impact is not always found when the data refer to previous periods. One possible factor accounting for this may be related to the slow pace of adoption of ICTs, particularly in European countries (Dalum et al., 1999). Another explanation, though, points to the methodological difficulties that this type of empirical studies entails. In fact, while the measurement of inputs does not present particular problems, the measurement of output of service activities is more complex than it is the case for manufacturing goods. Service output is hard to measure due to the heterogenous nature of services, the intense process of customisation and the great flexibility to users' needs, and the related difficulty to measure quality changes by using standard definitions (Griliches, 1994; Van Ark et al., 1999). Consequently, conventional ways to measure productivity may fail to catch the rapid process of quality and efficiency change that ICTs lead to in services, and a range of different methods have therefore been recently proposed (for an overview, see Heshmati, 2003).

The study of the impact of innovation on the dynamics of productivity in services has important implications for understanding their patterns of international competitiveness. A related strand of research focuses more directly on the international economic performance of service industries in terms of trade and specialization patterns.

This has in recent decades become a very relevant issue. International trade in services account now for more than 30% of total trade, and around 60% of FDI in the OECD area are directed towards service activities (Grünfeld and Moxnes, 2003). The emergence of new competitors in some rapidly developing economies contributes to make global competition for service market shares tougher. Service providers in some of these emerging markets, particularly in Asia (e.g. India), are now able to produce technologically advanced services at low costs, thus constituting a possible threat for other firms worldwide. At the same time, emerging markets do also open up new opportunities for the export of services produced by industrialized countries.

In the international economics literature, several analytical models have been proposed to study the trade patterns of the service sectors, and in particular of producer services. Most of these models have inserted producer services within a Heckscher-Ohlin framework, and have shown the advantages and welfare gains that liberalization and free trade of service activities may lead to (e.g. Markusen, 1989; Melvin, 1989; Van Marrewijk et al., 1997).

This type of analytical models also have an important policy dimension. The debate on the "trade-in-services" is currently vivid, and the liberalization of services that the GATS agreement seeks to promote may have important economic consequences worldwide (Hoeckman and Primo Braga, 1997). This debate and the related modelling exercises, though, have almost exclusively focused on the effects of

institutional reforms (e.g. liberalization) and related price factors for the international exchange of services through trade and FDI, while the role of innovation has not been considered to the same extent. Why have the service sectors been neglected by most previous studies of innovation and international competitiveness? We point out two main reasons for this.

The first has to do with the lack of relevant data. Until recently, data on innovative activities and international performance in services were scarce and often not comparable across countries. However, the last decade has seen the emergence and rapid diffusion of new data sources such as, among others, the Community Innovation Survey and the OECD database on International Trade in Services. In addition, the rapid diffusion and greater use of new firm-level datasets now provide a great variety of information on innovation and the economic performance of large samples of manufacturing and service enterprises.

The second reason refers to some important conceptual issues. The study of the international competitiveness of services is quite complex, due to the specific characteristics of service activities and to the great differences with the patterns prevailing in manufacturing industries. As discussed above, the provision of services is characterised by important peculiarities, such as the co-terminality between production and consumption, the importance of customisation and user-producer interactions, and the relevance of organisational factors and non-technological types of knowledge (Drejer, 2004; Miles, 2005). These characteristics frequently require a close proximity between service providers and consumers, and thus tend to hamper the international exchange of services through trade. This has led to the common, though not entirely correct, perception that ‘services are non tradable’.

However, in recent decades, information and communication technologies have in many cases overcome the co-terminality of production and consumption of services, mainly through two interrelated channels. First, innovations in ICT-related advanced services (e.g. software, telecommunications) have created a digital network infrastructure that has significantly increased the scope for the internationalisation and tradability of services (Hoeckman and Primo Braga, 1997; Miozzo and Soete, 2001; Freund and Weinhold, 2002). Secondly, the creation of new advanced services and the quality improvements of existing ones have led to the emergence of new opportunities for the international exploitation of these in foreign markets.

Thus, though recognising that some methodological and conceptual difficulties exist, it is important to emphasize that these may to a large extent be overcome. The lack of previous studies on the relationships between innovation and international trade in services does therefore constitute a limitation of current research and an important area of investigation for the future.

The number of previous studies on this topic is very scant, but a few recent empirical works do indeed suggest that innovation is a key dimension to understand the determinants of international competitiveness in services (Windrum and Tomlinson, 1999; Freund and Weinhold, 2002; Di Cagno and Meliciani, 2005; Guerrieri and Meliciani, 2005). The most significant aspect that these recent works indicate is that, in order to understand the role of innovation for the trade performance of services, it is necessary to look at one crucial factor, namely the intensity and the direction of inter-sectoral linkages and exchanges of advanced knowledge between different groups of service and manufacturing activities. The next section will analyse this aspect in greater details.

4.3 Innovation and intersectoral linkages: an integrated framework

Structural change is a complex and multifaceted process. The growth of services is, as we have seen, related to various interrelated factors, such as the rise of income levels and demand for services, and the greater technological and economic specialization that characterizes the modern knowledge-based productive process. Innovation is at the centre of these complex transformations, which lead to an intense reorganization of the division of labour among industrial sectors where some of the tasks previously performed by manufacturing firms are increasingly outsourced and carried out by specialised service providers.

The process of structural change strengthens therefore the interactions and the process of knowledge exchange between manufacturing and services. 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; Midelfart et al., 2000; Franke and Kalmbach, 2005). The key to understand the relationships between innovation and the international competitiveness of services is therefore the analysis of the interdependence and vertical linkages that tie together different groups of manufacturing and service sectors.

A limited number of empirical studies have previously pointed out this relevant aspect by making use of input-output data (Antonelli, 1998; Windrum and Tomlinson, 1999; Guerrieri and Meliciani, 2005). However, a full understanding of the interactions and co-evolutionary process linking together manufacturing and services is still lacking. This section points to the need to set up an integrated framework combining together manufacturing and service industries, and it proposes a first attempt in this direction.

The integrated framework we propose combines two related taxonomies of sectoral patterns of innovation, namely Pavitt's (1984) for manufacturing industries and Miozzo and Soete's (2001) for services. Figure 2 shows this integrated framework. The diagram depicts the various groups of manufacturing industries originally identified by Pavitt (supplier-dominated, scale intensive, specialised suppliers and science-based) as well as the three groups of service sectors described by Miozzo and Soete (supplier-dominated, scale intensive infrastructural services, and knowledge-intensive business services). The arrows in the diagram represent vertical linkages and knowledge exchanges linking together different groups of industries, indicating, for each of them, the innovative input received from, and the knowledge output provided to, different parts of the system of innovation.

This integrated framework represents services as embedded in the whole system of innovation, rather than as a separate entity disentangled from it. This enables to analyse their function within the economy and, relatedly, to reflect upon the major factors determining their international competitiveness. Based on this general conceptual framework, table 1 summarizes the main characteristics of sectoral patterns of innovation in services and the related implications in terms of international competitiveness.

Scale intensive infrastructural services, constituting both the physical and the information network infrastructure of the economy, assume a central role in the system of innovation. Innovative activities for this type of infrastructural and distributive service providers greatly depend on the acquisition of advanced capital equipments, and particularly ICT-related devices, from manufacturing industries, whose application leads to increases of efficiency and quality improvements of the network infrastructure of the economy. In turn, advances in the latter have a pervasive

effect on the whole system of innovation by leading to cost reductions and productivity gains in all other industries. In addition, an advanced communication infrastructure favours the process of technological and economic specialization and, hence, it enables the deepening of the division of labour and the outsourcing of activities that the process of structural change entails (Antonelli, 1998).

For these service sectors, the dominant modes of internationalization are through foreign direct investments (e.g. in financial services) and cross-border trade (in telecommunications). The rapid diffusion of ICTs have greatly increased the tradability of this type of services, and both of these channels have in fact dramatically increased in recent decades (Freund and Weinhold, 2002).

The international competitiveness of this bunch of services depends therefore on the existence of a dynamic process of interaction between advances in the network infrastructure and the process of technological change in all other manufacturing and service industries. Infrastructural services sustain, and are sustained by, the competitiveness of the whole system of innovation.

Knowledge intensive business services (KIBS) do also play a crucial role within the knowledge-based economy. The diagram in figure 2 shows that they have emerged as a key part of the most dynamic branch of the system of innovation, namely at the intersection between science-based and specialised suppliers manufacturing industries. The dynamic interactions between these two groups of manufacturing sectors played a crucial role for the creation of advanced technological knowledge in the Fordist economy, a stylised representation of which was presented by Pavitt's model. Now, in the ICT-based techno-economic paradigm, KIBS have emerged as a new and increasingly central actor in the innovative process of high-tech industries.

KIBS have in fact emerged as a result of the increasing complexity of the productive process, and are closely related to the process of outsourcing of manufacturing activities previously discussed (Antonelli, 1998). They produce specialised 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 specialised manufacturing industries.

The prevailing modes of internationalization for KIBS firms are both cross-border trade and foreign direct investments, so that, also for these industries, the increasing patterns of globalization of production and of technological activities have led in recent decades to an intensification of international competition, and the opening up of new challenges as well as new opportunities.

In a nutshell, their international competitiveness depends on the existence of strong linkages between technologically advanced manufacturing and service sectors. These linkages refer to both, the demand for a new range of intermediate products and services and, relatedly, the inter-sectoral exchanges of advanced knowledge between manufacturing and services (Windrum and Tomlinson, 1999; Guerrieri and Meliciani, 2005). An advanced industrial structure sustains the international competitiveness of KIBS services.

Finally, *supplier-dominated services* represent a heterogenous set of activities providing final (personal) services to the consumers, rather than distributive, infrastructural or producer (intermediate) services. As such, their role in the system of innovation is more peripheral as compared to the previous two groups. These service providers mainly innovate by acquiring capital equipments from science-based and

scale intensive manufacturing industries. Their technological levels are also enhanced by increases of efficiency and quality improvements in the physical and information network infrastructure of the economy.

The provision of personal services commonly requires a close proximity between service providers and consumers. The co-terminality issue tends to hamper trade and the international exchange of this type of services. The process of internationalization, consequently, requires either the producer to establish abroad (FDI) or the consumer to travel abroad to purchase the service (e.g. tourism). Both of these channels have been enhanced by the development of ICTs and economic globalisation, although supplier-dominated services are still much less international in scope than infrastructural and KIBS services.

In short, the international competitiveness of this type of service industries depends on their ability to exploit the opportunities provided by the diffusion of technological knowledge produced by more advancved manufacturing and service sectors.

In summary, what this integrated framework shows is that the relationships between innovation and the international competitiveness of services cannot be investigated in isolation from innovative patterns in manufacturing. The modern knowledge-based economy is characterized by a complex web of linkages between manufacturing and service activities. These linkages, and the co-evolution between these interrelated branches of the economy, constitute the key factor to explain the dynamics of specialization patterns and the trade performance of services in international markets.

The combined framework presented here points out, in addition, that different groups of service industries are characterized by markedly different innovative patterns and different channels and modes of internationalization. The sector-specific nature of

innovation is thus one major aspect that needs to be considered in the investigation of the international competitiveness of services.

< Figure 2 and table 1 here >

5. Conclusions

The paper has presented a survey of the empirical literature studying the impacts of innovation on the international competitiveness of industries. The number of applied works on the subject published in the last couple of decades is vast, and the progress achieved by this literature is considerable. However, there does not exist yet a clear understanding and a conclusive set of empirical results on the various channels through which innovation and the intersectoral diffusion of advanced knowledge sustain the competitiveness of domestic industries in foreign markets.

Most of the existing literature broadly falls into two different schools of thought, namely new growth theory and evolutionary economics. Section 2 has presented the mainstream strand of research on R&D spillovers, while section 3 has surveyed the heterogenous set of studies within the evolutionary economics tradition. The two approaches differ considerably in terms of the way they conceptualise knowledge and innovation. The R&D spillovers literature is greatly inspired by new growth models, according to which knowledge has the characteristics of a public good and hence, by its own nature, leads to externalities and increasing returns in the growth process. Evolutionary economics, on the other hand, points to the paradigmatic, sector-specific and context-dependent nature of innovative activities, and argues that these require a

systemic type of understanding, rather than a linear model based on a unidirectional relationship between inputs (R&D) and output (productivity).

This different conceptualization is also reflected in the way the two approaches conceive the inter-sectoral diffusion of advanced knowledge, which is the other major source of international competitiveness in this type of studies. In the mainstream literature, the concept of *spillovers* implicitly refers to a quasi-automatic process of diffusion of knowledge across sectors, and the related economic benefits that this process leads to. In the evolutionary view, the inter-sectoral diffusion of knowledge is related to the so-called *vertical linkages*, where this term contains a more or less explicit reference to the function of each sector as provider (supplier) or recipient (user) of intermediate goods and new technologies within the system of innovation. The notion of vertical linkages implicitly points to the sector-specific nature of innovation, which emphasizes that industries are characterized by different innovative strategies and modes, and which therefore implies that different groups of industries lead to different types of (rent and technological) spillovers.

However, while the two approaches greatly differ in terms of the microfoundations of the process of growth and structural change, at a more general and a more aggregate level of analysis they also share important similarities. In fact, the general story emerging from the last two decades of research in the field is indeed consistent, and it is basically the same in the two approaches. In this story, innovation and the intersectoral diffusion of technologies are the major engines of industrial competitiveness and, due to several factors hampering the international flow of knowledge and to the tacit nature of innovative activities, the latter frequently cluster in successful regions, rather than spreading uniformly in the geographic space. These factors explain aggregate outcomes and empirical patterns such as increasing returns,

cumulative causation paths, persistent patterns of technological and economic specialization, and persistent inequalities across regions and countries.

The applied studies within these mainstream and evolutionary economics traditions do also share one additional common aspect, namely their prevailing focus on manufacturing industries and their frequent neglect of the service sectors. Services, though, represent by now a significant share of value added, employment and trade in most industrialized countries, so that the lack of previous studies on innovation and the international competitiveness of services marks an important area for future research.

Section 4 has shifted the focus to this relevant aspect by briefly presenting the state of the art of the literature on innovation in services, and by proposing some ideas on how to extend this type of studies to the analysis of the economic performance of services, particularly in terms of their patterns of internationalization and cross-border trade. The section, in particular, has put forward a new taxonomy of sectoral patterns of innovation that combines manufacturing and service industries within the same general framework, and that focuses on the intersectoral exchange of advanced knowledge that continuously arises in the innovation system.

The main idea underlying this taxonomy may be summarized as follows. The growth of services is closely related to the increasing complexity and deeper division of labour that characterizes the knowledge-based economy, with the related process of outsourcing of manufacturing activities to specialized service firms, and the emergence of the latter as a key actor in the innovation system. Therefore, the relationships between innovation and the international competitiveness of services cannot be investigated in isolation from innovative patterns in manufacturing. The modern knowledge-based economy is characterized by a complex web of linkages

between manufacturing and service activities. These linkages, and the co-evolution between these interrelated branches of the economy, constitute the key factor to explain the dynamics of specialization patterns and the trade performance of services in international markets.

The empirical relevance of this taxonomy to explain the patterns and performance of different systems of innovation constitutes an interesting question for future research.

References

Abramovitz, M. (1986): "Catching-up, forging ahead and falling behind", *Journal of Economic History*, 46: 385-406.

Abramovitz, M. (1994): "The origins of the postwar catch-up and convergence boom", in Fagerberg, J., Verspagen, B. and von Tunzelmann, N. (eds): *The Dynamics of Technology, Trade and Growth*, Edward Elgar, Aldershot.

Acs, Z. J., Audretsch, D. B. and Feldman, M. P. (1992): "Real effects of academic research: a comment", *American Economic Review*, 82: 363-367.

Acs, Z. J., Audretsch, D. B. and Feldman, M. P. (1994): "R&D spillovers and recipient firm size", *Review of Economics and Statistics*, 76: 336-340.

Aghion, P. and Howitt, P. (1992): "A model of growth through creative destruction", *Econometrica*, 60: 323-351.

Almeida, P. and Kogut, B. (1997): "The exploration of technological diversity and the geographic localization of innovation", *Small Business Economics*, 9: 21-31.

Amable, B. (1993): "Catch-up and convergence in a model of cumulative growth", *International Review of Applied Economics*, 7:1-25.

Amable, B. (2000): "International specialisation and growth", *Structural Change and Economic Dynamics*, 11: 413-431.

Amable, B. and Verspagen, B. (1995): "The role of technology in market shares dynamics", *Applied Economics*, 27: 197-204.

Amendola, G., Dosi, G. and Papagni, E. (1993): "The dynamics of international competitiveness", *Weltwirtschaftliches Archiv*, 129 (3): 451-471.

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., and Iammarino, S. (2003): "The policy implications of the globalisation of innovation", *Research Policy*, 28: 317-336.

Archibugi, D. and Pianta, M. (1994): "Aggregate convergence and sectoral specialization in innovation", *Journal of Evolutionary Economics* (1994) 4, pp. 17-33.

Asheim, B and Coenen, L. (2005): "Knowledge bases and regional innovation systems: comparing Nordic clusters", *Research Policy*, 34: 1173-1190.

Asheim, B and Gertler, M. (2005): "The geography of innovation: regional innovation systems", in J. Fagerberg, D. C. Mowery and R. R. Nelson (Eds.), *The Oxford Handbook of Innovation,* Oxford University Press, Oxford.

Audretsch, D. B. and Feldman, M. P. (1996): "R&D spillovers and the geography of innovation and production", *American Economic Review*, 86: 630-640.

Azariadis, C. and Drazen, A. (1990): "Threshold externalities in economic development", *Quarterly Journal of Economics*, May 1990: 501-526.

Baptista, R. (1998): "Clusters, innovation and growth: a survey of the literature", in Swann, P., Prevezer, M. and Stout, D. (Eds.), *The Dynamics of Industrial Clustering. International Comparisons in Computing and Biotechnology*, Oxford University Press, Oxford.

Barba Navaretti, G. and Tarr, D. G. (2000): "International knowledge flows and economic performance: a review of the evidence", *The World Bank Economic Review*, 14 (1): 1-15.

Barro, E. J. and X. Sala-i-Martin (1991): "Convergence across States and regions", *Brooking Papers on Economic Activity*, 1: 107-182.

Barro, E. J. and X. Sala-i-Martin (1992): "Convergence", *Journal of Political Economy*, 100 (2): 223-251.

Bartelsman, E. J. and Doms, M. (2000): "Understanding productivity: lessons from longitudinal microdata", *Journal of Economic Literature*, 38 (3): 569-594.

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

Begg, I., Dalum, B., Guerrieri, P., and Pianta, M. (1999): "The impact of specialization in Europe", in J. Fagerberg, P. Guerrieri and B. Verspagen (Eds.), *The Economic Challenge for Europe – Adapting to Innovation Based Growth*, Edward Elgar, Cheltenham.

Breschi, S. and Lissoni, F. (2001a): "Knowledge spillovers and local innovation systems: a critical survey", *Industrial and Corporate Change*, 10 (4): 975-1005.

Breschi, S. and Lissoni, F. (2001b): "Localised knowledge spillovers vs. innovative milieux: knowledge 'tacitness' reconsidered", *Papers in Regional Science*, 80 (3): 255-273.

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

Breschi, S. and F. Malerba (2001): "The geography of innovation and economic clustering: some introductory note", *Industrial and Corporate Change*, 10 (4): 817-833.

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

Brouwer, E., Nadvornikova, H. B. and Kleinknecht, A. (1999): "Are urban agglomerations a better breeding place for product innovations? An analysis of new product announcements", *Regional Studies*, 33: 541-549.

Cainelli, G., Evangelista, R. and Savona, M. (2006): "Innovation and economic performance in services: a firm-level analysis", *Cambridge Journal of Economics*, 30: 435-458.

Cantwell, J. (2005): "Innovation and Competitiveness", in J. Fagerberg, D. C. Mowery and R. R. Nelson (Eds.), *The Oxford Handbook of Innovation,* Oxford University Press, Oxford.

Cappelen, A., J. Fagerberg and B. Verspagen (1999): "Lack of Regional Convergence", in J. Fagerberg, P. Guerrieri and B. Verspagen (eds), *The Economic Challenge for Europe. Adapting to Innovation Based Growth*, Aldershot, UK, Edward Elgar.

Cappelen A., Castellacci, F., Fagerberg J. and Verspagen, B. (2003a): "The impact of regional support on growth and convergence in the European Union", *Journal of Common Market Studies* 41 (4): 621-644.

Cappelen A., Castellacci, F., Fagerberg J. and Verspagen, B. (2003b): "Regional disparities in income and unemployment in Europe", in Fingleton, B. (Ed.), *European Regional Growth*, Springer-Verlag.

Carree, M.A. (2003): "Technological progress, structural change and productivity growth: a comment", *Structural Change and Economic Dynamics*, 14: 109-115.

Castellacci, F. (2004): "A neo-Schumpeterian approach to why growth rates differ", *Revue Economique*, 55 (6): 1145-1169.

Castellacci, F. (2005): "Technological regimes and sectoral differences in productivity growth", in Castellacci, F., *Empirical Studies on Innovation, Structural Change and Economic Growth*, PhD Dissertation, University of Rome La Sapienza.

Castellacci, F. (2006a): "Theoretical convergence? A critical review of evolutionary and new growth theories", *Journal of Economic Surveys*, forthcoming.

Castellacci, F. (2006b): "The interactions between national systems and sectoral patterns of innovation. A cross-country analysis of Pavitt's taxonomy", *DIME Working Paper* 2006.01.

Cefis, E. and Orsenigo, L. (2001): "The persistence of innovative activities: a cross-countries and cross-sectors comparative analysis", *Research Policy* 30, pp. 1139-1158.

Chui, M., Levine, P., Murshed, S. M. and Pearlman, J. (2002): "North-South models of growth and trade", *Journal of Economic Surveys*, 16 (2): 123-165.

Coe, D.T. and Helpman, E. (1995): "International R&D spillovers", *European Economic Review*, 39: 859-887.

Coe, D.T., Helpman, E. and Hoffmaister, A. (1997): "Nort-South R&D spillovers", *Economic Journal*, 107: 134-149.

Cohen, W.M. and Levin, R. (1989): "Empirical studies of innovation and market structure", in R. Schmalensee and R.D. Willig (ed) *Handbook of Industrial Organization, Volume II*, North Holland.

Cooke, P. (2001): "Regional innovation systems, clusters and the knowledge economy", *Industrial and Corporate Change*, 10 (4): 945-973.

Cornwall, J. (1977): *Modern Capitalism, its Growth and Transformations*, London, Martin Robertson.

Dalum, B., Laursen, K. and Villumsen, B. (1998): "Structural change in OECD export specialisation patterns: de-specialisation and 'stickiness'", *International Review of Applied Economics*, 12 (3): 423-442.

Dalum, B., Laursen, K. and Verspagen, B. (1999): "Does specialization matter for growth?", *Industrial and Corporate Change*, 8: 267-288.

Darity, W. and Davis, L. S. (2005): "Growth, trade and uneven development", *Cambridge Journal of Economics*, 29: 141-170.

David, P., Hall, B. and Toole, A. (2000): "Is public R&D a complement or substitute for private R&D? A review of the econometric evidence", *Research Policy*, 29: 497-529.

Di Cagno, D. and 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. and Soete, L. (1983): "Technology gaps and cost-based adjustments: some explorations on the determinants of international competitiveness", *Metroeconomica*, 35 (3): 197-222.

Dosi, G. Pavitt, K. and L. Soete (1990): *The Economics of Technical Change and International Trade*, Harvester Wheatsheaf, London.

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

Eaton, J. and Kortum, S. (1996): "Trade in ideas – Patenting and productivity in the OECD", *Journal of International Economics*, 40: 251-278.

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 Technology*, 9: 183-221.

Fagerberg, J. (1988): "International competitiveness", *Economic Journal*, 98: 355-374.

Fagerberg, J. (1995): "User-producer interaction, learning and comparative advantage", *Cambridge Journal of Economics*, 19: 243-256.

Fagerberg, J. (1996): "Technology and competitiveness", *Oxford Review of Economic Policy*, 12 (3): 39-51.

Fagerberg, J. (2000): "Technological progress, structural change and productivity growth: a comparative study", *Structural Change and Economic Dynamics*, 11: 393-411.

Fagerberg, J. (2002): *Technology, Growth and Competitiveness: Selected Essays*, Edward Elgar, Cheltenham, UK.

Fagerberg, J. and Verspagen, B. (1996): "Heading for Divergence? Regional Growth in Europe Reconsidered", *Journal of Common Market Studies* 34: 431–448.

Fagerberg, J., B. Verspagen and M. Caniëls (1997): "Technology, Growth and Unemployment across European Regions", *Regional Studies*, 31: 457–66.

Fagerberg, J. and Verspagen, B. (2000): "Productivity, R&D spillovers and trade", in van Ark, B., Kuipers, S.K. and Kuper, G.H. (eds.), *Productivity, Technology and Economic Growth*, Kluwer Academic Publishers, Dordrecht.

Fagerberg, J. and Verspagen, B. (2002): "Technology-gaps, innovation-diffusion and transformations: an evolutionary interpretation", *Research Policy* 31: 1291-1304.

Fai, F. and von Tunzelmann, N. (2001): "Industry-specific competencies and converging technological systems: evidence from patents", *Structural Change and Economic Dynamics*, 12: 141-170.

Feldman, M. (1999): "The new economics of innovation, spillovers and agglomeration: a review of empirical studies", *Economics of Innovation and New Technology*, 8: 5-25.

Feldman, M. and Florida, R. (1994): "The geographic sources of innovation: technological infrastructure and product innovation in the United States", *Annals of the Association of American Geographers*, 84: 210-229.

Feldman, M. and Audretsch, D. B. (1999): "Innovation in cities: science-based diversity, specialisation and localised competition", *European Economic Review*, 43: 409-429.

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

Franke, R. and 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 (2005): 467-488.

Freeman, C., Clark, J. and Soete, L. (1982): *Unemployment and Technical Innovation*, Pinter, London.

Freund, C. and Weinhold, D. (2002): "The Internet and international trade in services", *American Economic Review*, 92 (2): 236-240.

Gallouj, F. and Weinstein, O. (1997): "Innovation in services", *Research Policy*, 26: 537-556.

Gardiner, B., Martin, R. and Tyler, P. (2004): "Competitiveness, productivity and economic growth across the European regions", *Regional Studies*, 38 (9): 1045-1067.

Gerschenkron, A. (1962): *Economic Backwardness in Historical Perspective*, Harvard University Press, Cambridge.

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

Giannetti, M. (2002): "The effects of integration on regional disparities: convergence, divergence or both?", *European Economic Review*, 46: 539-567.

Gittleman, M. and Wolff, E.N. (1995): "R&D activity and cross-country growth comparisons", *Cambridge Journal of Economics*, 19: 189-207.

Gregory, M., Salverda, W. and Schettkat, R. (2006): *The US-European Gap in Service Demand and Employment*, in press.

Griliches, Z. (1979): "Issues in assessing the contribution of research and development to productivity growth", *The Bell Journal of Economics*, 10: 92-116.

Grilliches, Z. (1992): "The search for R&D spillovers", *Scandinavian Journal of Economics*, 94: S29-S47.

Grilliches, Z. (1994): "Productivity, R&D, and the data constraint", *American Economic Review*, 84: 1-23.

Grünfeld, L. A. and Moxnes, A. (2003): "The intangible globalization – Explaining the patterns of international trade in services", *NUPI Working Paper* N. 657.

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

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

Heshmati, A. (2003): "Productivity growth, efficiency and outsourcing in manufacturing and service industries", *Journal of Economic Surveys*, 17 (1): 79-112.

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

Hoeckman, B. and Primo Braga, C. (1997): "Protection and trade in services: a survey", *Open Economies Review*, 8 (3): 285-308.

Jaffe, A.B. (1986): "Technological opportunities and spillovers from R&D: evidence from firms' patents, profits, and market value", *American Economic Review*, 76: 984-1001.

Jaffe, A.B. (1989): "Real effects of academic research", *American Economic Review*, 79: 957-970.

Jaffe, A.B., Trajtenberg, M. and Henderson, R. (1993): "Geographic localisation of knowledge spillovers as evidenced by patent citations", *Quarterly Journal of Economics*, 108: 577-598.

Keller, W. (2000): "Do trade patterns and technology flows affect productivity growth?", *The World Bank Economic Review*, 14 (1): 17-47.

Kelly, M. and Hageman, A. (1999): "Marshallian externalities in innovation", *Journal of Economic Growth*, 4: 39-54.

Krugman, P. (1991): *Geography and Trade*, MIT Press, Cambridge, MA.

Krugman, P. (1994): "Competitiveness: A Dangerous Obsession", *Foreign Affairs*, 73 (2): 28-44.

Krugman, P. (1995): *Development, Geography and Economic Theory*, MIT Press, Cambridge, MA.

Krugman, P. (1996): *The Self-Organising Economy*, Blackwell, Oxford.

Krugman, P. and Venables, A. (1996): "Integration, specialization and adjustment", *European Economic Review*, 40: 959-967.

Landesmann, M. and Stehrer, R. (2001): "Convergence patterns and switchovers in comparative advantage", *Structural Change and Economic Dynamics*, 12: 399-423.

Laursen, K. (1999): "The impact of technological opportunity on the dynamics of trade performance", *Structural Change and Economic Dynamics*, 10: 341-357.

Laursen, K. (2000): "Do export and technological specialisation patterns co-evolve in terms of convergence or divergence? Evidence from 19 OECD countries, 1971-1999, *Journal of Evolutionary Economics*, 10: 415-436.

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

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

Laursen, K. and 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.

Laursen, K. and Salter, A. (2005): "The fruits of intellectual production: economic and scientific specialisation among OECD countries", *Cambridge Journal of Economics*, 29, pp. 289-308.

Lee, K. and Lim, C. (2001): "Technological regimes, catching-up and leapfrogging: findings from the Korean industries", *Research Policy*, 30: 459-483.

Levin, R.C., Klevorick, A.A., Nelson, R.R. and Winter, S.G. (1987): "Appropriating the returns from industrial R&D", *Brookings Papers on Economic Activity*, 3: 783-820.

Licht, G. and Moch, D. (1999): "Innovation and information technology in services", *The Canadian Journal of Economics*, 32 (2): 363-383.

Lichtenberg, F. (1995): "The output contributions of computer equipment and personnel: a firm-level analysis", *Economics of Innovation and New Technology*, 3: 201-217.

Los, B. and Verspagen, B. (2004): "Technology spillovers and their impact on productivity", in H. Hanusch and A. Pyka (eds.), *Elgar Companion to Neo-Schumpeterian Economics*, Edward Elgar, Cheltenham.

Lucas, R. (1988): "On the mechanics of economic development", *Journal of Monetary Economics*, 22: 3-42.

Lundvall, B.A. (1992): *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning,* Pinter Publishers, London.

Lundvall, B. A. and S. Borrás (2005): "Science, technology and innovation policy", in J. Fagerberg, D. C. Mowery & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation,* Oxford University Press, Oxford.

Magnier, A. and Toujas-Bernate, J. (1994): "Technology and trade: empirical evidences for the major five industrialized countries, *Weltwirtschaftliches Archiv*, 130 (3): 494-520.

Mairesse, J. and Kremp, E. (1993): "A look at productivity at the firm level in eight French service industries", *The Journal of Productivity Analysis*, 4: 211-234.

Malerba, F. (2005): "Sectoral systems: how and why innovation differs across sectors", in J. Fagerberg, D. C. Mowery & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford.

Malerba, F. and Montobbio, F. (2003): "Exploring factors affecting international technological specialization: the role of knowledge flows and the structure of innovative activity", *Journal of Evolutionary Economics*, 13: 411-434.

Malerba, F. and Orsenigo, L. (1995): "Schumpeterian patterns of innovation", *Cambridge Journal of Economics*, 19: 47-65.

Malerba, F. and Orsenigo, L. (1996): "Schumpeterian patterns of innovation are technology-specific", *Research Policy*, 25: 451-478.

Markusen, J. (1989): "Trade in producer services and in other specialized intermediate inputs", *American Economic Review*, 79 (1): 85-95.

Marsili, O. (2001): *The Anatomy and Evolution of Industries: Technological Change and Industrial Dynamics,* Edward Elgar, Cheltenham, UK.

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.

Martin, R. (1999): "The new 'geographical turn' in economics: some critical reflections", *Cambridge Journal of Economics*, 23: 65-91.

Martin, R. and Sunley, P. (1996): "Paul Krugman's geographical economics and its implications for regional development theory: a critical assessment", *Economic Geography*, 72: 259-291.

Maurseth, P.B. and Verspagen, B. (2002): "Knowledge spillovers in Europe. A patent citation analysis", *Scandinavian Journal of Economics*, 104: 531-545.

Melvin, J. (1989): "Trade in producer services: a Heckscher-Ohlin approach", *Journal of Political Economy*, 97 (5): 1180-1196.

Midelfart-Knarvik, K. H., Overman, H. G., Redding, S. J. and Venables, A. J. (2000): "The location of European industry", *Report for the EC*, Brussels.

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. and Soete, L. (2001): "Internationalization of services: a technological perspective", *Technological Forecasting and Social Change*, 67: 159-185.

Montobbio, F. (2002): "An evolutionary model of industrial growth and structural change", *Structural Change and Economic Dynamics*, 13: 387-414.

Montobbio, F. (2003): "Sectoral patterns of technological activity and export market share dynamics", *Cambridge Journal of Economics*, 27: 523-545.

Mora, T., Vaya, E. and Surinach, J. (2005): "Specialisation and growth: the detection of European convergence clubs", *Economic Letters*, 86: 181-185.

Mowery, D. and Nelson, R. (1999): *The Sources of Industrial Leadership*, Cambridge University Press, Cambridge.

Mowery, D. and Sampat, B. (2005): "Universities in national innovation systems", in J. Fagerberg, D. C. Mowery & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford.

Murmann, J. P. and Homburg, E. (2001): "Comparing evolutionary dynamics across different national settings: the case of the synthetic dye industry, 1857-1914", *Journal of Evolutionary Economics*, 11: 177-205.

Nadiri, M. I. (1993): "Innovations and technological spillovers", NBER Working Paper No. 4423.

Narula, R. (2002): "Innovation systems and 'inertia' in R&D location: Norwegian firms and the role of systemic lock-in", *Research Policy*, 31 (5): 795-816.

Narula, R. and Zanfei, A. (2005): "Globalisation of innovation: the role of multinational enterprises", in J. Fagerberg, D. C. Mowery, R. R. Nelson (Eds.), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford.

Nelson, R. and Winter, S. (1977): "In search of a useful theory of innovation", *Research Policy*, 6: 36-76.

Nelson, R. and Winter, S. (1982): *An Evolutionary Theory of Economic Change*, The Belknap Press of Harvard University Press, Cambridge, USA.

Neven, D. and C. Gouyette (1995): "Regional Convergence in the European Community", *Journal of Common Market Studies*, 33: 47–65.

Padoan, P.C. (1998): "Trade, knowledge accumulation and diffusion: a sectoral perspective", *Structural Change and Economic Dynamics*, 9: 349-372.

Park, S. and 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.

Peneder, M. (2003): "Industrial structure and aggregate growth", *Structural Change and Economic Dynamics*, 14: 427-488.

Porter, M. (1990): *The Competitive Advantage of Nations*, Macmillan, London.

Posner, M. V. (1961): "International trade and technical change", *Oxford Economic Papers,* 13: 323-341.

Powell, W. and Grodal, S. (2005): "Networks of innovators", in J. Fagerberg, D. C. Mowery & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford.

Rivera-Batiz, L. and Romer, P. (1991): "International trade and endogenous technological change", *European Economic Review*, 35: 971-1004.

Romer, P. (1986): "Increasing returns and long-run growth", *Journal of Political Economy*, 94: 1002-1037.

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

Schettkat, R. and Yocarini, L. (2006): "The shift to service employment: a review of the literature", *Structural Change and Economic Dynamics*, 17 (2): 127-147.

Schumpeter, J. (1934): *The Theory of Economic Development,* Harvard University Press, Cambridge, USA.

Schumpeter, J: (1939): *Business Cycles,* Porcupine Press, Philadelphia.

Schumpeter, J. (1943): *Capitalism, Socialism and Democracy*, Harper, New York.

Soete, L. (1981): "A general test of technology gap trade theory", *Weltwirtschaftliches Archiv*, 117: 638-660.

Soete, L. (1987): "The impact of technological innovation on international trade patterns: the evidence reconsidered", *Research Policy*, 16: 101-130.

Todtling, F. and Trippl, M. (2005): "One size fits all? Towards a differentiated regional innovation policy approach", *Research Policy*, 34: 1203-1219.

Ten Raa, T. and Wolff, E.N. (2000): "Engines of growth in the US economy", *Structural Change and Economic Dynamics*, 11: 473-489.

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.

Van Ark, B., Monnikhof, E. and Mulder, N. (1999): "Productivity in services: an international comparative perspective", *The Canadian Journal of Economics*, 32 (2): 471-499.

Van Marrewijk, C., Stibora, J., de Vaal, A. and Viaene, J. M. (1997): "Producer services, comparative advantage, and international trade patterns", *Journal of International Economics*, 42: 195-220.

Verspagen, B. (1991): "A new empirical approach to catching up or falling behind", *Structural Change and Economic Dynamics*, 2: 359-380.

Verspagen, B. (1997a): "Measuring inter-sectoral technology spillovers: estimates from the European and US patent databases", *Economic Systems Research*, 9: 47-65.

Verspagen, B. (1997b): "Estimating international technology spillovers using technology flow matrices, *Weltwirtscaftliches Archiv*, 133: 226-248.

Verspagen, B. and Wakelin, K. (1997): "International competitiveness and its determinants", *International Review of Applied Economics*, 11 (2): 177-190.

Wieser, R. (2005): "Research and development productivity and spillovers: empirical evidence at the firm level", *Journal of Economic Surveys*, 19 (4): 587-621.

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

Winter, S. G. (1984): "Schumpeterian Competition in Alternative Technological Regimes", *Journal of Economic Behavior and Organization*, 5**:** 137-158.

Wolff, E. N. (1999): "The productivity paradox: evidence from indirect indicators of service sector productivity growth", *The Canadian Journal of Economics*, 32 (2): 281-308.

Figure 1: Innovation and the international competitiveness of manufacturing industries: an evolutionary interpretation

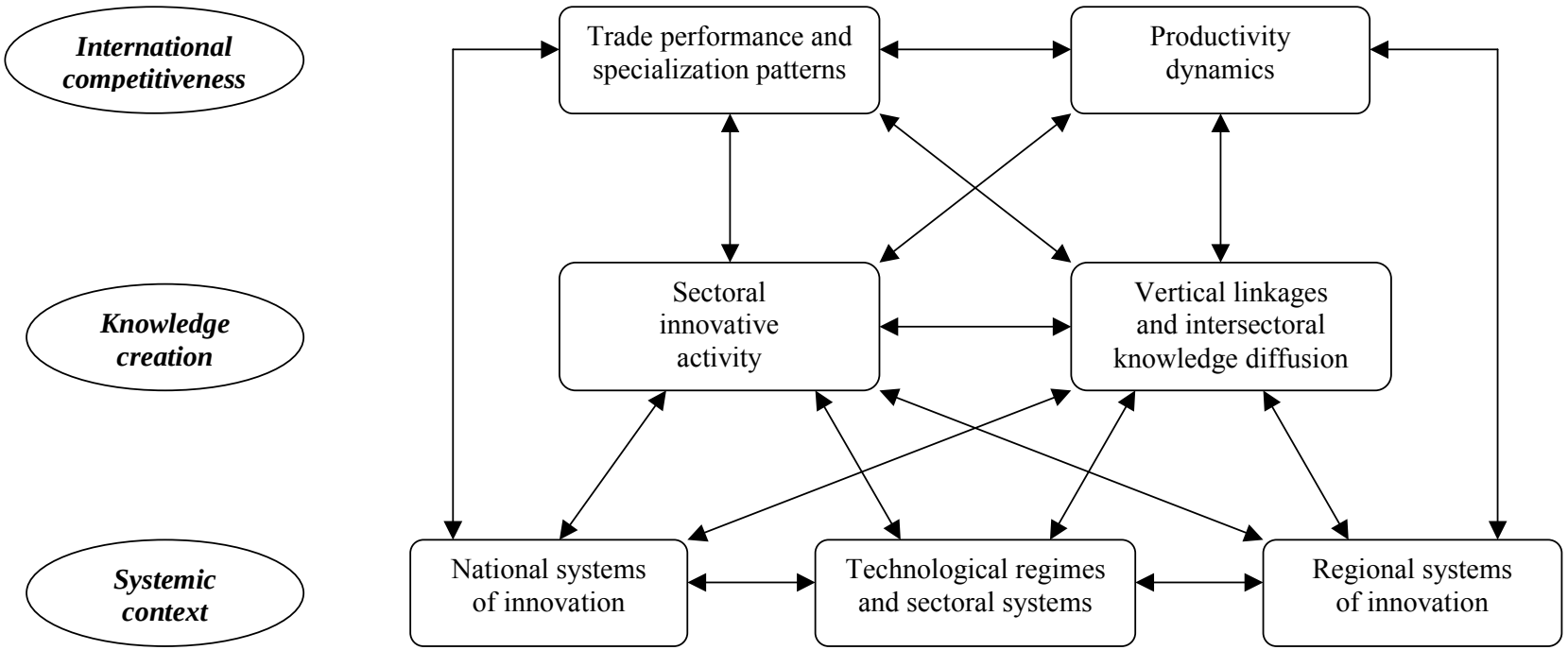

Figure 2: Sectoral patterns of innovation and intersectoral linkages among different groups of manufacturing and service industries: An integrated framework combining Pavitt's (1984) and Miozzo and Soete's (2001) taxonomies

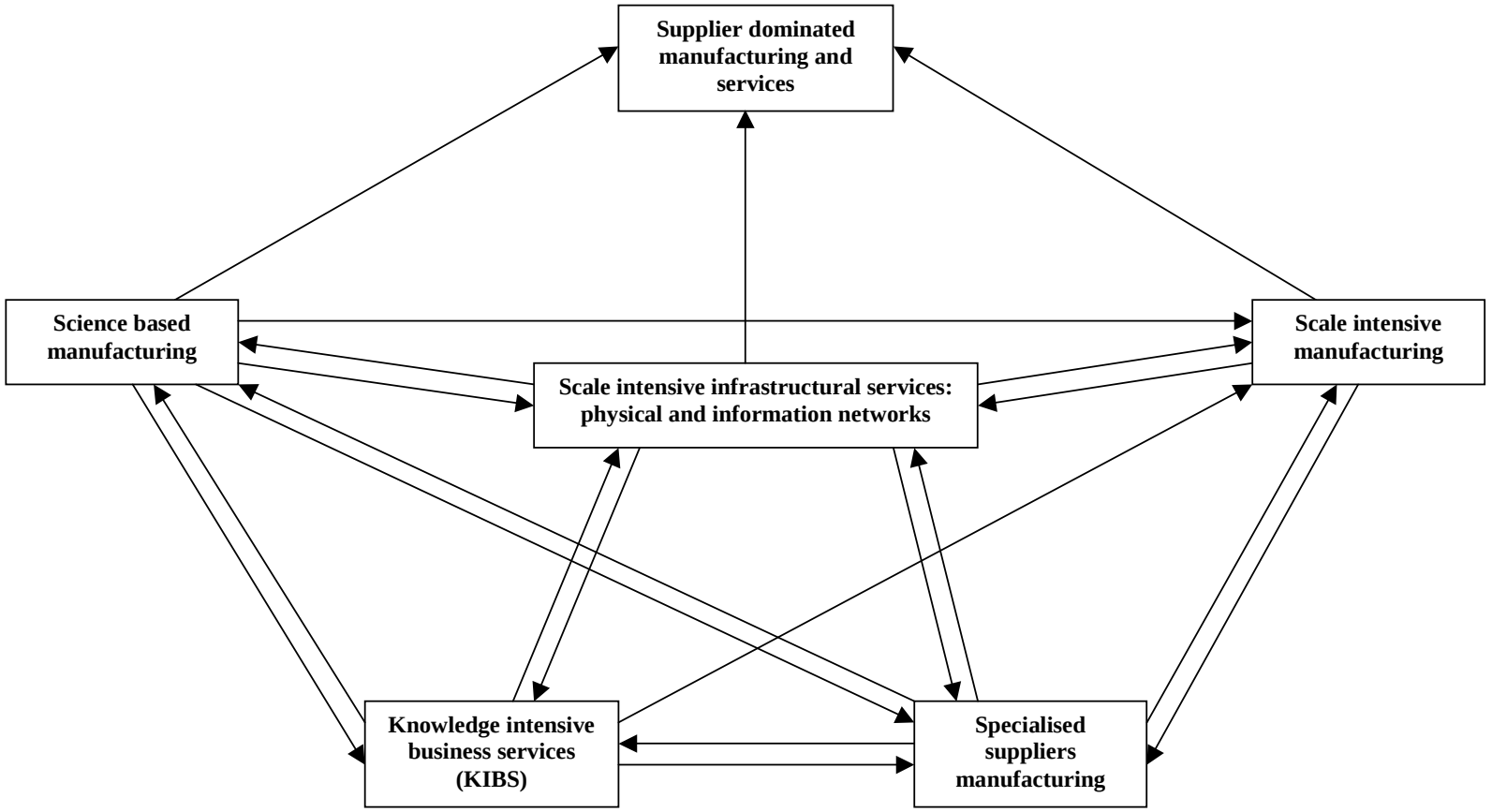

Figure 1, Legend:
Manufacturing and service industries in each category of the taxonomy

Supplier dominated:
(i) Manufacturing: textiles; wearing, leather and footwear; wood and related products; pulp and paper; printing and publishing; non-metallic mineral products; furniture; recycling
(ii) Services**:** restaurants and hotels; laundry; repair; barber and beauty

Scale intensive manufacturing:
Motor vehicles; other transport equipments; rubber and plastic products; basic metals; fabricated metal products; food and beverages

Scale intensive infrastructural services:
(i) Physical networks: transport, travel, wholesale trade, distribution
(ii) Information networks: finance, insurance, communications

Specialised suppliers manufacturing:
Machinery and equipments; medical and optical precision instruments

Science based manufacturing:
Electrical, radio and TV; office and computing; chemicals

Knowledge intensive business services (KIBS):
R&D; engineering; software; ICT services; consultancy

Table 1: Vertical linkages, knowledge spillovers and competitiveness factors for different groups of service industries

Industry group	Source of technology	Provision of technology	Typical core sectors	Major factor of competitiveness
Scale intensive infrastructural services	The acquisition of advanced capital equipments from manufacturing industries brings efficiency and quality improvements in infrastructure services	Improvements in the network infrastructure lead to cost reduction and greater productivity in the whole economy	Transport services; Telecommunications; Financial services	A dynamic process of interaction between network infrastructure services and all other manufacturing and service industries
Knowledge intensive business services (KIBS)	Innovations in technologically advanced manufacturing industries; Increases of efficiency and quality in scale intensive infrastructural services	These sectors provide a broad range of technical solutions to advanced manufacturing industries, as well as to ICT-based infrastructure services	Software; R&D; engineering; Consultancy	The existence of strong linkages between technologically advanced manufacturing and service industries
Supplier dominated services	Acquisition of advanced capital equipments from science based and scale intensive manufacturing; Increases of efficiency and quality in scale intensive infrastructural services	They do not provide technology to other sectors, but may enhance the quality of final products/services	Restaurants and hotels; Laundry	A rapid process of technology diffusion from manufacturing and other service industries