# Do KIBS make manufacturing more innovative? An empirical investigation of four European countries[1]

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## Abstract

This paper estimates the innovation impact of the vertical integration of knowledge-intensive business services (KIBS) into manufacturing. The concept of an economy's vertically-integrated sectors is used in order to measure the innovative knowledge transferred directly and indirectly from KIBS to manufacturing in a production-based manner, and to estimate its impact on various proxies for manufacturing inventions. By merging OECD data on sectoral R&D and input-output tables with sectoral patent applications and patent quality indicators from the Pastat and OECD Patent Quality Indicators databases, respectively, a panel of 18 manufacturing sectors is built for the four largest European countries – France, Germany, Italy and the UK – from the mid-1990s to the mid-2000s. Those industries which integrate R&D embodied in KIBS production flows more intensively and extensively are industries with greater inventive efforts and higher quality patents. In terms of policy, strengthening the linkage between KIBS and manufacturing appears to be as crucial as supporting KIBS activities and service innovations.

**Keywords:** KIBS; vertically integrated sectors; production-based R&D flows.

**JEL codes**: L60, L84, O33, O32, P00.

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# 1. Introduction

Two decades after the seminal contribution by Miles et al. (1995), Knowledge Intensive Business Services (KIBS) are still attracting a great deal of attention. Important new insights have been obtained into their role at different levels of analysis: micro and sectoral (e.g. Tether, 2005; Corrocher *et al*., 2009; Consoli and Elche-Hortelano, 2010, Doloreux and Shearmur, 2010), urban and regional (e.g. Tödtling *et al*., 2006; Savi and Lawton-Smith, 2013; Antonietti *et al.* 2013; Shearmur and Doloreux, 2014), and macroeconomic (e.g. Mas-Verdú *et al*., 2011; Hauknes and Knell, 2009, Di Cagno and Meliciani, 2005; Desmarchelier et al., 2013).

A feature shared by these streams of research is their attention to the complex kind of knowledge exchange that KIBS perform with their clients, especially with firms operating in manufacturing industries. The relative knowledge interaction occurs through both disembodied and embodied flows of codified and tacit knowledge, respectively, which overlap to differing extents with the production relationships between KIBS and manufacturing (Landry et al., 2012)

The present paper focuses on and extends the investigation of 'production-embodied' flows of knowledge between KIBS and manufacturing based on the use of input-output analysis (e.g. Baker, 2007; Tomlinson, 2000a, 2000b; Windrum and Tomlinson, 1999). In particular, it brings two pieces of value added to such investigation. Firstly, rather than a simple input-output approach, we adopt a more sophisticated one based on the notion of vertically-integrated sector (or subsystem). This perspective has recently proved quite useful in investigating the relationships between manufacturing and services, especially in the aftermath of the explosion of outsourcing practices from the former to the latter (Ciriaci and Palma, 2012; Montresor and Vittucci Marzetti, 2011). Secondly, rather than a standard production function approach to the impact of KIBS on the productivity of manufacturing (e.g. Antonelli, 2000; Katsoulacos and Tsounis, 2000), we use a 'knowledge production function' with a long tradition in innovation studies at the firm level (Griliches, 1979; Crepon et al., 1998). Using this original framework of analysis, we investigate the extent to which KIBS' innovative knowledge enters into vertically-integrated manufacturing sectors through production-based flows, and in so doing increases their innovation capacity, as it can be proxied by the quantity and quality of their inventive (i.e. patent) efforts.

An empirical investigation is carried out with respect to the four largest EU economies, whose KIBS have been shown to be pivotal and have different intersectoral patterns of vertical integration (Ciriaci and Palma, 2012; Windrum and Tomlinson, 1999), that is: France, Germany, Italy and the UK, for the decade which spans from 1995 to 2005. To this end, the OECD Input-Output and the ANBERD databases are combined and merged with sectoral patent applications from the Pastat dataset[2] and patent quality data from the OECD Patent Quality indicators database. In a panel framework, country, sector and time-specific effects are thus controlled for.

The paper is organised as follows. Section 2 illustrates the theoretical background. Section 3 describes the methodological approach, Section 4 sets out the data used and the empirical application. Section 5 comments on the results and Section 6 concludes.

# 2. Theoretical background

In nearly twenty years of intense research, the analysis of KIBS has been enriched with several definitions and approaches (for a review, see Muller and Doloreux, 2009). Some of them focus on the actors (companies or organisations) that deliver the services at stake (e.g. Miles et al., 1995; Bettencourt *et al.*, 2002) and treat a 'KIBS' as the supply of a qualified,

[2] On the combined use of R&D and patent data at the inter-industry level, see the recent work by Panizza and Squicciarini (2014).

knowledge-intensive service (e.g. Amara et al., 2009; Rodriguez and Ballesta, 2010). Other definitions instead address the nature of these service activities (e.g. Den Hertog, 2000; Gallouj, 2002b) and treat 'a KIBS' as a particular kind of economic sector with an important role in promoting innovation and growth at aggregate level (e.g. Baumol, 2002; Oulton, 2001).

Although it also draws on the former approach, this paper is grounded in the second research stream. Henceforth, KIBS will be understood as "a category of service activities, which is often highly innovative in its own right, as well as facilitating innovation in other economic sectors, including both industrial and manufacturing sectors" (den Hertog, 2000, pp. 504–505).[3]

This definition directly points to a function of KIBS which is the focus of this paper (on the other KIBS function, see Den Hertog and Bilderbeek, 2008). KIBS perform key activities in innovation systems (e.g. Muller and Zenker, 2001; Tether, 2005). Not only are they innovative *per se*, because they introduce new marketable services and technological applications; they also act as knowledge carriers with respect to other sectors, especially manufacturing ones, and in this way work as 'innovation propellers' at the system level (Castellacci, 2008).

Knowledge transfer is the core activity that KIBS undertake (especially) with respect to manufacturing sectors (Leiponen, 2006). This is a manifold activity which involves KIBS in the generation and diffusion of different types of knowledge, both codified and tacit, in developing problem-specific and innovative solutions for their manufacturing clients (Landry et al., 2012). In this process, two aspects require especial attention, possibly more than in the extant literature: i) the production-based transmission of KIBS knowledge; ii) the techno-

[3] KIBS thus include business-devoted activities such as consultancy, research and engineering, which are characterised by intensive professional knowledge (i.e. a technical area or discipline) and are dedicated to other productive sectors (providing them with customized problem solving), rather than to final consumption (Miles et al., 1995). A more precise account of the identification of these sectors will be provided in the next section. On the classification of KIBS see, among others, Miles et al. (1995), Muller and Zenker (2001), Martinez-Fernandez and Miles (2006).

economic impact of this knowledge transmission.

## 2.1. The ‘production-based’ transmission of KIBS knowledge

The production and use of KIBS knowledge occur through frequent and specialised interactions between KIBS and their clients (Koschatzky and Stahlecker, 2006), not only in the form of explicit (e.g. contractual) knowledge transfers and cooperation agreements, but also *via* production relationships like exchanges of services, intermediate commodities and capital goods. This latter kind of production flow between KIBS and manufacturing is beneficial for the latter in two main respects. Firstly, it conveys to manufacturing sectors a tacit kind of KIBS knowledge which cannot reach them in ways other than embodiment in the items exchanged (Hauknes and Knell, 2009; Papaconstantinou *et al.*, 1998). One can think of the purchase of a newly (KIBS) developed software product that encapsulates some ‘unwritten’ functions which the (manufacturing) client discovers by exploring its use.

Secondly, the production interaction between KIBS and manufacturing can also affect the diffusion of codified KIBS knowledge, even in the absence of an actual embodiment. As regional and urban studies have widely shown, by becoming involved in (repeated) market relationships, partners can build up and increase their ‘cognitive proximity’ (Boschma, 2005). In brief, they can augment the degree of overlap between their learning routines and mental frameworks, and become better able to understand and absorb the explicit knowledge that they exchange (Montresor and Vittucci Marzetti, 2008). One can think of a (disembodied) consultancy that a KIBS delivers to a (manufacturing) client in order to improve its strategic positioning, benefiting from the experience accumulated by interacting with it in the exchange of more ordinary services, like accounting, logistics support and HRM.

Overall, an important ‘production-based’ (and not only ‘embodied’) transmission of KIBS knowledge to manufacturing can be identified, and for the mapping of which input-output tables represent an important analytical tool. Indeed, the input-output approach to KIBS is one of the first to have been adopted (Tomlinson, 2000a, 2000b; Windrum and Tomlinson, 1999) and its use has been recently extended (e.g. Mas-Verdú et al., 2011; Hauknes and Knell, 2009; Rodriguez and Camacho, 2008; Baker, 2007). However, in this research stream limited attention has been paid to the 'complexity' of the production relationship between KIBS and manufacturing sectors: neglected in particular has been the fact that KIBS knowledge can reach a manufacturing sector on a production basis, both directly and indirectly. The relative knowledge flow occurs also through the contribution of the former to an intermediate input of the product of the latter, or to a further intermediate input of this intermediate input, and so on, in the classic Leontievian sequence of production rounds (Miller and Blair, 2009). The ICT service that has improved the component of an electronic device, which is used in turn by an R&D agency-consulting company for a PC producer, is just one example of this indirect, input-mediated relationship.

This is a crucial aspect which requires a shift from a simple input-output perspective to a more structural kind of approach which considers the vertical integration of KIBS into manufacturing in order to serve its final demand. In previous studies, this approach has been used to show that the latest stages of structural change (and the crucial role of outsourcing in it) have made this vertical integration of services into manufacturing quite substantial by blurring the sectoral boundaries between KIBS and manufacturing (Ciriaci and Palma, 2012) and by affecting the actual level of tertiarisation of their hosting economies (Montresor and Vittucci Marzetti, 2011).

Consistently with this last perspective, our argument is that the vertical integration of KIBS into manufacturing, which comes about through the direct and indirect contribution of the former to the final demand of the latter, represents a significant map of their production-based knowledge flows.

## 2.2. The ‘techno-economic’ impact of production-based KIBS knowledge

The majority of the studies that, in an input-output framework, have considered the economic impact of ‘production-embodied’ KIBS knowledge flows – although they are relatively few in number compared with those focused on their mapping alone – have focused on the productivity gains that client manufacturing sectors can obtain from them (Tomlinson, 2000a, 2000b; Barker, 2007).[4] This is the natural consequence of an exclusive focus on the embodied manner in which KIBS knowledge is supposed to reach manufacturing, and of the way in which the standard ‘embodiment hypothesis’ (Jorgenson, 1966) assumes that the knowledge obtained by the producer – typically through R&D – spills over to the user. According to this view, the knowledge of the former only creates a rent for the latter, to the extent that the price of the sold commodities/services incorporating such knowledge does not entirely reflect its actual higher quality/value. The translation of these ‘rent spillovers’ (Griliches, 1982) into productivity gains would thus be the most direct and uniquely relevant effect of production-embodied (KIBS) knowledge.

However, if we follow the wider production-based transmission illustrated in the previous section, the impact of KIBS knowledge acquired in this way is not only economic but also, and above all, technological – in brief, ‘techno-economic’. As said, the production exchanges that input-output tables map are also, and above all, the source of important learning-by-interacting (*à la* Lundvall, 1992) between the producer (KIBS) and the user (manufacturing) sectors. Through this kind of learning, the user can make innovative use of both the R&D embodied in the corresponding transaction and of the R&D which is transferred irrespectively of it, that is, in a disembodied way. Anecdotally, the case could be that of a client which, by

[4] Although these production relationships can be anchored to both domestic and international trade flows, the problem of accounting for the tradeability of services (and KIBS) has determined a certain focus on the former. Among the recent studies that also retain the latter see, for example, Nisioka and Ripoll (2012), and those reviewed in this article.

acquiring an improved software package, benefits from the R&D that a KIBS has spent on this improvement by introducing an innovative product/process based on its functioning. Furthermore, the market transaction of the software could increase the cognitive proximity between the KIBS and the client and, in so doing, make the latter better able to assimilate other disembodied knowledge inputs from the former. Finally, although not necessarily, in order to increase its capacity to 'absorb' the transferred embodied knowledge, the client might be willing to increase its own investments in R&D (Cohen and Levinthal, 1989) and, in so doing, augment its invention capacity.

Summing up, a broader approach to the knowledge transmitted by KIBS to manufacturing in a production-based manner makes the former an important input to the inventive capacity of the latter, as may be revealed by its patenting propensity and/or by the quality of its patents, by which is meant "[their] technological and economic value, and the possible impact that [they] might have on subsequent technological developments" (Squicciarini et al., 2013). In other words, we can expect a production-based exchange of KIBS-knowledge to become functional to the problem-solving process that the manufacturing client faces in its technological innovations. It may thus increase its capacity to make innovative use of the customised solution that it purchases from the KIBS provider. In brief, by acquiring from KIBS business-devoted services necessary for the realisation of their final products, manufacturing firms also learn by interacting, and they acquire technical knowledge and customized problem-solving experience which may have a positive impact on their innovation capacity.

On the basis of the foregoing argument, our central research hypothesis is that the more KIBS are vertically integrated into a certain manufacturing industry (sub-system), the more the relative firms will have opportunities to introduce innovative products for the final consumers of their sector.

As we will see (in Section 3), a test of this research hypothesis consistent with our theoretical argument (exposed in Section 2.1) entails adoption of a particular intersectoral perspective which represents the first value added of the paper. The test of our hypothesis will also entail recourse to variables other than standard productivity ones, and which instead account for the inventive capacity of the manufacturing sectors. This is an additional value added of the paper, which addresses a relatively neglected KIBS impact.[5]

# 3. Methodology

In order to address our research question, we adopt an extended input-output based methodology focused on the notion of 'subsystem' in production, and on the compact representation of it represented by a 'vertically integrated sector'.[6] Put briefly, this can be defined as the set of all the economic activities directly and indirectly required to satisfy the final demand of each economic sector. Unlike the standard generic sector, *j*, which accounts for the economic activities that its firms carry out to contribute directly to their final demand, its vertically integrated equivalent retains those activities of *j*, which are necessary to obtain their production inputs, and the production inputs of these inputs, and so on and so forth in subsequent production rounds: in brief, those activities of *j* that contribute to its final demand indirectly through other intermediate sectors.

Following the seminal work by Momigliano and Siniscalco (1982), the generic vertically integrated sector *j* can be represented by column *j* of the following (*n* x *n*) matrix (where *n* equals an economy's number of economic sectors):

[5] A possible explanation of this neglect may be the need, in order to measure the innovation impact of production-based KIBS knowledge, to plug into the analysis a variable for innovation output at the sectoral level (e.g. patents), which can only be obtained from less directly comparable datasets (less directly comparable than those for relating R&D efforts to input-output flows). Furthermore, a diachronic, rather than cross-sectional, dataset is required to investigate the innovative impact of KIBS on manufacturing as a proper causal relationship.

[6] On the genesis of these ideas, which date back to Sraffa (1960) and Pasinetti (1973), and on their application to the analysis of structural change and outsourcing in particular, see Montresor and Vittucci (2007).

$$\mathbf{B} = \hat{\mathbf{q}}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}} \qquad (1)$$

In Eq.(1), $\hat{\mathbf{q}}$ is the diagonalised vector of sectoral gross production, **A** is the inter-sectoral matrix of input-output coefficients, and $\hat{\mathbf{y}}$ is the diagonalised vector of total final demand by sector. Given the conventional meaning of the Leontief inverse, $(\mathbf{I} - \mathbf{A})^{-1}$ (for which see Miller and Blair, 2009), each generic element, $b_{ij}$, indicates the total contribution – that is, direct and indirect – of sector *i* to the final demand of sector *j*.

The application of this perspective to the analysis of intersectoral embodied innovation/knowledge flows is then straightforward. Taking the expenditure on Research and Development (R&D) in sector *j* ($r_j$) as an input kind of proxy for the new knowledge generated by its firms (a standard assumption in innovation studies), the following ($n$ x $n$) focal matrix, **R**, can be obtained:

$$\mathbf{R} = \hat{\mathbf{r}}\mathbf{B} \qquad (2)$$

where $\hat{\mathbf{r}}$ is the diagonal vector of sectoral R&D expenditure.

Under a number of hypotheses (for whose implications, see Leoncini and Montresor, 2003), the generic element of **R**, $r_{ij}$, measures the amount of sector *i*'s R&D knowledge that becomes embodied in the intermediate commodities required to *i* by sector *j*, both directly and indirectly (that is, in subsequent production rounds), in order to satisfy one unit of its final demand.[7] In other words, the correspondent knowledge flow, from *i* to *j*, takes into account that the former sector can contribute to the latter also by being the intermediate input of a

[7] Among these hypotheses, the temporal reference of the variables that enter into the definition of Eq.(2) is an important one. As our time-neutral notation suggests, we assume an instantaneous kind of diffusion process in which the R&D expenditure of sector *i* at time *t* becomes totally embodied in (that is, it is proportional to) its input requirements by sector *j* of the same year. While this could actually happen at most partially, a temporisation of these effects would remain subject to a great amount of ad-hocness (on this point, see Leoncini and Montresor, 2003).

third generic sector, $z$, which is in turn an input for sector $j$. Furthermore, the knowledge flow that reaches sector $j$ from sector $i$, is made possible also by the innovative knowledge that the latter has obtained from the former, again directly and indirectly.

In synthesis, the matrix **R** appears suitable for dealing with the complex relationships that link sectors to each other. In our case, **R** allows us to Consider that KIBS typically provide knowledge inputs that industries absorb, combine and transform into innovative products and processes through multiple intersectoral rounds. Furthermore, it accounts for the fact that knowledge of client manufacturing sectors is an essential knowledge input for KIBS' innovation as well. The relevant knowledge interaction is in fact a 'chain', rather than linear (Kline and Rosenberg, 1986) one, in which the occurrence of feedbacks is a crucial aspect of innovation diffusion.

The use of matrix **R** for the analysis of production-based flows of KIBS knowledge acquired by manufacturing is quite straightforward. In aggregate terms, for the generic industry (or, better, the vertically-integrated sector), $j$, this is given by:

$$KIBS_j = \sum_{i=k}^{s} r_{ij} \qquad (3)$$

where the row-sectors of **R** which go from $k$ to $s$ are the KIBS sectors of the $n$ industries of the relevant economic system. In other words, $KIBS_j$ is the sum by row of the $(s - k)$ cells of column $j$. In disaggregated terms, each of the *addenda* in Eq.(3) from $r_{kj}$ to $r_{sj}$ is the production-based flow of knowledge that goes from each and every of the KIBS sectors to sector $j$.[8]

[8] An important issue in building these indicators is making them free from scale effects across sectors. Different relativisation procedures have been put forward in this regard in the literature, but they all suffer from some kind of bias (for a discussion, see Montresor and Vittucci Marzetti, 2009). As we will see in the next section, the econometric strategy that we follow enables us to control for size effects in sectoral R&D without resorting to these procedures.

# 4. Application

## 4.1. Empirical context

The issue addressed by this paper is investigated with respect to the four largest economies of the European Union (EU), that is: France, Germany, Italy and the UK. The choice of these countries is primarily motivated by the increasing importance of the KIBS vertical integration into manufacturing that previous studies have found in these four countries over the past decade. As shown by Ciriaci and Palma (2012), when the vertical integration of Eq.(1) is measured in terms of employment (that is, by substituting **r** with a sectoral vector of labour, **l**, in Eq.(2)), an increasing degree of KIBS vertical integration into manufacturing emerges in France and Germany over the years 1995-2005: a trend which is more evident in the higher technological intensive manufacturing subsystems, albeit with differences between the two countries.[9] In the UK, instead, the vertical integration of KIBS into manufacturing shows an inverted U-shape over the same period, with a turning point of its initial increasing trend in the year 2000, when the 'service-based' economy took off.[10] Finally, although an increasing trend is confirmed also in the case of Italy, here KIBS appear to be relatively less integrated than elsewhere, indicating the influence of the specialisation patterns of one economy (notably low-tech in Italy) on the vertically-integrated role of KIBS.[11]

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[9] In France, for example, in 2005 KIBS accounted for 12.5% and 15% of the total employment needed to satisfy the final demand for low and medium/low-tech subsystems' products, respectively, while the corresponding shares in 1995 were 10.7% and 10.5%. The 2005 shares were significantly higher in the case of medium/high-tech (20.3%) and high-tech manufacturing subsystems (19.9%), whose values in 1995 were 17.4% and 18.7%, respectively. In Germany, the increase in this degree of vertical integration over the same period was even more accelerated – possibly in response to the policy support for services that began in the late 1980s (Windrum and Tomlinson, 1999). However, the same trend was more concentrated in the medium and high-tech manufacturing subsystems than in France.

[10] The results for the UK are in line with the findings of other empirical studies adopting the same subsystem approach as used in this study (Montresor and Vittucci Marzetti, 2011 and 2007).

[11] The previous picture is generally consistent with that the one found by Barker (2007) when considering the 'simple' share of business service inputs of total intermediate inputs in manufacturing. France (13.9% in 1995), Germany (10.8% in 1995), and the UK (10.7% in 1998) stand apart from Italy (4.1% in 1992) and from other countries with a lower weight of KIBS in manufacturing (e.g. Denmark, 5% in 1997; Finland, 6.6% in 1995; Greece, 5.4% in 1995; Spain, 4.9% in 1995).

Our empirical analysis of these four countries [12] refers to the same period as considered by Ciriaci and Palma (2012): that is, 1995-2005. More precisely, because of the notably discontinuous availability of input-output data over time, we also refer – as in Ciriaci and Palma (2012) – to two sub-periods of this temporal window: from 1995 to 2000; and from 2000 to 2005.

## 4.2. Econometric strategy and variables

In order to estimate the innovation impact of the vertical integration of KIBS into manufacturing, we use a standard 'knowledge (log-) production-function' (Griliches, 1979) at the sub-system level. In this model, the innovative knowledge ($Inno_j$) obtained by each vertically-integrated manufacturing sector, $j$, depends on the flow of its KIBS production-based knowledge ($KIBS_j$) – as from Eq.(3) – and on a set of theoretically consistent variables – that is, its available knowledge ($RD$), physical ($K$), and human ($L$) capital :

$$\ln(Inno_{j,T}) = \alpha_0 + \alpha_1 \ln(KIBS_{j,t}) + \alpha_2 \ln(RD_{j,t}) + \alpha_4 \ln(K_{j,t}) + \alpha_5 \ln(L_{j,t}) + \omega_j + \varepsilon_j \tag{4}$$

where $\omega_j$ is the country/sector fixed effect, $\varepsilon_j$ is an error term with standard properties, and the temporal notation ($T$, $t$) denotes a lag between dependent and independent variables.

As far as the *dependent variable* is concerned, while we are aware of the still lively debate on the *pros* and *cons* of patent data as reliable innovation indicators[13] (Watanabe et al., 2001; Guellec and van Pottelsberghe de la Potterie, 2000), we try to make empirically accurate and theoretically consistent use of them.

[12] Although this is a limited set of countries, their selection has been also prompted by the attempt to maintain a relatively high number of sectors when the different datasets needed for the application are merged. For the majority of the smaller European countries, in fact, this combination entails a substantial decay of sectors for which data are not available. Also the choice of the temporal span of the application has been promoted by the attempt to build a panel with a satisfactory level of sectoral disaggregation.

[13] This debate dates back at least to Griliches' (1990, p. 1669) famous concern about the use of patents.

Therefore, $Inno_T$ is first proxied with the (log of the) number of patent applications (*PATApp*) filed at the European Patent Office (EPO) and available in the Patent Statistical Database (PATSTAT) of the same office. Adhering to conventional choices in the use of patents as an innovation proxy at the micro-level (e.g. Acs and Audretsch, 1989), we have referred to the priority-date patents applied for by inventors in the four relevant nationalities in 43 manufacturing sectors following NACE Rev. 1 classification (Table A1).[14] In fact, the International Patent Classification (IPC) codes contained in the patent documents can been classified into sectors following standard taxonomies in the literature (e.g. Schmoch, 2008). On the one hand, this proxy should be logically and temporally closer than others (e.g. patent citations) to the manufacturing use of the R&D-knowledge acquired from KIBS. Furthermore, we deem patent applications to be less volatile and less affected than other proxies (e.g. local and international co-operation in the invention process) by antecedents other than our focal one (Jaffe and Trajtenberg, 2002). On the other hand, the choice of patent applications is also consistent with the empirical evidence on their role in signalling the different features/performances of different technological regimes and sectoral systems of innovation (Breschi et al., 2000; Malerba and Orsenigo, 1997): that is, of our level of analysis.

Being concerned with the robustness of our results to different patent-based proxies, we test whether the production-based flows of KIBS' R&D have an impact, not only on the 'quantity' of the inventive efforts of manufacturing sectors, but also on the 'quality' of those efforts (Guellec and van Pottelsberghe de la Potterie, 2007), by which is meant their capacity to reward and incentivise innovations with further technological and economic impact. For the same set of countries and sectors, we have thus considered the (log of) the composite indicator of patent quality (*PATQual*) recently put forward by the OECD (Squicciarini et al., 2013, pp.59-60), as an un-weighted synthesis (based on Lanjouw and Shankerman, 2004) of

[14] Standard fractional-counting procedures have been used in the cases of patents with multiple co-inventors of different nationalities.

the following patent quality dimensions: i) forward citations; ii) patent family size; iii) number of claims; iv) generality; v) backward citations; and vi) grant lag (for each and every of these dimensions and for the respective indicators, see Squicciarini et al., 2013). More precisely, following the same source, we have made use of the two versions of the composite quality indicator, which include the first four (*PATQual4*) and the all six (*PATQual6*) of the above dimensions, respectively.

An important aspect of the patent measurement of $Inno_T$ is its temporal specification. On the one hand, counted patent applications are subject to quite erratic year-by-year variation which needs to be smoothed for the purpose of their econometric analysis (Wang et al., 1998). On the other hand, in spite of the arguments concerning their inventive-input nature, a substantial impact of R&D (and R&D spillovers) on patent applications can be expected only with a temporal delay, during which the acquired knowledge is processed, absorbed and codified into a patent document. Apparently, this is even more so for the impact of our focal regressor on patent quality, given the evidence found for the lagged impact of patent applications on changes in economic performance (Ernst, 2001). In order to account for these issues, with respect to both the patent proxies of *Inno*, we have set their temporal reference ($T$ in Eq.(4)) to the average of the three years after that of the retained KIBS flows and of the measurement of the other regressors ($t$ in Eq.(4)). This means that we have used the average number of *PATApp* and *PATQual*(*4* and *6*) for: (i) 1995-1997, with respect to KIBS vertical integration in 1995; (ii) 2000-2002, with respect to that in 2000; and (iii) 2005-2007, with respect to 2005.[15]

The correspondence among Nace (Rev1) patent data, our key independent variable ($KIBS_j$) and the other variables in Eq.(4) – whose sectoral level of disaggregation follows the ISIC Rev. 1 classification (see Table A2) – has been obtained following the NACE-ISIC

[15] A longer, forward temporal span would have suffered from the substantial truncation which is inevitably registered in the number of patent applications from the year 2007 onwards.

concordance table developed by the United Nations (UN). The sectoral disaggregation adopted in the econometric analysis, which includes 18 manufacturing sectors and 7 service sectors, is reported in Table A3.

As far as the *independent variables* are concerned, the focal regressor, $KIBS_{j,t}$, has been obtained by following Eq.(2) and combining two sets of data: (i) the OECD STAN Input-Output dataset, from which we have drawn the matrices of domestic intermediate production flows (PPP dollars at current prices) for the 37 sectors of the ISIC Rev. 1 classification, for the three years covered by our analysis, 1995, 2000 and 2005; and (ii) the OECD Analytical BERD (ANBERD) dataset, from which we have collected data on R&D expenditures (PPP dollars at current prices) for the same years and 37 sectors of the ISIC Rev. 1 classification.[16] $KIBS_{j,t}$ has been computed first in aggregate terms.[17] For each sector (column) $j$ of the 18 manufacturing ones that we have been able to include, $KIBS_{j,t}$ is thus the sum by row of the following sectors of **R**: Computer and related activities (*KIBS-COMP*, corresponding to sector C72 of the ISIC Rev. 1 classification), Research and Development services (*KIBS-RD*, sector C73), and Other business activities (*KIBS-BUS*, sector C74).[18] Secondly, in order to account for the diversity of KIBS sectors, we have also separately considered their corresponding rows in **R** for the aforementioned 18 manufacturing sectors – that is, $KIBS\text{-}COMP_{j,t}$, $KIBS\text{-}RD_{j,t}$, and $KIBS\text{-}BUS_{j,t}$ – and inserted them – alternatively to $KIBS_{j,t}$ – in Eq.(4).

[16] On the reasons for using domestic, rather than total, intermediate production flows, mainly due to problems in constructing and interpreting the corresponding vertically-integrated sectors, see Momigliano and Siniscalco (1982) and Montresor and Vittucci Marzetti (2007). As for the use of current, rather than constant prices, the invariance of **B** with respect to relative prices should be kept in mind. Finally, in those few cases in which R&D data were available only at the next more aggregated level than the disaggregated one for the IO data, they have been artificially disaggregated in proportion to the corresponding value added. R&D sectoral data at current prices were the only ones available for the time period under study. However we believe that this does not represent a drawback for the analysis, because we controlled price variations by taking advantage of the actual sectoral relevance of innovative activities through time in the estimation.

[17] As said, given the bias introduced by any relativisation procedure for **R**, the *KIBS* variables are constructed with respect to the absolute values of the same matrix, leaving control for size effects to the econometric model.

[18] Although sometimes also classified as KIBS, Post and Telecommunications (C64), and Finance and Insurance (C65T67) have not be considered in our analysis because of their lower impact on the kind of technological innovations that we are considering, and because of gaps in the available data.

Turning to the other regressors of Eq.(4), the own knowledge capital of sector *j* has been proxied by referring to two kinds of R&D expenditure at time *t*. Firstly, as an indicator of the innovation opportunities from which sector *j* can benefit in a disembodied way, we have built the R&D intensity of sector *j* at time *t*, $RD\text{-}INT_{j,t}$, as (the log of) the ratio of total R&D expenditure over total employment (source: OECD-STAN). Secondly, we have referred to the cells of the main diagonal of matrix **R**, $RD\text{-}INTRA_{j,t}$, as an indicator of the amount of R&D available in sector *j* at time *t* in an embodied way, as the result of the production flows occurring among firms belonging to the same sector.

Finally, the physical and human capital inputs of the production function (Eq.(4)) have been proxied with, respectively, the fixed-capital intensity of sector *j* at time *t* ($K\text{-}INT_{j,t}$) obtained by relating its fixed investments to its total employment (source: OECD-STAN, PPP dollars at current prices), and its total employment at time *t* ($L_{j,t}$) (source: OECD STAN).

The different data sources used to build our variables are summarised in Table A4.

# 5. Results

## 5.1. Some descriptive statistics

Table 1 reports the main descriptive statistics of the dependent and independent variables described in the previous section, for the overall sample and by country. As a preliminary insight concerning our research hypothesis, Figure 1 displays the relationship between our main dependent variable (*PATApp*) and our key explanatory variable (KIBS) by showing both the data scatterplot and the ordinary least-squares fitted line. As shown by the figure, there is evidence of a positive relationship between the two.

Insert Table 1 around here

Insert Figure 1 around here

As shown in Table 2, the pair-wise correlations among the adopted regressors are in general low. In particular, the KIBS variables are in general not significantly correlated with the R&D-based ones, supporting our theoretical conjecture that the innovation impact of the former is not (necessarily) due to an induced increase in the latter. A notable exception is represented by the correlation between *RD-INT* and *RD-INTRA*, which appears nearly collinear between them. Given that the largest sector contributions to each sub-system are normally those of the corresponding sector – that is, sector *j* vs. sub-system *j* – this is not unexpected and suggests that one of the two variables should be dropped from the estimates. As our focus on KIBS relies on the production-based transmission of their knowledge, for the sake of consistency we have opted to keep *RD-INTRA*. Finally, note that, beyond pair-wise correlations, the variance inflation factors (VIF)[19] are low, and this signals the lack of multicollinearity.

Insert Table 2 around here

Before presenting and commenting on the results of the econometric analysis, it is interesting to note that the key explanatory variable of our study – that is, KIBS expenditure in R&D acquired by manufacturing sectors through vertical integration in production – evolved differently over the period investigated in the four countries of our application (Figure 2).

Insert Figure 2 around here

[19] Available from the authors upon request.

On the one hand, although with some exceptions, in Italy and Germany nearly all the 18 manufacturing sectors considered increased the percentage points of their total embodied R&D acquired from KIBS between 1995 and 2005. More specifically, in Italy this increase appears relatively more homogenous across the three kinds of KIBS considered than it is in Germany. In Italy, the vertical integration of KIBS innovative knowledge into manufacturing has mainly concerned that produced by computer and related activities, especially in the case of technologically close sectors (e.g. sector C30, office, accounting and computing machinery). On the other hand, France and the UK show a completely different pattern, with a decreasing reliance of manufacturing on KIBS-embodied R&D over the decade. Whilst in France this is limited to the percentage weight of other business activities – with that of R&D services remaining basically unaltered and that of computer and related activities generally increasing over time – in the UK it is indeed a general (with some few exceptions for computer and related activities) pattern. Given the increasing weight of KIBS in these economic systems over time, this last result might come as a surprise. However, in interpreting it, one should consider that the kind of knowledge diffusion that we are considering is that of the production-based approach (see Section 2.1), which attributes a pivotal role to the underlying production transactions. In this last respect, the 'generic' (e.g. in terms of employment) vertical integration of KIBS in manufacturing that previous studies have detected for the countries concerned over the focal period (see Section 4.1) is an important piece of information, and it is consistent with our results (Ciriaci and Palma, 2012). For example, in the case of the UK, the registered decrease does not exclude that KIBS have increased their contribution to manufacturing in a disembodied manner by exploiting a degree of development of the relative knowledge-interfaces that in the UK are quite well-established. Of course, some sort of substitution in recourse to the two channels can be posited and would require further testing in future research.

For the time being, our analysis instead focuses on the importance of production-based R&D flows for the innovative performance of manufacturing sectors, in the way it can be captured by their patent applications and patent quality. In this latter respect, Figure 3 shows heterogeneous trends across the four countries in the period investigated when we consider the cumulated number of patent applications in our 18 manufacturing sectors – a result consistent with other evidence on the country-specificity of patent applications (e.g. Ramani and de Loze, 2002). Germany and Italy are extreme cases among the four, with respectively the highest and lowest numbers of patent applications in the 18 sectors considered: a result that appears interesting for our research hypothesis when we think of the high and low contributions, respectively, of KIBS to manufacturing in the two countries (Barker, 2007). Both in Germany and Italy, the machinery sector (sector C29) appears to be the most innovative one, followed at a certain distance by chemicals (sector C24) and by a small group of high-tech sectors, providing a picture consistent with their role in the relative systems of innovation (Malerba, 2009). On the other hand, the UK and France are somewhere in-between in terms of (cumulated) number of patent applications, and they share the dominant role of chemicals over machinery. Even when cumulated patents are considered, their temporal variations across the periods considered remain rather erratic, confirming their well-known noisy nature (Jaffe and Trajtenberg, 2002). Overall, however, in the majority of sectors, they increase from the beginning to the end of period, passing through a slight decrease in the intermediate phase.

Insert Figure 3 about here

## 5.2. Econometric results

Before presenting the results of the econometric estimation of Eq.(4), it should be noted that the distribution of our main dependent variable (*PATApp*) and of its 'robustness' counterparts (*PATQual4* and *PATQual6*) is not substantially dissimilar from a normal one (see Figures A1, A2 and A3). Accordingly, recourse to a probit or count model, of the kind usually adopted to estimate the knowledge production function at micro-level, does not appear necessary in our case.

Secondly, given the complex relationships that link KIBS and manufacturing in the production-based transmission of knowledge (see Section 2.1), our focal regressor, $KIBS_j$, may suffer from possible endogeneity, which may persist even in the presence of a lag in the assumed impact of the latter on the former.[20] In order to account for this problem, we have instrumented our focal regressor using the degree of vertical integration of KIBS into sector *j* in terms of employment *(L-KIBSj*). This index can be calculated following the same approach explained in Section 4.1 by substituting **r** with a sectoral vector of labour, **l**, in Eq.(2)[21].

From a theoretical point of view, this appears to be an appropriate choice. On the one hand, as we found when commenting on the descriptive results of the previous section, manufacturing subsystems with the larger shares of labour employed in their vertically-integrated KIBS are more likely to acquire larger shares of production-based KIBS (R&D) knowledge. On the other hand, as recent studies in innovation economics and industrial organization have shown (e.g. Mazzanti et al., 2007), an impact of the degree of vertical disintegration (i.e. as a consequence of outsourcing) on innovation, and thus of its vertical integration counterpart, cannot be theoretically supported on a systematic basis because of a number of conflicting forces. More in general, because the vertical integration in terms of labour is a structural characteristic of an economic system, in our context it can be considered as exogenous and uncorrelated with the error term. Of course, this theoretical conjecture about our proposed instrument will have to be tested.

[20] For example, *PATApp* (1995-1997) may have affected the KIBS knowledge flow in 2000. Then, the KIBS knowledge flow in 2000 may have affected *PATApp* (2000-2002), in turn. We thank a reviewer for having raised this point.
[21] See Ciriaci and Palma (2012) for a more detailed illustration.

In search of a model suitable for estimating Eq.(4), given the structure of our panel data, we first conducted a Breusch-Pagan Lagrange Multiplier (LM) test. The test rejected the null hypothesis that OLS residuals do not contain individual specific error components, thus confirming the presence of random effects. However, given that the simple presence of random effects does not imply that the relative model is more efficient than a fixed effect one, we also ran a Hausman test (Hahn *et al*., 2011) to finalize the choice between the two (Table 3).[22] The results of the test suggest that the fixed effect estimation is the way forward, as we rejected the null hypothesis of zero correlation between the regressors and the error term.[23]

Insert Table 3 around here

Table 4 reports the results of our estimates for patent applications (*PATApp*) in a step-wise fashion. In particular, columns (i) to (iv) report the estimates of the model obtained by inserting the regressors sequentially; column (v) shows the robust fixed effect estimates obtained with respect to our reference model; column (vi) those obtained by fitting the panel data model with a two-stage least-squares within estimator (that is, instrumenting (IV) $KIBS_j$ with $L\text{-}KIBS_j$). Columns (vii) and (viii) report the estimates obtained, instead, when the three KIBS-sectors – and their vertical integration with the generic manufacturing sector *j* ($KIBS\text{-}RD_j$, $KIBS\text{-}COMP_j$, and $KIBS\text{-}BUS_j$) – were separately considered. In this regard, to be noted is that the very low level of vertical integration of *KIBS-RD* for France (close to zero), prevented us from obtaining reliable estimates at this sectoral disaggregated level. Therefore,

[22] To be borne in mind is that, unlike the fixed effect model, which assumes that individual heterogeneity can be captured by the intercept term, the random one identifies it as a part of the error term. The advantage of the fixed effect model is that the intercepts can be correlated with the regressors, allowing for a limited form of endogeneity. On the other hand, the advantage of the random effect model is that it yields estimates for all the coefficients. Accordingly marginal effects, even those of time-invariant regressors, can be estimated.

[23] As a rule of thumb, if both estimates were similar, we could use a random effects estimator, whereas if they differed the fixed effects estimator was preferred. The same approach was followed in the case of the robustness check, i.e. when *PATQuality4* and *PATQuality6* were used as dependent variables. Also in these two additional cases, the Hausman tests suggested a fixed effect model as the way forward.

in trying to overcome this problem, in column (vii) we report the estimates of Eq.(4) obtained for this sectoral level of disaggregation excluding France, and in column (viii) the estimates obtained by considering all four countries, but omitting *KIBS-RD*. For the sake of clarity, our reference estimates are those reported in column (v).

When we consider all KIBS in aggregate terms (Model (v) and Model (vi)), our research hypothesis is confirmed in terms of the significance of the relative relationship: the larger the amount of R&D that manufacturing sectors acquire from KIBS through their vertical integration, the higher their innovative performance in terms of patent applications. The production-based flows of R&D coming from KIBS and used by the manufacturing subsystems to satisfy their final demand actually correlate with their ability to introduce new inventions. This result is in line with the theoretical framework reviewed in Section 2, emphasising the manifold innovative role that KIBS play in an economic system. In spite of the structural differences that we have detected among the four countries, in all of them KIBS appears to be an innovation-effective carrier of production-based R&D to manufacturing.

Comparison between the IV results and those in column (i) shows that the coefficient on KIBS is significant at a lower confidence interval (IV standard errors are larger).[24] Given the loss of efficiency observed, we have performed an Hausman test to detect systematic differences between the OLS and IV estimates, whose results induce us to accept the null hypothesis of not systematically different coefficients (Table 5).

Returning to the results of Model (v), to be noted is that the significant impact of our focal regressor, $KIBS_j$, on $PATApp_j$, is also non-negligible in size: a one-percent increase in the former at time *t* leads to an increase of nearly one fifth (0.19%) in the latter at time *t+2*. As a mere term of reference, in this regard it is worth emphasizing that the underlying production impact of KIBS input on manufacturing output, calculated for a pool of EU countries

[24] Regarding the instrument chosen, results from the first stage regression corroborated *L-KIBSj* as a relevant instrument.

(including some of our own) over the 1990s, is only 0.10% (Baker, 2007, p. 109), suggesting that on a vertically integrated basis such an economic channel conveys a larger technological impact.

Again with respect to KIBS in aggregated terms, it is interesting that, when KIBS-embodied R&D is plugged into the knowledge production function, *RD-INTRA* becomes non-significant. This result suggests that, in the countries considered, the only kind of 'embodied' R&D that enables manufacturing sectors to obtain commercially exploitable inventions is that invested by specialist knowledge producers and acquired from them through economic transactions related to the production processes of the recipient sector.[25] Conversely, as suggested by previous studies (e.g. Marengo and Sterlacchini, 1990), intra-sectoral embodied R&D flows can be deemed inputs of incremental/process innovations that usually do not find a patent outcome. Finally, to be noted is the significant negative sign that *K-INT* assumes in the 'augmented' knowledge production function that we consider. A one-percent increase in manufacturing capital intensity at time *t* decreases the average number of patent applications in the following two years, though only by 0.13%. Apparently, by 'deepening' their physical capital the manufacturing sectors of our analysis decrease, rather than increase, their invention capacity. Although apparently counter-intuitive, this interpretation is consistent with the findings of other studies on the decreasing innovation returns that equipment investments face with the increase in the industrialisation level of the investing sectors/countries (e.g. De Long and Summers, 1991; Dullek and Foster, 2008). Indeed, in our case it seems that the switch from industrialisation to tertiarisation may even have made these returns slightly negative (Montresor and Vittucci Merzetti, 2011).

[25] As an additional robustness check, we inserted an interaction term between our variable of interest (*KIBSj*) and *RD-INTRA* in EQ(4), to test whether *within-sector* embodied knowledge was innovation-enhancing if combined with specialized knowledge coming from KIBS. The results (available upon request) did not confirm this hypothesis, and were in line with those reported and commented on in the main text.

Disaggregated analysis of the relationship in question (Models (vii) and (viii)) yields interesting results concerning the contribution of specific KIBS sectors to manufacturing patenting activity. However, these should be interpreted with extreme caution, given the biases introduced by the aforementioned ad-hoc exclusions. When *KIBS-RD* is considered together with the other two kinds of KIBS – that is, by focusing only on the UK, Germany and Italy (Model (vii)) – what emerges is an interesting external, production-based version of the standard linear innovation mode: the only KIBS whose transmitted knowledge makes manufacturing sectors more innovative in Germany, Italy and the UK is that offering R&D services as such. Furthermore, the relative elasticity in the respective equation is greater than that detected for KIBS in general: a 0.25% increase in patent applications for a 1% increase in *KIBS-RD*. By contrast, the innovative knowledge that the manufacturing sectors of the countries investigated obtain by interacting in the production realm with less innovation-dedicated services – that is, business services and ICT – does not significantly help. Taking the results on *RD-INTRA* into account (and on *RD-INT* in alternative specifications, available from the authors on request), it seems that in the countries considered, providing it occurs within the same sub-system (on which, see Montresor and Vittucci Marzetti, 2007), the externalisation of R&D from manufacturing to services appears to be a viable strategy from an innovation point of view.

Finally, when we impose our *ad-hoc* misspecification in the model, by omitting *KIBS-RD* in order to consider all four countries (model (viii), the other two KIBS regain a significant role as predictors of manufacturing inventions. In spite of the possible bias arising from variables omission, it is interesting to note that the contributions of *KIBS-COMP* and *KIBS-BUS* are lower than that found for KIBS at aggregate level. Furthermore, they are significantly different from each other,[26] confirming the inner heterogeneity that KIBS have

[26] An F-test was used to test the null hypothesis that the difference between the KIBS' coefficients was equal to zero.

been found to have in the extant literature (see, for example, Consoli and Elche-Hortelano, 2010; Doloreux and Shearmur, 2010). More precisely, the impact of *KIBS-COMP* is higher than that of *KIBS-BUS*: an increase of one percentage point in the flows of vertically integrated R&D from these two KIBS increases the average patent applications in manufacturing by 0.07% and 0.05%, respectively, in the following two years. Considering the production-based mechanism that the complementarity between software and hardware entails, and the impact that this complementarity has been found to have on the relationship between manufacturing and services (Stanback, 1979; 1981), this result is not unexpected. Of course, this does not underscore the pivotal role of the services that business consultants (sectors) provide to manufacturing. However, their contribution to innovation may be expected to be higher when the transmission of their knowledge is purely disembodied, rather than being production-based as in the focus of this paper.

A last set of results emerge when, for the purpose of a robustness check, we refer to the patent quality of our manufacturing sectors (Table 6). Firstly, regardless of the specific indicator used (both columns (i) in Table 6), those manufacturing sectors with a higher degree of vertically-integrated KIBS-R&D are also more capable of inventions with a higher techno-economic value.

Insert Table 6 around here

The results on *PATApp* are fully coherent with the previous ones obtained for patent applications also when we separately consider the three different categories of *KIBS* included in the analysis. *KIBS-RD* is still the only significant positive predictor of *PATQual4* and *PATQual6* (when France is excluded; columns (ii) in Table 6). When all four countries are considered, at the price of omitting *KIBS-RD*, *KIBS-COMP* confirms its dominant role with respect to *KIBS-BUS*, whose impact on patent quality becomes even non-significant (columns (iii) in Table 6).

# 6. Conclusions

The importance of KIBS for manufacturing clients/sectors has been largely established. On this basis, important policy initiatives have been promoted – at both national and European level – to increase their weight in economic systems and to develop the market and the institutional conditions for manufacturing firms to be able to exploit them (the support for "A Knowledge intensive future for Europe" is just one example).

Despite the evidence, however, the multiplicity of channels through which KIBS can contribute to improvement in manufacturing economic performances has not yet been fully addressed. In particular, the innovative role that KIBS can play for manufacturing still deserves further analysis. This is especially so in regard to the extent to which the innovative knowledge obtained from KIBS – typically through their R&D expenditures – is acquired by manufacturing sectors through the direct and indirect production relationships that constitute their vertically-integrated sectors, and finally increase their innovation performance. The pervasive diffusion of outsourcing strategies by manufacturing firms towards service providers makes this an issue extremely important to address.

The present paper has contributed to meeting this research need with a new empirical application that has three original features. Firstly, it tries to retain both direct and indirect production relationships between KIBS and manufacturing by using the vertically-integrated sector (or sub-system) methodology. Secondly, it goes beyond the simple mapping of these relationships and directly addresses their actual innovation impact by referring to both the quantity and quality of inventive (i.e. patent) efforts in manufacturing. Thirdly, for this purpose, it combines different data sources (input-output tables, R&D and patent data) to obtain a panel in which causality relationships can be more accurately identified.

Although limited to four European countries, over the period 1995-2005 – both because of data availability and continuity with previous research – the results that we have obtained are quite interesting and have a number of policy implications. Firstly, production-based R&D flows acquired from KIBS actually make manufacturing sectors more innovative, whether patent applications or patent quality are considered as proxies for the latter. Given the results obtained on the R&D carried out within the vertically integrated sectors, the quantity and quality of manufacturing inventions can be most increased by exploiting the features of the so-called Schumpeter Mark III model and reinforcing the (production) interactive linkages between industry and services. As has been widely recognised, policy support for R&D cooperation and technology transfer between the two realms can have a role in this. Our results suggest that an important innovation impact can also accrue from the extensive processes of vertical integration of services into manufacturing that are occurring in the aftermath of the outsourcing strategies of industrial firms (Montresor and Vittucci Marzetti, 2011). Accordingly, the same holds true for the policies that address the specialisation patterns of countries and/or regions, and that in doing so bring about structural changes in their vertically integrated sub-systems.

A further interesting result of our application is its confirmation of the fact that KIBS differ from each other also in their capacity to convey R&D to manufacturing sectors in such a way as to increase their inventive capacity. In particular, the extent to which KIBS are related to an underlying production transaction – in a sort of software/hardware relationship – is a key factor in their innovative impact on manufacturing. From a policy point of view, this result provides an interesting insight into the choice of the so-called key-enabling technologies through which manufacturing can be advanced towards more innovative developments.

Of course, our analysis is not free from limitations, to which future research will be devoted. In particular, production-based flows of R&D have been proxied by sticking to a number of standard assumptions in the extant literature, whose relaxation will have to be considered, although by facing additional problems in the interpretation of the vertically integrated sector construct. The analysis of disembodied R&D flows will also have to be better integrated than in the synthetic way (i.e. through the RD regressors) it has been done in the paper. Last, but not least, a natural extension of the paper will be to see whether our main research hypothesis about the innovation impact of KIBS in manufacturing holds true with respect to a larger number of countries.

# References


Acs, Z.J and Audretsch, D.B. (1989), Patents as a measure of innovative activity. *Kyklos*, 42(2), 171–180.

Amara, N. and Landry, R. and Doloreux, D., (2009). Patterns of innovation in knowledge-intensive business services. *The Service Industries Journal* 29: 407-430.

Antonelli, C. (2000) 'New information technology and localized technological change in the knowledge based economy', in M. Boden and I. Miles (eds) Services and the Knowledge-Based Economy. London and New York: Continuum, pp. 170–91.

Antonelli, C., Geuna, A. and Steinmueller, W.E., (2000). Information and communication technologies and the production, distribution and use of knowledge. *International Journal of Technology Management* 20, 72-94.

Antonietti, R., Cainelli, G., and Lupi, C., (2013). Vertical disintegration and spatial co-localization: The case of KIBS in the metropolitan region of Milan. Economics Letters, 118(2), 360--363.

Baumol, W.J., (2002). Services as leaders and the leader of the services. In: Gadrey, J., Gallouj, F. (Eds.), *Productivity, Innovation and Knowledge in Services*. Edward Elgar, pp. 147–163.

Baker, P., (2007). The impact of business-services use on client industries: Evidence from input–output data, in Rubalcaba, L. and Kox, H. (eds.), Business Services in European Economic Growth. Palgrave Macmillan, 97-116.

Bettencourt, L., Ostrom, A., Brown, S. and Roundtree, R., (2002). Client co-production in knowledge-intensive business services. *California Management Review* 44, 100–128.

Bettencourt, L., Ostrom, A., Brown, S., and Roundtree, R. (2002). Client co-production in knowledge-intensive business services. California Management Review, pages 100-128.

Boschma, R. (2005) 'Proximity and Innovation: A Critical Assessment', *Regional Studies*, 39: 1, 61 — 74.

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

Brouwer E. and , Kleinknecht A., (1999). Innovative output, and a firm's propensity to patent. An exploration of CIS micro data. *Research Policy* 28, 615–624.

Cassiman, B. and Veugelers, R. (2006). In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. Management Science, 52(1):68.

Cassiman, B. and Veugelers, R., (2002). R&D cooperation and spillovers: some empirical evidence from Belgium. *The American Economic Review* 92, 1169—1184.

Castellacci, F., (2008). Technological paradigms, regimes and trajectories: manufacturing and service industries in a new taxonomy of sectoral patterns of innovation. *Research Policy* 37, 978–994.

Chesbrough, H., Vanhaverbeke, W. and West, J., (2006). *Open innovation: Researching a new paradigm*. Oxford: Oxford University Press, USA.

Ciriaci, D. and Palma, D., (2012). To what extent are knowledge-intensive business services contributing to manufacturing? A subsystem analysis. IRI-IPTS Working Paper 2/2012.

Cohen, W. M. and Levinthal, D. A. (1989). Innovation and learning: The two faces of R&D. The Economic Journal, 99, 569-596.

Consoli, D. and Elche-Hortelano, D., (2010). Variety in the knowledge base of Knowledge Intensive Business Services. *Research Policy* 39, 1303-1310.

Corrocher, N., Cusmano, L., and Morrison, A. (2009). Modes of innovation in knowledge-intensive business services evidence from Lombardy. *Journal of Evolutionary Economics*, 173-196.

Crèpon, B., Duguet, E., and Mairessec, J., (1998), Research, innovation and productivity: An econometric analysis at the firm level, *Economics of Innovation and new Technology*, 7(2) 115—158.

Czarnitzki, D. and Spielkamp, A., (2003). Business services in Germany: bridges for innovation. *The Service Industries Journal* 23, 1-30.

David, P., Foray, D., (1995). Accessing and Expanding the Science and Technology Knowledge-Base". STIREVIEW, no 16. Paris. OECD.

De Long, J.B. and Summers, L.H. (1991). Equipment investment and economic growth. *Quarterly Journal of Economics*, 106, 445-502.

den Hertog, P., (2000). Knowledge-intensive business services as co-producers of innovation. *International Journal of Innovation Management* 4.

Den Hertog, P., Bilderbeek, R., (1998). Conceptualising (service) innovation and the knowledge between KIBS and their clients. SI4S Topical paper. Apeldoorn.

Desmarchelier, B., Djellal, F. and Gallouj, F., (2013). Knowledge intensive business services and long term growth. *Structural Change and Economic Dynamics*, 25, 188–205.

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* 3, 149-171.

Doloreux, D. and Shearmur, R., (2010). Exploring and comparing innovation patterns across different knowledge intensive business services, *Economics of Innovation and New Technology* 19, 605-625.

Dulleck, U. and Foster, N. (2008), Imported equipment, human capital and economic growth in developing countries. *Economic Analysis and Policy*, 38, 233-250.Ernst, H. (2001). Patent applications and subsequent changes of performance: evidence from time-series cross-section analyses on the firm level. *Research Policy* 30, 143–157.

Evangelista, R. and Savona, M. (2003). Innovation, employment and skills in services.Firm and sectoral evidence. Structural Change and Economic Dynamics, pages 449{474.

Gallouj, F. and Djellal, F., (2010). Introduction: filling the innovation gap in the service economy – a multidisciplinary perspective. In: Gallouj, F., Djellal, F. (Eds.), *The Handbook of Innovation and Services. A Multi-disciplinary Perspective*. Edward Elgar, pp. 1–23.

Gallouj, F. and Savona, M. (2009). Innovation in services: a review of the debate and a research agenda. *Journal of Evolutionary Economics*, 149-172.

Gallouj, F., (2002a). Interactional innovation: a neo-Schumpeterian model. In: Sundbo, J., Fuglsang, L. (Eds.), *Innovation as Strategic Reflexivity*. Routledge.

Gallouj, F., (2002b). Knowledge-intensive business services: processing knowledge and producing innovation. In: Gadrey, J., Gallouj, F. (Eds.), *Productivity Innovation and Knowledge in Services*. Edward Elgar, pp. 256–284.

Griliches, S. (1979) Issues in assessing the contribution of R&D to productivity growth, *Bell Journal of Economics,* 10, pp. 92–116.

Griliches, Z., (1982). The search for R&D spillovers, National Bureau of Economic Research NBER Working Paper No. 3768.

Griliches, Z., (1990). Patent statistics as economic indicators: a survey. *Journal of Economic Literature*, 18(4), 1661–1707.

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

Guellec, D. and van Pottelsberghe de la Potterie, B., (2000), Applications, grants and the value of patent, *Economics Letters*, 69(1), 109-114.

Guellec, D., and B. van Pottelsberghe de la Potterie (2007). *The Economics of the European Patent System: IP Policy for Innovation and Competition*. Oxford University Press, Oxford (UK).

Hall, B. H., and D. Harhoff (2012). Recent Research on the Economics of Patents”. NBER Working Papers No. 17773, National Bureau of Economic Research, Inc., www.nber.org/papers/w17773.

Hahn, J., Ham, J. C. and Moon, H.R., (2011), The Hausman test and weak instruments, Journal of Econometrics, Elsevier, vol. 160(2), pages 289-299.

Hauknes, J. and Knell, M., (2009). Embodied knowledge and sectoral linkages: An input–output approach to the interaction of high- and low-tech industries. *Research Policy* 38, 459–469.

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.

Jaffe A.B., Trajtenberg M. (2002). Patents, citations, and innovations: A window on the knowledge economy, MIT Press.

Jorgenson, Dale W. , (1966). The embodiment hypothesis, *The Journal of Political Economy*, 74(1), 1—17.

Katsoulacos, Y. and Tsounis, N. (2000) ‘Knowledge-Intensive Business Services and productivity growth: the Greek evidence’, in M. Boden and I. Miles (eds), Services and the Knowledge-based Economy. London: Continuum, pp. 192–208.

Kline, S., Rosenberg, N., (1986). An Overview of Innovation. In: Landau, R., Rosenberg, N. (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. National Academy Press, Washington, DC, 275–305.

Jorgenson, D. W. (1966). The embodiment hypothesis. *Journal of Political Economy* 74(1): 1-17.

Koschatzky, K., & Stahlecker, T. (2006). Structural couplings of young knowledge-intensive business service firms in a public-driven regional innovation system. *International Studies in Entrepreneurship*, 14, 171–193.

Lanjouw, J. and M. Schankerman (2004), Patent quality and research productivity: Measuring innovation with multiple indicators", *The Economic Journal*, 114(495): 441-465.

Landry, R., Amara, N. and Doloreux, D. (2012). Knowledge-exchange strategies between KIBS firms and their clients. *The Service Industries Journal*, 32(2), 291–320.

Laursen, K. and Salter, A., (2005). Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal* 27, 131-150.

Leiponen, A. (2006). Organization of knowledge exchange: an empirical study of knowledge-intensive business service relationships. *Economics of Innovation and New Technology*, 15(4/5), 443–464.

Leoncini, R. and Montresor, S. (2003) (editors), *Technological Systems and Intersectoral Innovation Flows*, 33-49. Edward Elgar, Cheltenham.

Lichtenthaler, U. (2009). Absorptive capacity, environmental turbulence, and the complementarity of organizational learning processes. The Academy of Management Journal (AMJ), 52(4):822-846.

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

Malerba, F. and Orsenigo, L. (1997). Technological regimes and sectoral patterns of innovative activities. *Industrial and Corporate Change* 6(1), 83-117.

Malerba, F. , (2009) Sectoral Systems of Innovation: Concepts, Issues and Analysis of six Major Sectors in Europe, Cambridge University Press.

Marengo, L. and Sterlacchini, A. (1990). Intersectoral technology flows. Methodological aspects and empirical applications. *Metroeconomica* 41 (1), 19–39.

Martinez-Fernandez, M. and Miles, I., (2006). Inside the software firm: co-production of knowledge and KISA in the innovation process. *International Journal of Service Technology Management* 7, 115–125.

Mas-Verdú, F., Wensley, A., Alba, M., Garcıa Alvarez-Coque, J.M., (2011). How much does KIBS contribute to the generation and diffusion of innovation? *Service Business* 5, 195–212

Mazzanti M., Montresor S., Pini P., Outsourcing and innovation: evidence for a local production system of Emilia-Romagna, «INNOVATION», 2007, 9, pp. 324 – 342.

Miles, I. (2005). Knowledge intensive business services: prospects and policies. Strategic Thinking and Policy, 39-63.

Miles, I., Kastrinos, N., Flanagan, K., Bilderbeek, R., Den Hertog, P., Huntik, W., Bouman, M., (1995). Knowledge-Intensive Business Services: Users, Carriers and Sources of Innovation. *Rapport pour DG13 SPRINT-EIMS*, March.

Miller, R.E.and Blair, D.B. (2009), *Input-Output Analysis. Foundations and Extensions*. Cambridge, Cambridge University Press.

Momigliano, F. and Siniscalco, D., (1982). The growth of service employment: a reappraisal, *BNL Quarterly Review* 142, 269-306.

Montresor, S. and Vittucci Marzetti, G., (2007). Outsourcing and structural change. What can input-output analysis say about it? *Economia Politica* I, 43-78.

Montresor, S. and Vittucci Marzetti, G.V., (2008). Innovation clusters in technological systems: a network analysis of 15 OECD countries for the mid-1990s. *Industry & Innovation* 15, 321- 346.

Montresor, S. and Vittucci Marzetti, G., (2009). Applying social network analysis to input-output based innovation matrices: an illustrative application to 6 OECD technological systems for the middle 1990's. *Economic Systems Research* 21, 129 -149.

Montresor, S. and Vittucci Marzetti, G., (2011). The deindustrialisation/tertiarisation hypothesis reconsidered: a subsystem application to the OECD7. *Cambridge Journal of Economics* 35, 401–421.

Muller, E. and Doloreux, D., (2009). What we should know about knowledge-intensive business services. *Technology in Society* 31, 64-72.

Muller, E. and Zenker, A., (2001). Business services as actors of knowledge transformation: the role of KIBS in regional and national innovation systems. *Research Policy* 30, 1501-1516.

Muller, E., (2001). Innovation Interactions Between Knowledge-Intensive Business Services and Small- and Medium sized Enterprises — Analysis in Terms of Evolution, Knowledge and Territories. Physica, Heidelberg.

Nishioka, S. and Ripoll, M., (2012). Productivity, trade and the R&D content of intermediate inputs, European Economic Review, 56(8), 1573—1592.

Panizza, A. and Squicciarini, M. (2014). Technology flows and innovation output in Italy: industry-level evidence from R&D and patent data. *Economia e Politica Industriale*, n.3, 109-131.

Oulton, N., (2001). Must the growth rate decline? *Oxford Economic Papers* 53 (4), 605–627.

Papaconstantinou, G., Sakurai, N., and Wyckoff, A., (1998). Domestic and international product-embodied R&D diffusion. *Research Policy* 27, 301–314.

Pasinetti, L.L., (1973). The notion of vertical integration in economic analysis, *Metroeconomica* 1, 1-29.

Pasinetti, L.L., (1981). *Structural Change and Economic Growth. A Theoretical Essay on the Dynamics of the Wealth of the Nations*, Cambridge, Cambridge University Press.

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

Ramani, S.V. and de Looze, M.A. (2002). Country-Specific characteristics of patent applications in France, Germany and the UK in the biotechnology sectors, *Technology Analysis & Strategic Management*, 14(4), 457-480.

Rodriguez, M. and Ballesta, J.A.C., (2010). Are knowledge-intensive business services so "hard" innovators? Some insights using Spanish microdata, *Journal of Innovation Economics* 1, 41-65.

Rodriguez, M. and Camacho, J.A., (2008). Are KIBS more than intermediate inputs? An examination into their R&D diffuser role in Europe. *International Journal of Services Technology and Management* 10, 254—272.

Savic, M. and Lawton-Smith, H., (2013), Determinants of innovation in Knowledge Intensive Business Services (KIBS) SMEs: some implications for de-industrialised regions in the UK, Regional Studies (in-press).

Schmoch, U. (2008), "Concept of a Technology Classification for Country Comparisons", Final Report to the World Intellectual Property Organisation (WIPO), revised August 2011, WIPO, www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf (last accessed 30 October 2012).

Shearmur, R. and Doloreux, D., (2014). Knowledge-Intensive Business Services (KIBS) use and user Innovation: High-order services, geographic hierarchies and internet use in Quebec's manufacturing sector, *Regional Studies*, online version, 1—18.

Squicciarini, M., Dernis, H. and Criscuolo, C. (2013), "Measuring Patent Quality: Indicators of Technological and Economic Value", OECD Science, Technology and Industry Working Papers, 2013/03, OECD Publishing. http://dx.doi.org/10.1787/5k4522wkw1r8-en.

Sraffa P. (1960), *Production of Commodities by Means of Commodities*, Cambridge, Cambridge University Press.

Stanback, T. M. (1979). *Understanding the Service Economy*, Baltimore, MD, Johns Hopkins University Press.

Stanback, T. M. (1981). *Services: The New Economy*, Totowa, NJ, Littlefield Adams.

Tether, B.S., (2005). Do services innovate (differently)? Insights from the European Innobarometer Survey. *Industry and Innovation* 12, 153–184.

Tödtling, P., Lehner, P. and Trippl, M., (2006). Innovation in knowledge intensive industries: The nature and geography of knowledge links, *European Planning Studies* 14, 1035-1058.

Tomlinson, M. (2000a) 'Information and Technology Flows from the Service Sector: a UK–Japan Comparison', in M. Boden and I. Miles (eds), *Services and the Knowledge-Based Economy*. London and New York: Continuum, pp. 209–21.

Tomlinson, M. (2000b) 'The Contribution of Knowledge-Intensive Services to the Manufacturing Industry', in B. Andersen, J. Howells, R. Hull, I. Miles and J. Roberts (eds), *Knowledge and Innovation in the New Service Economy*. Cheltenham: Edward Elgar.

Verspagen, B., (1997). Measuring intersectoral technology spillovers: estimates from the European and US patent office databases. *Economic Systems Research* 9, 47—65.

Wang, P., Cockburn, I.M, and Puterman, M.L. (1998). Analysis of patent data—A Mixed-Poisson-Regression-Model approach, *Journal of Business & Economic Statistics*, 16:1, 27-41.

Watanabe C., Youichirou S.T., and Griffy-Brown C., (2001) Patent statistics: deciphering a 'real' versus a 'pseudo' proxy of innovation. *Technovation* 21 (2001) 783–790.

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

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica* 48: 817–830.

Wooldridge, J.M., (2002). Econometric Analysis of Cross-section and Panel data. MIT Press.

# Tables and Figures

## Table 1 – Descriptive statistics of the variables

| Variable | Overall sample | | | | |
|---|---|---|---|---|---|
| | Obs | Mean | Std. Dev. | Min | Max |
| *PATApp* | 216 | 5.2526 | 1.4535 | 1.7918 | 8.6595 |
| *PATQual4* | 216 | 3.2173 | 1.3543 | 0.4886 | 6.6148 |
| *PATQual6* | 216 | 3.4538 | 1.3924 | 0.5653 | 6.8613 |
| *KIBS* | 216 | 16.3206 | 1.0132 | 13.4786 | 18.6968 |
| *KIBS-COMP* | 216 | 14.9538 | 1.2734 | 11.4825 | 17.8369 |
| *KIBS-RD* | 216 | 11.0073 | 6.5062 | 0.0000 | 17.8971 |
| *KIBS-BUS* | 216 | 13.9992 | 2.0366 | 7.6014 | 17.5350 |
| *RD-INT* | 216 | 5.8011 | 3.9644 | 0.0000 | 10.4341 |
| *K-INT* | 214 | 8.9031 | 0.8025 | 6.2742 | 11.7686 |
| *L* | 216 | 12.2077 | 0.9325 | 9.0775 | 13.9631 |
| *RD-INTRA* | 216 | 5.2022 | 1.9119 | 0.0000 | 9.4448 |
| | ***France*** | | | | |
| *PATApp* | 54 | 5.30048 | 1.313537 | 2.224623 | 7.317763 |
| *PATQual4* | 54 | 3.359749 | 1.230924 | 0.727549 | 5.267497 |
| *PATQual6* | 54 | 3.59979 | 1.247834 | 0.916291 | 5.488317 |
| *KIBS* | 54 | 16.29423 | 1.007847 | 13.47864 | 18.08009 |
| *KIBS-COMP* | 54 | 15.20832 | 1.08369 | 12.03172 | 17.32813 |
| *KIBS-RD* | 54 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| *KIBS-BUS* | 54 | 15.04415 | 1.10969 | 11.98917 | 17.25564 |
| *RD-INT* | 54 | 6.850044 | 3.650889 | 0.000000 | 10.43414 |
| *K-INT* | 53 | 9.049161 | 0.740515 | 7.267001 | 11.76856 |
| *L* | 54 | 11.93967 | 0.8226936 | 9.077495 | 13.24871 |
| *RD-INTRA* | 54 | 5.526059 | 1.739273 | 1.200868 | 8.276429 |
| | ***Germany*** | | | | |
| *PATApp* | 54 | 6.209465 | 1.423548 | 3.681779 | 8.659453 |
| *PATQual4* | 54 | 4.164316 | 1.353425 | 1.811562 | 6.614779 |
| *PATQual6* | 54 | 4.464738 | 1.372154 | 2.028148 | 6.861313 |
| *KIBS* | 54 | 16.41957 | 1.072082 | 14.19395 | 18.6968 |
| *KIBS-COMP* | 54 | 14.94366 | 1.501709 | 11.54249 | 17.83689 |
| *KIBS-RD* | 54 | 13.93618 | 1.797612 | 10.16589 | 17.89706 |
| *KIBS-BUS* | 54 | 15.58331 | 0.9673464 | 13.66119 | 17.53499 |
| *RD-INT* | 54 | 6.437595 | 3.617021 | 0.000000 | 10.20363 |
| *K-INT* | 54 | 8.90837 | 0.6369268 | 7.94189 | 11.09874 |
| *L* | 54 | 12.65352 | 0.9999713 | 9.903538 | 13.96307 |
| *RD-INTRA* | 54 | 6.024803 | 1.788242 | 2.306975 | 9.444845 |

**Table cont'd**

| | | | | | |
|---|---|---|---|---|---|
| | ***Italy*** | | | | |
| *PATApp* | 54 | 4.695305 | 1.261626 | 1.941185 | 7.099398 |
| *PATQual4* | 54 | 2.599199 | 1.113289 | 0.672945 | 5.079539 |
| *PATQual6* | 54 | 2.834156 | 1.146192 | 0.770108 | 5.29451 |
| *KIBS* | 54 | 16.09687 | 1.077924 | 13.64116 | 18.22363 |
| *KIBS-COMP* | 54 | 14.14088 | 1.125996 | 11.48248 | 16.55144 |
| *KIBS-RD* | 54 | 15.53913 | 1.127824 | 13.19002 | 17.60265 |
| *KIBS-BUS* | 54 | 13.77176 | 1.189856 | 11.2385 | 16.12139 |
| *RD-INT* | 54 | 4.456423 | 4.078364 | 0.000000 | 9.615872 |
| *K-INT* | 54 | 9.35855 | 0.6144005 | 8.080791 | 11.21478 |
| *L* | 54 | 12.16308 | 0.9765148 | 9.857496 | 13.82744 |
| *RD-INTRA* | 54 | 4.294164 | 1.701016 | 0.903408 | 7.052602 |
| | ***United Kingdom*** | | | | |
| *PATApp* | 54 | 4.804996 | 1.330592 | 1.791759 | 7.226823 |
| *PATQual4* | 54 | 2.746052 | 1.141952 | 0.48858 | 4.903124 |
| *PATQual6* | 54 | 2.916607 | 1.167394 | 0.565314 | 5.114755 |
| *KIBS* | 54 | 16.47178 | 0.8672458 | 14.16264 | 17.99246 |
| *KIBS-COMP* | 54 | 15.52228 | 0.9008845 | 13.19189 | 16.97217 |
| *KIBS-RD* | 54 | 14.55392 | 1.134622 | 11.54249 | 16.52529 |
| *KIBS-BUS* | 54 | 11.5975 | 1.908878 | 7.601402 | 15.50819 |
| *RD-INT* | 54 | 5.460146 | 4.149416 | 0.000000 | 10.34177 |
| *K-INT* | 53 | 8.287448 | 0.8171986 | 6.274218 | 10.39303 |
| *L* | 54 | 12.07437 | 0.775212 | 10.0993 | 13.15025 |
| *RD-INTRA* | 54 | 4.963853 | 2.004291 | 0.000000 | 8.460532 |

*Data are expressed in natural log.*

## Table 2 – Pairwise correlation coefficients

| | *PATApp* | *PATQual4* | *PATQual6* | *KIBS* | *KIBS-COMP* | *KIBS-RD* | *KIBS-BUS* | *RD-INT* | *K-INT* | *L* | *RD-INTRA* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *PATApp* | 1 | | | | | | | | | | |
| *PATQual4* | 0.9807* | 1 | | | | | | | | | |
| *PATQual6* | 0.9791* | 0.9981* | 1 | | | | | | | | |
| *KIBS* | 0.4656* | 0.4653* | 0.4513* | 1 | | | | | | | |
| *KIBS-COMP* | 0.3641* | 0.3657* | 0.8765* | 0.8767* | 1 | | | | | | |
| *KIBS-RD* | 0.0304 | -0.0150 | -0.0163 | 0.1382* | -0.0179 | 1 | | | | | |
| *KIBS-BUS* | 0.4347* | 0.4742* | 0.4931* | 0.4728* | 0.3042* | -0.2410* | 1 | | | | |
| *RD-INT* | 0.5793* | 0.5776* | 0.5656* | 0.2006* | 0.2251 | -0.1247* | 0.1354* | 1 | | | |
| *K-INT* | 0.0838* | 0.0545* | 0.0500* | -0.0342 | -0.1031* | -0.073* | 0.2099* | 0.3487* | 1 | | |
| *L* | 0.2430* | 0.2877* | 0.2970* | 0.5501* | 0.3518* | 0.2195* | 0.4363* | -0.3627* | -0.4005* | 1 | |
| *RD-INTRA* | 0.7894* | 0.7990* | 0.7892* | 0.6086* | 0.5330* | -0.0357 | 0.4224* | 0.7693* | 0.1723* | 0.1334* | 1 |

**Indicates correlation coefficients significant at least at the 5% level.*

**Table 3. Hausman test results. Ho: non-syst. difference in coefficients**

| | (b) fixed | (B) . | (b-B) Difference |
|---|---|---|---|
| *KIBS* | 0.1908395 | 0.1599169 | 0.0309226 |
| *RD-INTRA* | -0.0320519 | 0.2324218 | -0.2644737 |
| *K-INT* | -0.1290995 | -0.0620209 | -0.0670786 |
| *L* | -0.0283704 | 0.0754647 | -0.1038351 |
| *D_time1* | -0.1052946 | -0.0724862 | -0.0328083 |
| *D_time2* | 0.0495089 | 0.0582831 | -0.0087742 |
| chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)= 140.96 | | | |
| Prob>chi2 = 0.0000 | | | |

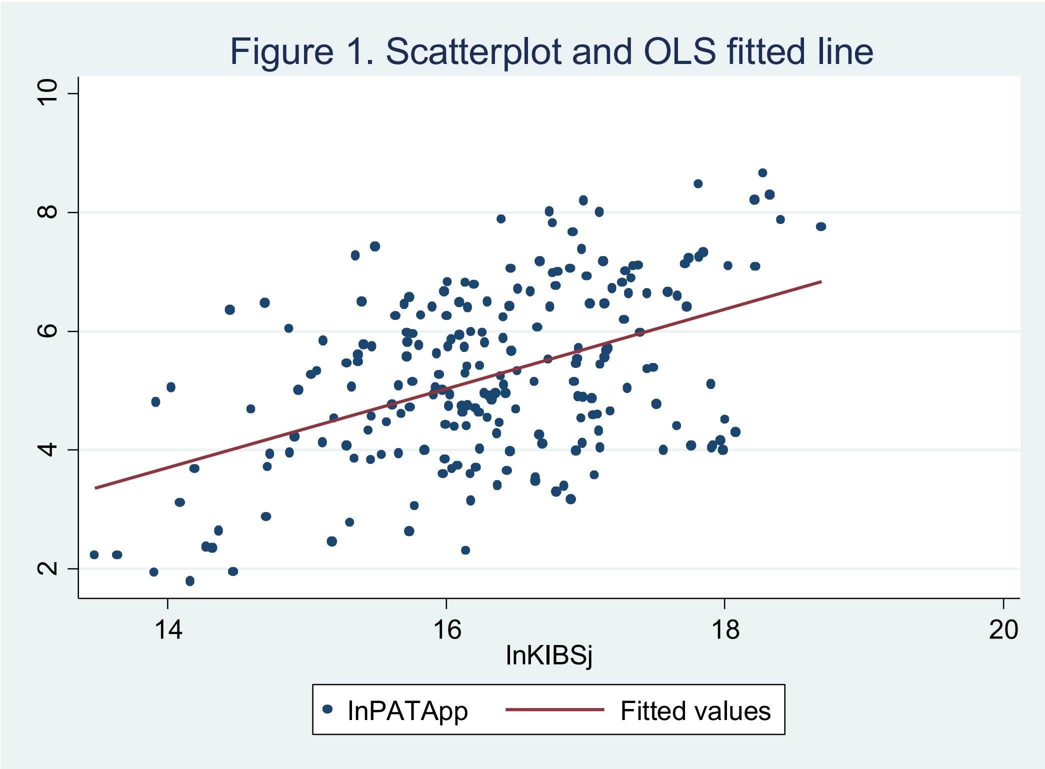
Figure 1. Scatterplot and OLS fitted line
2
4
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Fitted values

**Figure 2 - KIBS' R&D acquisitions by manufacturing sectors: 1995-2005**

(% change of total intersectoral acquisitions)

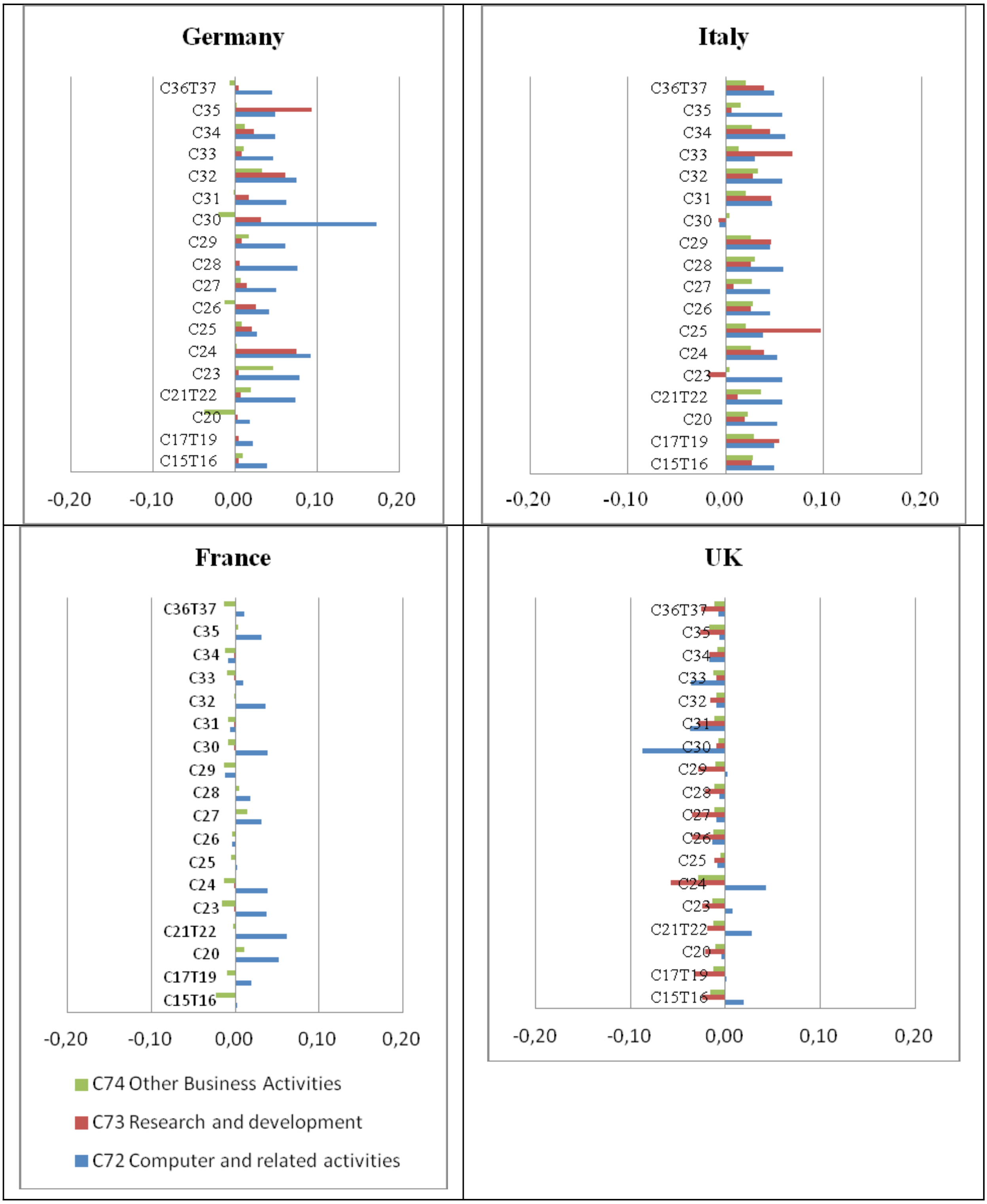
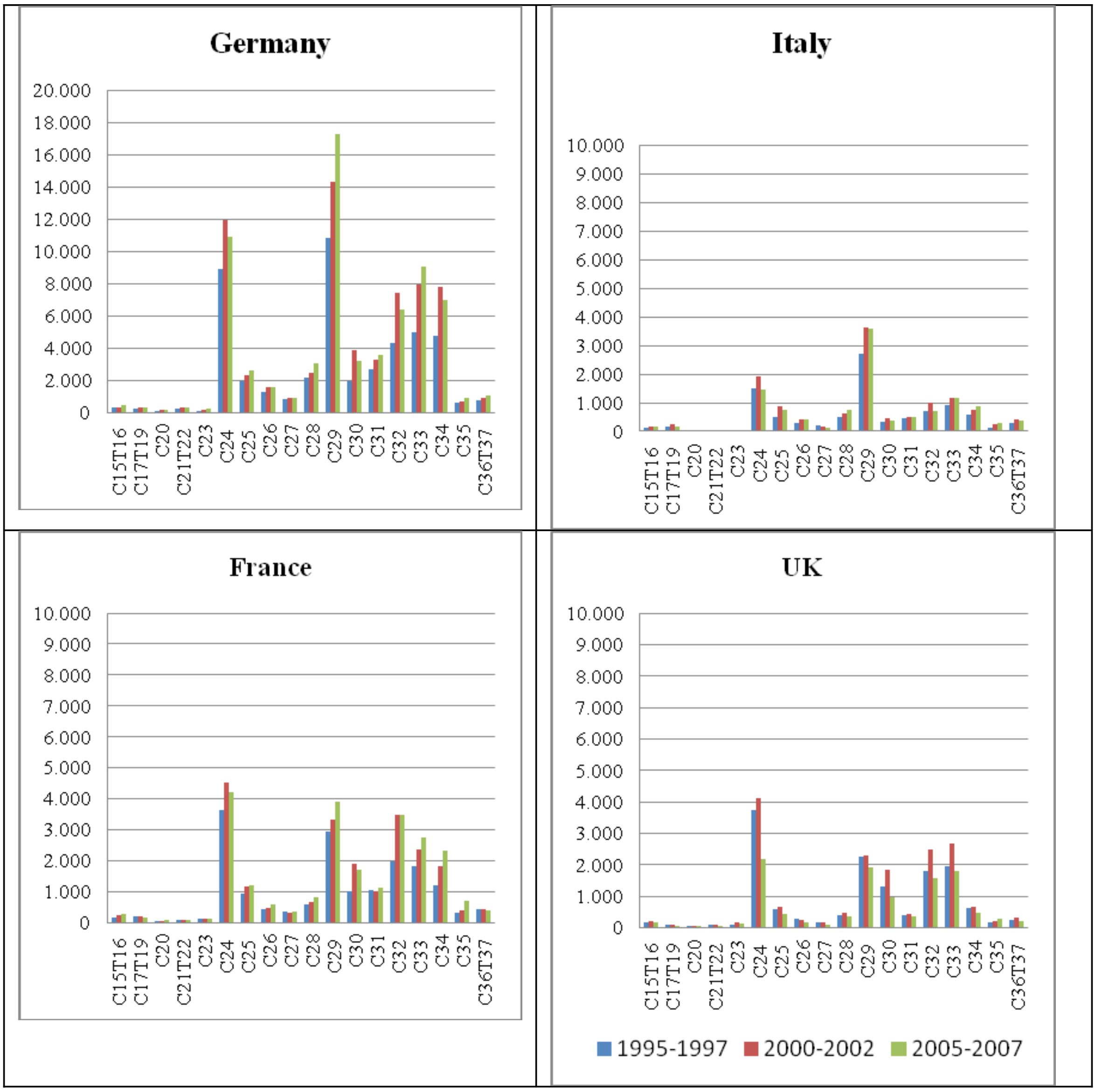


**Figure 3 – Cumulated number of patents in manufacturing: 1995-2005**



## Table 4. Estimates results: Dependent variable *PATApp*

| | (i) | (ii) | (iii) | (iv) | (v) | (vi) | (vii) | (viii) |
|---|---|---|---|---|---|---|---|---|
| | Within estimator | Within estimator | Within estimator | Within estimator | **Within estimator** | Two-stage within estimator | Within estimator (France excluded) | Within estimator (KIBS-RD excluded) |
| KIBS | 0.273*** | 0.275*** | 0.278*** | 0.278*** | **0.191*** ** | 0.368* | | |
| | (0.0292) | (0.0309) | (0.0304) | (0.0299) | **(0.0387)** | (0.224) | | |
| KIBS-COMP | | | | | | | -0.0393 | 0.0725*** |
| | | | | | | | (0.0498) | (0.0191) |
| KIBS-RD | | | | | | | 0.250*** | |
| | | | | | | | (0.0449) | |
| KIBS-BUS | | | | | | | 0.0204 | 0.0514*** |
| | | | | | | | (0.0163) | (0.0167) |
| RD-INTRA | | -0.00612 | -0.0177 | -0.0170 | **-0.0321** | -0.0638 | -0.0364 | -0.0355 |
| | | (0.0545) | (0.0492) | (0.0481) | **(0.0388)** | (0.0644) | (0.0423) | (0.0399) |
| K-INT | | | -0.0918** | -0.129** | **-0.129** ** | -0.154** | -0.165** | -0.138** |
| | | | (0.0459) | (0.0569) | **(0.0536)** | (0.0605) | (0.0647) | (0.0581) |
| L | | | | -0.139 | **-0.0284** | -0.0254 | -0.194 | -0.0684 |
| | | | | (0.151) | **(0.193)** | (0.320) | (0.162) | (0.172) |
| D_time1 | | | | | **-0.105** ** | 0.0183 | -0.212*** | -0.152*** |
| | | | | | **(0.0514)** | (0.162) | (0.0476) | (0.0481) |
| D_time2 | | | | | **0.0495** | 0.0841 | -0.0585 | 0.0597 |
| | | | | | **(0.0402)** | (0.0571) | (0.0524) | (0.0401) |
| Constant | 0.794 | 0.799 | 1.635** | 3.641 | **3.820** | 4.010* | 6.810*** | 5.728** |
| | (0.477) | (0.486) | (0.635) | (2.315) | **(2.621)** | (2.053) | (2.416) | (2.418) |
| Observations | 216 | 216 | 214 | 214 | **214** | 214 | 160 | 214 |
| R-squared | 0.337 | 0.337 | 0.364 | 0.370 | **0.443** | | 0.508 | 0.496 |
| Number of i_panel | 72 | 72 | 72 | 72 | **72** | 72 | 54 | 72 |

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

## Table 5. Hausman test results. Ho: non-systematic difference in coefficients

| | (b) endogenous | (B) . | (b-B) Difference |
|---|---|---|---|
| *KIBS* | 0.3683226 | 0.1908395 | 0.1774831 |
| *RD-INTRA* | -0.0637949 | -0.0320519 | -0.031743 |
| *K-INT* | -0.1541514 | -0.1290995 | -0.0250518 |
| *L* | -0.2535305 | -0.2283704 | -0.0251601 |
| *D_time1* | 0.0183497 | -0.1052946 | 0.1236443 |
| *D_time2* | 0.0840956 | 0.0495089 | 0.0345867 |

chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)= 0.65

Prob>chi2 = 0.9955

**Table 6. Estimates results: Dependent variables *PATQual4* and *PATQual6***

| | *PATQuality4* | | | *PATQuality6* | | |
|---|---|---|---|---|---|---|
| | (i) | (ii) | (iii) | (i) | (ii) | (iii) |
| | **Within estimator** | Within estimator (France excluded) | Within estimator (KIBS-RD excluded) | **Within estimator** | Within estimator (France excluded) | Within estimator (KIBS-RD excluded) |
| KIBS | **0.120*** ** | | | **0.118*** ** | | |
| | **(0.031)** | | | **(0.032)** | | |
| KIBS-COMP | | 0.054 | 0.061*** | | 0.074 | 0.060*** |
| | | (0.057) | (0.015) | | (0.057) | (0.015) |
| KIBS-RD | | 0.120** | | | 0.123** | |
| | | (0.051) | | | (0.050) | |
| KIBS-BUS | | 0.010 | 0.0245 | | 0.010 | 0.027 |
| | | (0.016) | (0.017) | | (0.016) | (0.017) |
| RD-INTRA | **0.029** | 0.0353 | 0.0212 | **0.033** | 0.038 | 0.025 |
| | **(0.033)** | (0.044) | -0.035 | **(0.033)** | (0.044) | (0.034) |
| K-INT | **-0.161*** ** | -0.226*** | -0.166*** | **-0.152*** ** | -0.224*** | -0.159*** |
| | **(0.041)** | (0.0519) | -0.044 | **(0.042)** | (0.054) | (0.045) |
| L | **0.195** | -0.0778 | 0.179 | **0.22** | -0.0981 | 0.194 |
| | **(0.187)** | (0.19) | (0.185) | **(0.193)** | (0.192 | (0.190) |
| D_time1 | **-0.026** | -0.0301 | -0.038 | **0.100** ** | 0.106* | 0.089* |
| | **(0.048)** | -0.054 | -0.048 | **(0.049)** | (0.056) | (0.048) |
| D_time2 | **0.061* ** | 0.048 | 0.078** | **0.183*** ** | 0.177*** | 0.199*** |
| | **(0.036)** | -0.056 | -0.038 | **(0.038)** | (0.059) | (0.040) |
| Constant | **0.147** | 3.522 | 1.144 | **-0.066** | 3.543 | 1.012 |
| | **(2.439)** | (2.406) | (2.400) | **(2.504)** | (2.411) | (2.463) |
| Observations | **214** | 160 | 214 | **214** | 160 | 214 |
| R-squared | **0.384** | 0.447 | 0.416 | **0.465** | 0.536 | 0.495 |
| Number of i_panel | **72** | 54 | 72 | **72** | 54 | 72 |

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

# Appendix

**Tab. A1: Nace Rev.1 sectoral disaggregation of patent applications data**

| | |
|---|---|
| 15 | Manufacture of food products and beverages |
| 16 | Manufacture of tobacco products |
| 17 | Manufacture of textiles |
| 18 | Manufacture of wearing apparel; dressing and dyeing of fur |
| 19 | Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear |
| 20 | Manufacture of wood and of products of wood and cork, except furniture; |
| 21 | Manufacture of pulp, paper and paper products |
| 22 | Publishing, printing and reproduction of recorded media |
| 23 | Manufacture of coke, refined petroleum products and nuclear fuel |
| 24 | Manufacture of chemicals and chemical products |
| 24.1 | Manufacture of basic chemicals |
| 24.2 | Manufacture of pesticides and other agro-chemical products |
| 24.3 | Manufacture of paints, varnishes and similar coatings, printing ink and mastics |
| 24.4 | Manufacture of pharmaceuticals, medicinal chemicals and botanical products |
| 24.5 | Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations |
| 24.6 | Manufacture of other chemical products |
| 24.7 | Manufacture of man-made fibres |
| 25 | Manufacture of rubber and plastic products |
| 26 | Manufacture of other non-metallic mineral products |
| 27 | Manufacture of basic metals |
| 28 | Manufacture of fabricated metal products, except machinery and equipment |
| 29 | Manufacture of machinery and equipment n.e.c. |
| 29.1 | Manufacture of machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines |
| 29.2 | Manufacture of other general purpose machinery |
| 29.3 | Manufacture of agricultural and forestry machinery |
| 29.4 | Manufacture of machine-tools |
| 29.5 | Manufacture of other special purpose machinery |
| 29.6 | Manufacture of weapons and ammunition |
| 29.7 | Manufacture of domestic appliances n.e.c. |
| 30 | Manufacture of office machinery and computers |
| 31 | Manufacture of electrical machinery and apparatus n.e.c. |
| 31.1 | Manufacture of electric motors, generators and transformers |
| 31.2 | Manufacture of electricity distribution and control apparatus |
| 31.3 | Manufacture of insulated wire and cable |
| 31.4 | Manufacture of accumulators, primary cells and primary batteries |
| 31.5 | Manufacture of lighting equipment and electric lamps |
| 31.6 | Manufacture of electrical equipment n.e.c. |
| 32 | Manufacture of radio, television and communication equipment and apparatus |
| 32.1 | Manufacture of electronic valves and tubes and other electronic components |
| 32.2 | Manufacture of television and radio transmitters and apparatus for line te |
| 32.3 | Manufacture of television and radio receivers, sound or video recording orlephony and line telegraphy |
| 33 | Manufacture of medical, precision and optical instruments, watches and clockS |
| 33.1 | Manufacture of medical and surgical equipment and orthopaedic appliances |
| 33.2 | Manufacture of instruments and appliances for measuring, checking, testing , navigating and other purposes, except industrial process control equipment |
| 33.3 | Manufacture of industrial process control equipment |
| 33.4 | Manufacture of optical instruments and photographic equipment |
| 33.5 | Manufacture of watches and clocks |
| 34 | Manufacture of motor vehicles, trailers and semi-trailers |
| 35 | Manufacture of other transport equipment |
| 36 | Manufacture of furniture; manufacturing n.e.c. |

**Tab. A2: ISIC Rev.1 sectoral classification of input-output tables**

| |
|---|
| R1: C01T05 Agriculture, hunting, forestry and fishing |
| R2: C10T14 Mining and quarrying |
| R3: C15T16 Food products, beverages and tobacco |
| R4: C17T19 Textiles, textile products, leather and footwear |
| R5: C20 Wood and products of wood and cork |
| R6: C21T22 Pulp, paper, paper products, printing and publishing |
| R7: C23 Coke, refined petroleum products and nuclear fuel |
| R8: C24 Chemicals and chemical products |
| R9: C25 Rubber and plastics products |
| R10: C26 Other non-metallic mineral products |
| R11: C27 Basic metals |
| R12: C28 Fabricated metal products except machinery and equipment |
| R13: C29 Machinery and equipment n.e.c |
| R14: C30 Office, accounting and computing machinery |
| R15: C31 Electrical machinery and apparatus n.e.c |
| R16: C32 Radio, television and communication equipment |
| R17: C33 Medical, precision and optical instruments |
| R18: C34 Motor vehicles, trailers and semi-trailers |
| R19: C35 Other transport equipment |
| R20: C36T37 Manufacturing n.e.c; recycling |
| R21: C40T41 Electricity, gas and water supply |
| R22: C45 Construction |
| R23: C50T52 Wholesale and retail trade; repairs |
| R24: C55 Hotels and restaurants |
| R25: C60T63 Transport and storage |
| R26: C64 Post and telecommunications |
| R27: C65T67 Finance and insurance |
| R28: C70 Real estate activities |
| R29: C71 Renting of machinery and equipment |
| R30: C72 Computer and related activities |
| R31: C73 Research and development |
| R32: C74 Other Business Activities |
| R33: C75 Public admin. and defence; compulsory social security |
| R34: C80 Education |
| R35: C85 Health and social work |
| R36: C90T93 Other community, social and personal services |
| R37: C95 Private households with employed persons |

**Table A3: Sectoral disaggregation adopted for the study**

*Manufacturing*

C15T16 Food products, beverages and tobacco
C17T19 Textiles, textile products, leather and footwear
C20 Wood and products of wood and cork
C21T22 Pulp, paper, paper products, printing and publishing
C23 Coke, refined petroleum products and nuclear fuel
C24 Chemicals and chemical products
C25 Rubber and plastics products
C26 Other non-metallic mineral products
C27 Basic metals
C28 Fabricated metal products except machinery and equipment
C29 Machinery and equipment n.e.c
C30 Office, accounting and computing machinery
C31 Electrical machinery and apparatus n.e.c
C32 Radio, television and communication equipment
C33 Medical, precision and optical instruments
C34 Motor vehicles, trailers and semi-trailers
C35 Other transport equipment
C36T37 Manufacturing n.e.c; recycling

*Services and KIBS*

C64 Post and telecommunications
C65T67 Finance and insurance
C70 Real estate activities
C71 Renting of machinery and equipment
**C72 Computer and related activities**
**C73 Research and development**
**C74 Other Business Activities**

**Tab. A4: Sectoral variable data sources by country**

| | **Patent applications and Patent quality** | **Input-output tables** | **R&D Expenditures** | **Fixed capital investments** | **Employment** |
|---|---|---|---|---|---|
| | *Source: PATSTAT EPO Database and Patent Quality OECD database* | *Source: OECD-IO Database* | *Source: OECD Anberd Database* | *Source: OECD-STAN Database* | *Source: OECD-STAN Database* |
| **Years** | 1995 – 2007 | 1995, 2000, 2005 | 1995, 2000, 2005 | 1995, 2000, 2005 | 1995, 2000, 2005 |

**Figure A1: *PATApp* distribution**

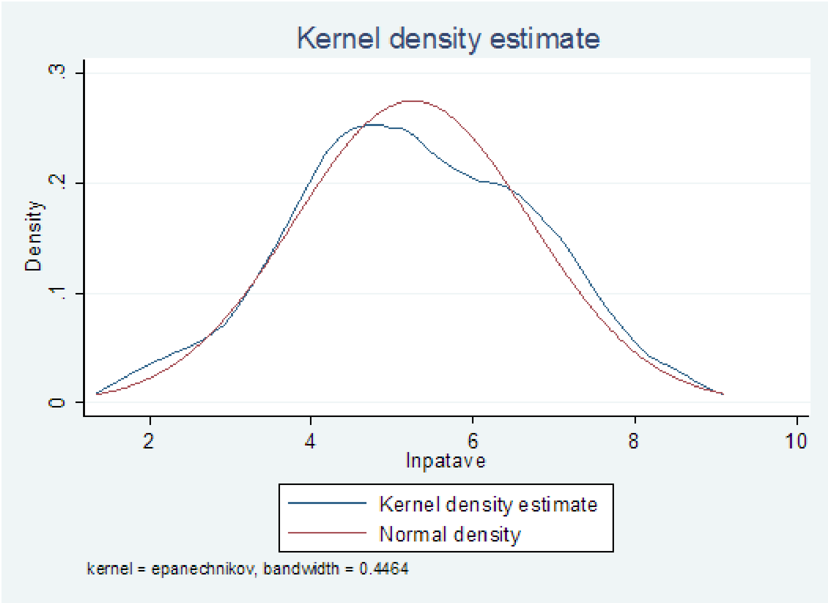



**Figure A2: *PATQual4* distribution**

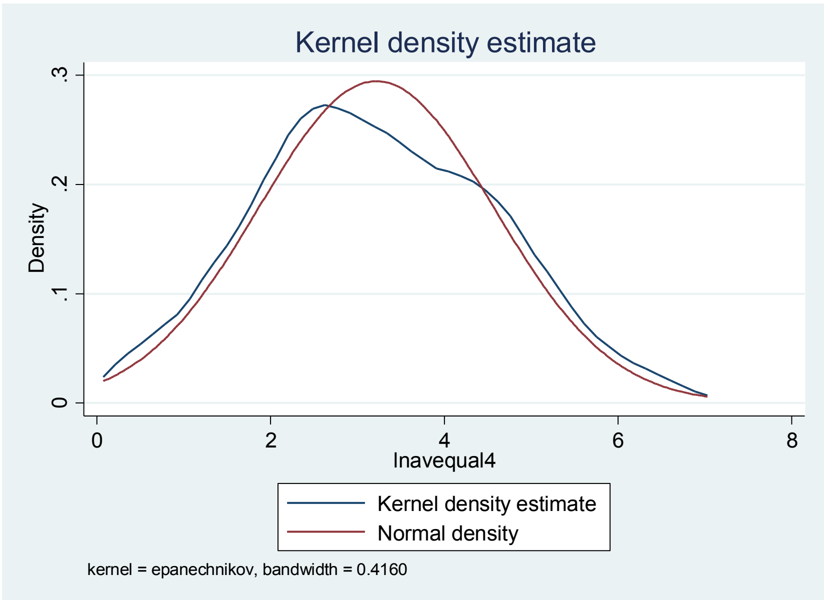
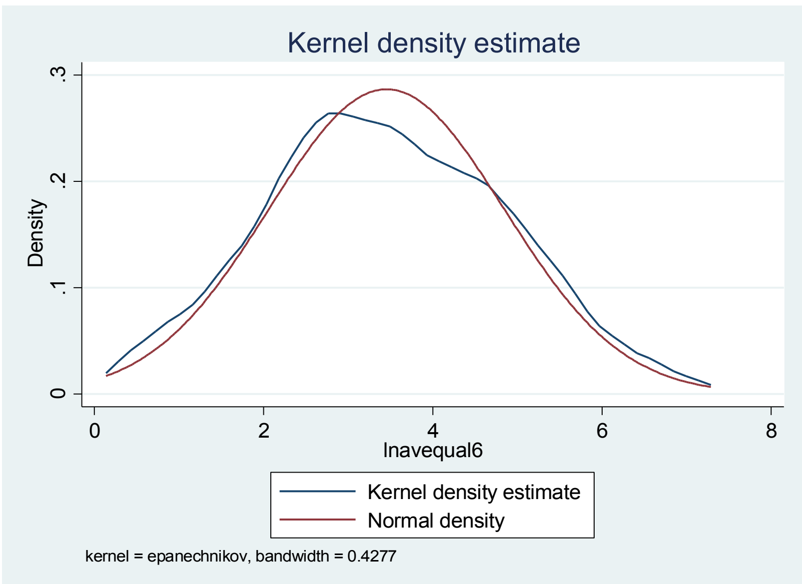



**Figure A3: *PATQual6* distribution**



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