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Working Paper

Do KIBS make manufacturing more innovative? An empirical investigation for four European countries

IPTS Working Papers on Corporate R&D and Innovation, No. 04/2013

Provided in Cooperation with:
Joint Research Centre (JRC), European Commission

Suggested Citation: Ciriaci, Daria; Montresor, Sandro; De Palma, Daniela (2013) : Do KIBS make manufacturing more innovative? An empirical investigation for four European countries, IPTS Working Papers on Corporate R&D and Innovation, No. 04/2013, ISBN 978-92-79-34784-9, European Commission, Joint Research Centre (JRC), Seville, https://doi.org/10.2791/58386

This Version is available at:
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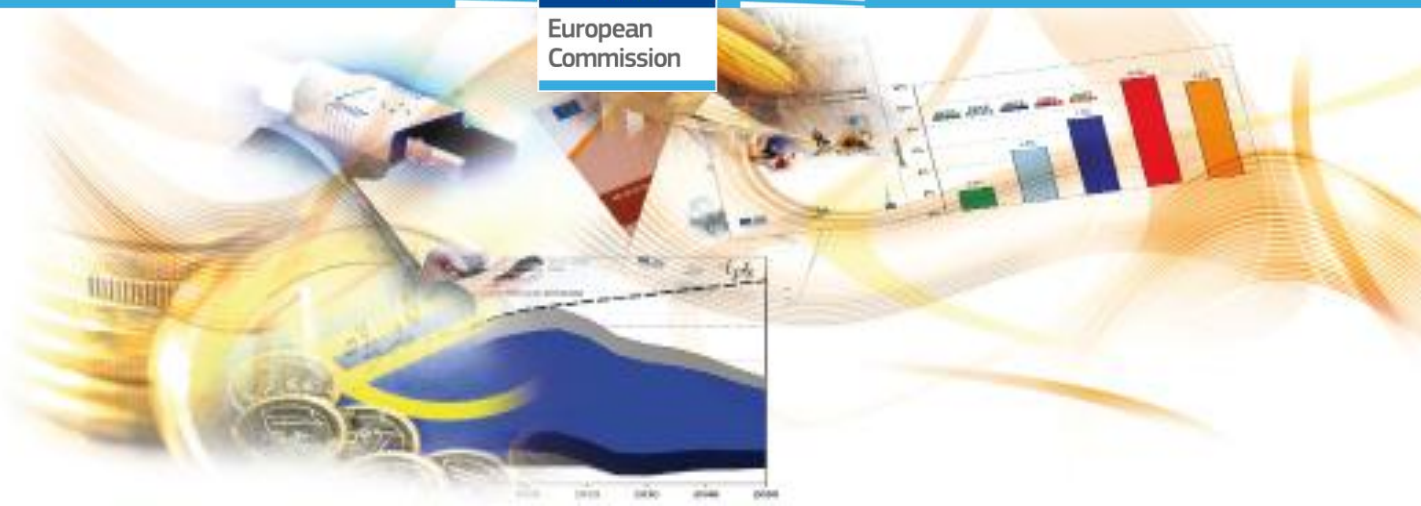

JRC TECHNICAL REPORTS

IPTS WORKING PAPERS ON CORPORATE R&D AND INNOVATION – NO. 04/2013

Do KIBS make manufacturing more innovative? An empirical investigation for four European countries

Daria Ciriaci, Sandro Montresor, Daniela Palma

2013

Report EUR 26362 EN

Joint Research Centre

European Commission
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JRC86432

EUR 26362 EN

ISBN 978-92-79-34784-9 (pdf)

ISSN 1831-9424 (online)

doi:10.2791/58386

Luxembourg: Publications Office of the European Union, 2013

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Printed in Spain

Abstract

The paper aims at estimating the innovation impact of the vertical integration of knowledge intensive business services (KIBS) into manufacturing. Referring to the vertically integrated sectors of an economy allows innovative knowledge, which is transferred directly and indirectly from KIBS to manufacturing in an embodied way, to be measured. Its impact on manufacturing innovation is then estimated. By merging OECD data on sectoral R&D and input-output tables with sectoral patent applications from the Pastat dataset, a panel of 18 manufacturing sectors is built up for the four largest European countries – France, Germany, Italy and the UK – spanning from the mid-90s to the mid-00s. The more innovative sectors are actually those making more intensive and extensive use of R&D embodied into KIBS production flows. In policy terms, strengthening the bridge between KIBS and manufacturing appears to be as crucial as supporting KIBS activities and service innovations.

Keywords: KIBS; vertically integrated sectors; embodied R&D flows.

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

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Introduction

Nearly 20 years after the seminal contribution by Miles et al. (1995), Knowledge Intensive Business Services (KIBS) have recently gained a novel research and policy momentum. On the one hand, new studies at the firm level have obtained additional results about the idiosyncratic modes of innovation in KIBS (e.g. Tether, 2005; Corrocher et al., 2009), the inner variety of their learning patterns and skill bases (e.g. Consoli and Elche-Hortelano, 2010, Doloreux and Shearmur, 2010), and the role of geographical proximity and clustering for their impact (e.g. Tödtling et al., 2006; Antonietti and Cainelli, 2008). On the other hand, macroeconomic studies have obtained new insights into the intersectoral relationships between KIBS and the other industries of an economic system, and about their implications in terms of knowledge diffusion (e.g. Mas-Verdú et al., 2011; Hauknes and Knell, 2009), structural change and economic growth (e.g. Di Cagno and Meliciani, 2005; Desmarchelier et al., 2012).

Taking stock of this reinvigorated debate, after the initial boost it gave to KIBS projects in the late '90s (e.g. the KISINN, the SI4S, and the RISE projects), the European Commission is targeting new socio-economic research on the issue. Consistently, Member States are encouraged to introduce new measures for supporting innovation in KIBS and services in general, as part of their "smart" strategies of growth (European Commission, 2010).

In spite of these research efforts and policy initiatives, additional analysis is required to empirically address the complex way in which KIBS work for the generation and diffusion of new knowledge in the economic system. In a nutshell, this complexity is due to the "interactional innovation" model (Gallouj, 2002a), which the recent wave of the knowledge-based economy and the explosion of the related tertiary sectors have brought about.

A crucial aspect of the knowledge interaction between KIBS and manufacturing is its occurrence through direct and indirect production linkages, as these are represented by the input-output tables of an economic system. Input-output analysis actually offers us interesting tools to empirically investigate the innovation impact of KIBS. In particular, the vertically-integrated-sectors approach that, following Luigi Pasinetti's seminal ideas (1973, 1981), Momigliano and Siniscalco (1982) put forward in the early '80s, could be extremely useful in this respect.

The aim of the paper is to estimate the extent to which production-embodied KIBS knowledge enters into the manufacturing subsystems (or vertically integrated sectors) and increases their innovation capacity. In so doing, it moves an original step forward with respect to existing studies dedicated to mapping and accounting of these sectoral flows, and fills a gap in identifying their actual innovation impact at economy-system level. More generally, it provides an original structural change perspective on a phenomenon that has been mainly investigated at the micro/industry level. It also helps in providing policy makers with a more comprehensive picture of the consequences of tertiarisation and about the recently emerged European argument of "contrasting" it with an industrialisation revival.

More precisely, an empirical investigation is carried out with respect to four large 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 a period which spans from the mid-90s to the mid-00s. In order to do so, the OECD Input-Output and the ANBERD databases are combined and merged with sectoral patent applications coming from the Pastat dataset. In a panel framework, country, sector and time specific effects are thus controlled for.

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

Theoretical background and research hypothesis

In nearly 20 years of research and debate, the analysis of KIBS has inevitably become enriched with several, different definitions and approaches (for a review, see for example 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, 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 deal with "a KIBS" as a particular kind of economic sector, whose role in promoting innovation and growth at aggregate level is important (e.g. Baumol, 2002; Oulton, 2001).

Although it also draws on some elements from the first one, this paper is grounded in the second research stream. Hereafter, KIBS will be thus meant 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). This category includes 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 customized problem solving), rather than to final consumption (Miles et al., 1995). [1]

Among those available, the definition provided above directly points to a function of KIBS, which is of special interest in this paper.[2] KIBS sectors carry on key-activities in innovation systems (e.g. Muller and Zenker, 2001; Tether, 2005). Not only are they innovative *per se*, as they introduce new marketable services and technological applications (an issue which is out of this paper's scope). They also act as knowledge and innovation carriers with respect to other sectors, especially manufacturing ones, and in this way they work as "innovation propellers" at the system level (Castellacci, 2008).

The analysis of this last function is the subject of the present paper. Its investigation makes *intersectoral innovation flows* particularly important, especially those occurring between KIBS and manufacturing sectors. It has been widely recognised (see, for example, Leoncini and Montresor, 1993; Papaconstantinou et al., 1996) that these flows can be of two different kinds: *disembodied* and *embodied*. Disembodied intersectoral (or inter-firm) flows occur from one sector (or firm) to another because of the nature of innovative knowledge itself: interactively generated and only partially appropriable. In his seminal contribution, Zivi Griliches (1982) refers to them as "pure-knowledge spillovers". Embodied innovation flows, instead, require an underlying economic transaction to occur. Through it, the producer (sector or firm) sells to the user (sector or firm) a product/service, which has been made feasible by the innovative efforts of the former, but for which the former is not able to (fully) charge the latter: in Griliches's words (1982), these could be deemed "rent spillovers".

[1] A more precise account of the identification of these sectors will be provided in the next section. On the classification of KIBS see, among the others, Miles et al. (1995), Muller and Zenker (2001), Martinez-Fernandez and Miles (2006).

[2] For a discussion of the KIBS function in the innovation process see, for example, Den Hertog and Bilderbeek (2008).

Given their business and professional nature, an important part of KIBS-related innovation flows are of an embodied nature. Even in the absence of an actual embodiment mechanism, production flows of an input-output nature represent at least a "functional map" in orienting the diffusion of (KIBS) innovative knowledge in the techno-economic space (Montresor and Vittucci Marzetti, 2008).

This argument has recently spurred a specific field of studies, in which KIBS are investigated by looking at the embodied knowledge that they acquire from, and diffuse to other sectors (e.g. Mas-Verdú et al., 2011; Hauknes and Knell, 2009; Rodriguez and Camacho, 2008). One important result of these studies is that, as expected, knowledge-intensive business services (KIBS) are essential for the production, diffusion and use of technology, and hence for economic growth.

The present study directly connects to this last research stream on KIBS and contributes by addressing two relatively unexplored issues in it. First of all, the actual contribution of KIBS to innovation (and growth) at the system/intersectoral level - in particular within manufacturing industries - that the extant studies detect is mainly potential and conjectural. A possible explanation can be the need, in order to actually measure this impact, of plugging into the analysis a variable of innovation output at the sectoral level (e.g. patents), which can only be obtained from less directly comparable datasets (than those for relating R&D efforts to input-output flows). Furthermore, a dataset of diachronic nature, rather than cross-sectional, is required to investigate the innovative impact of KIBS on manufacturing as a proper causal relationship. In both respects, this article provides a first important step ahead by directly addressing the actual innovation impact of the KIBS-manufacturing link in generating and diffusing new technological knowledge.[3]

A second problematic issue is the lack of attention of the extant literature to the "complexity" of the relationships between KIBS and manufacturing sectors.[4] First of all, empirical analyses hardly account for the fact that KIBS and manufacturing sectors interact in a way that mutually contributes to their respective innovation capacities. KIBS typically

[3] To start with, such an improvement is obtained by limiting the analysis to intersectoral flows of intermediate commodities only, and without distinguishing their domestic or foreign origin.

[4] This complexity is the distinguishing feature of what Gallouj (2002a) called the "Schumpeter Mark 3" model of innovation, as marked by two features: the role of innovation key-driver that the interaction with external knowledge providers has assumed with the advent of the knowledge-based economy and with the open innovation mode in it (Chesbrough et al., 2006; Laursen and Salter, 2005; Cassiman and Vougelers, 2002); the role of "knowledge bridges" (Czarnitzki and Spielkamp 2000), "knowledge interfaces" (Antonelli et al., 2000) or "vectors of knowledge" (Mas-Verdú et al., 2011) that KIBS have assumed in economic systems with the last wave of the tertiarisation process (Gallouj and Djellal, 2010; Gallouj, 2002b; Hipp and Grupp, 2005).

provide knowledge inputs that industries absorb, combine and transform into innovative products and processes. However, the knowledge of the client manufacturing sectors is also an essential knowledge input for KIBS' innovation. The relevant knowledge interaction is thus a "chain-one", rather than linear (Kline and Rosenberg, 1986), in which the occurrence of feed-back is a crucial aspect of innovation diffusion. This aspect requires a suitable intersectoral matrix to be captured, in which the mutual knowledge interaction among sectors is accounted for. A similar need emerges with respect to the opportunity of capturing, more satisfactorily than in extant literature, that KIBS (manufacturing) knowledge inputs can reach a manufacturing (KIBS) sector both directly and indirectly. The relative knowledge flow occurs also through the contribution of the former to an intermediate input of the product (service) outcome of the latter, or to a further intermediate input of this intermediate input, and so on and so forth. The ICT service that has served to ameliorate the component of an electronic device, which is then used in turn by an R&D agency-consulting for a PC producer, is just an example of this indirect, input-mediated relationship. This is another aspect the framework to be used should encapsulate and that in the present work we suggest as a second step forward in the relative analysis.

By combining the previous two developments of the extant literature, our main research hypothesis is that, once properly accounted for, the vertical production-integration of KIBS into manufacturing can represent a significant predictor of the innovation output of its sectors. In other words, by acquiring from KIBS business-devoted services necessary for the realisation of their final products, manufacturing firms also learn by interacting and acquire technical knowledge and customized problem solving experience, which can have a positive impact on their innovation capacity. Accordingly, the more vertically integrated KIBS are 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.

Methodological approach

In order to address the aforementioned research question, we follow an input-output based perspective, which is focused on the notion of "subsystem" in production (Sraffa, 1960) and on the compact representation of it represented by that of "vertically integrated sector"

(Pasinetti, 1973).[5] In brief, 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 also retain those activities of *j* which are necessary for obtaining their production inputs, and the production inputs of these inputs, and so and so forth in subsequent production rounds: in brief, those activities of *j* that contribute to its final demand indirectly, that is through other intermediate sectors.

As Momigliano and Siniscalco showed in a series of studies on the tertiarisation of the Italian economy in the early '80s, the generic vertically integrated sector *j* can be represented by column *j* of the following (*n* x *n*) matrix (with *n* equal to the number of economic sectors of an economy):

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

In Eq.(1), $\hat{\mathbf{q}}$ is the diagonalized vector of gross production, A is the matrix of input-output coefficients, and $\hat{\mathbf{y}}$ is the diagonalized vector of total final demand. 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 flows is then straightforward. This is represented by the following (*n* x *n*) matrix **R**:

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

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

Its generic element, r_{ij}, measures the amount of embodied R&D required, both directly and indirectly (that is, in subsequent production rounds), from sector *i* in order to satisfy the final demand of sector *j*. In other words, the correspondent innovation flow, from *i* to *j*, takes into account that the former sector can contribute to the latter also being the intermediate input of a third generic sector, *z*, which is in turn an input for sector *j*. Furthermore, the innovation flow which reaches sector *j* from sector *i*, is made possible also

[5] On the genesis of these ideas, and on their application to the analysis of structural change and outsourcing in particular see Montresor and Vittucci (2007).

by the innovative knowledge that the latter has got from the former, again directly and indirectly.

In synthesis, the matrix **R** appears suitable to deal with the complex relationships that link sectors to each other. This matrix can be then easily used to consistently determine the amount of innovative knowledge that manufacturing sectors get from KIBS in an embodied way. In the case of the generic industry (or better to say, subsystem, *j*), this is given by:

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

where the sectors which go from *k* to *r* are the KIBS sectors of the relevant economic system. In other words, our $KIBS_j$ indicator is nothing but the row-sum of the relevant column *j* of **R**, with respect to the *r* - *k* number of KIBS sectors.[6] This indicator is the core of the empirical application we describe in the following section.

Empirical application

The issue at stake in the paper is investigated with respect to the largest four EU economies, whose KIBS have been shown by previous studies to have different patterns of vertical integration in the correspondent manufacturing sub-systems, that is: France, Germany, Italy and the UK (Ciriaci and Palma, 2012; Windrum and Tomlinson, 1999). Their empirical analysis refers to a period that, because of the discontinuous temporal availability of OECD input-output kind of data, spans from the mid-90s (1995 and/or years around that) to the mid-00s (2005 and/or years around that), passing through the early-00s (2000 and/or years around that).[7]

[6] An important issue in building up these sectoral kinds of indicators is that of how to make them free from scale effects across sectors. Different relativisation procedures have been put forward for that in the literature, which 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 will follow enable us to control for size effects in R&D and thus allows us to deal with the absolute values of **R**.

[7] Although this is a limited set of countries, their choice has been also inspired by the attempt at keeping a relatively high number of sectors when the different datasets that are needed for the application are merged. For the majority of the smaller European counties, this combination actually entails a substantial decay of sectors for which data are not available. Also the choice of the temporal span of the application has been inspired by the attempt at building up a panel with a satisfactory level of sectoral disaggregation.

In order to estimate the innovation impact of the vertical integration of KIBS into manufacturing, we plug $KIBS_j$ (as from Eq. (3)) into a standard "knowledge (log-) production-function" (Griliches, 1979) at the sub-system level, where the sectoral innovativeness of the generic sector *j* ($Inno_j$) depends on a set of theoretically consistent variables as in the following model:

$$\ln(Inno_j) = \alpha_0 + \alpha_1 \ln(KIBS_j) + \alpha_2 \ln(RD_j) + \alpha_3 \ln(K_j) + \alpha_4 \ln(L_j) + \varepsilon_j \qquad (4)$$

In addition to the previous positions, RD_j, refers to the own knowledge capital of sector *j*, as it can be captured by its R&D efforts. K_j, and L_j are, respectively, the physical and human capital of sector *j* , while ε_j is an error term with standard properties.

The empirical analysis makes use of different datasets for building up the requested variables. First of all, the innovative outcome of the relevant manufacturing sectors (*Inno* in Eq.(4)) is proxied with the number of patent applications (*PAT*) available in the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO). Following conventional choices in the use of patents as innovative proxy at the micro-level (Acs and Audretsch, 1989), these numbers have been obtained by referring to the priority-date patents applied worldwide by inventors of the four relevant nationalities in 43 manufacturing sectors of the NACE classification (Rev1), between 1963 – 2009 (see Table A1). Standard fractional-counting procedures have been used in the cases of patents with multiple co-inventors of different nationalities.

As far as the independent variables are concerned, the core variable of the application, $KIBS_j$, has been obtained following Eq.(2) and by combining two sets of data: (i) the OECD STAN Input-Output dataset, from which we have drawn the matrices of total intermediate production flows (at current prices) for the 37 sectors of the ISIC Rev1 classification (see Table A2), for the three years 1995, 2000 and 2005; (ii) the OECD Analytical BERD (ANBERD) dataset, from which we have collected data on the R&D expenditures (PPP dollars at current prices) of the same set of sectors and periods.[8] By referring to the resulting sectoral disaggregation (see Table A3), $KIBS_j$ has been disaggregated into three different typologies, whose indirect, embodied innovative impact could be expected to be

[8] 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 of the correspondent value added. R&D sectoral data at current prices were the only available ones for the time period under study. However we believe that this does not represent a drawback for the analysis, as we controlled price variations while taking advantage of actual sectoral relevance of innovative activities through time in the estimation.

different: computer and related activities (*KIBS-COMP*, correspondent to sector C72), encompassing services whose innovation impact is mainly obtained through the informatisation, automation and automatic control of industrial processes; Research and Development services (*KIBS-RD*, correspondent to C73), which are the most direct providers of the innovative knowledge manufacturing sectors acquire from them; other business activities (*KIBS-BUS*, correspondent to C74), whose impact on manufacturing is accompanied by the development of business solutions and dedicated consultancy to producers.[9] More precisely, $KIBS\text{-}COMP_j$, $KIBS\text{-}RD_j$, and $KIBS\text{-}BUS_j$ are the values of the correspondent *KIBS* rows of matrix **R** (Eq.(2)), for each and every *j* sector of the 18 manufacturing ones we have been able to include, in each of the three observed periods.[10]

As far as the other regressors of Eq.(4) are concerned, OECD-STAN data on sectoral R&D expenditures have also been used to proxy the role that the technological knowledge of sector *j* plays for its innovativeness in other respects than KIBS. On the one hand, we have considered the weight that its total R&D expenditure has on its employment and built up its total R&D intensity (RD_INT_j), as an indicator of the innovation opportunities the sector can benefit from in a *disembodied* way. On the other hand, we have also singled out the R&D available in the sector in an *embodied* way, as it is incorporated in the production flows occurring among firms belonging to the same sector *j* (RD_INTRA_j). In other words, while $KIBS_j$ captures the inter-sectoral R&D flows occurring between KIBS and sector *j*, RD_INTRA_j represents its intra-sectoral, embodied R&D: that is, the correspondent cell of the main diagonal of matrix **R** in Eq.(2).

Finally, the physical and human inputs of the production function (Eq.(1)) have been proxied with, respectively, the fixed-capital intensity of sector *j* ($K\text{-}INT_j$), obtained by relating its fixed investments to its total employment, and its total employment itself (L_j)

In order to estimate Equation (4), patent data have been converted into the sectoral level of disaggregation of the regressors, using the NACE-ISIC concordance table developed by the United Nations (*UN*). Furthermore, in order to smooth the erratic year-by-year variations in their total numbers, and to account for the delay with which the relevant regressors impact

[9] 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 we are considering, and because of the gaps in the available data. The remaining sectors out of the 37 are classified as: Primary sectors (P), Public Utilities (PU), Construction (C), Market services (MS), and Non-Market services (NM).

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

on them, we have considered the average number of applications ($PATAVE_j$) in the three years after that of the retained KIBS flows, that is: 1995-1997, with respect to 1995; 2000-2002, with respect to 2000; and 2005-2007, with respect to 2005.[11]

Table 1 reports the main descriptive statistics of the dependent and independent variables we have built up.

Insert Table 1 around here

As reported in Table 2, the correlation among the adopted regressors is low, apart from one notable case, between *RD_INT* and *RD_INTRA*, which appear nearly collinear between them. Given that the largest sector contributions to each sub-system are normally those of the correspondent sector – that is, sector *j* vs. sub-system *j* - this is not unexpected and suggests to us that one of the two from the estimates should be dropped. As our focus on KIBS relies on the embodiment hypothesis, for the sake of consistence we have opted for retaining *RD_INTRA*. Finally, let us observe that, looking beyond pair-wise correlations, the variance inflation factors (VIF)[12] are low, as it is symptomatic in the lack of multicollinearity.

Insert Table 2 around here

As far as the econometric strategy is concerned it should be noted that, using patent applications at the sector-country level, the distribution of our dependent variable (reported in the Appendix (Figure A1)) is such to exclude the need of a probit or count model, of the kind normally used to estimate the knowledge production function at micro-level. In search for a suitable model for our panel data, we first conducted a Breusch-Pagan Lagrange Multiplier (LM) test, which rejected the null hypothesis that OLS residuals did 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 ran a Hausman test (Hahn et al., 2011) to address the choice between the two (Table 3).[13] As a rule of thumb, if both estimates are similar, we can use a random effects estimator, whereas if they differ the fixed effects

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

[12] Available from the authors at request.

[13] Let us remember 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.

estimator is preferred. Once the test was performed, results suggested that the fixed effect estimation was the way forward, as we rejected the null hypothesis of zero correlation between the regressors and the error term.

Insert Table 3 around here

Results

As an introduction to the results, it is interesting to note that the phenomenon we are investigating – that is, KIBS expenditure in R&D acquired by manufacturing sectors through vertical integration – has evolved differently over the retained period in the four countries at word (Figure 1).

Insert Figure 1 around here

On the one hand, although with some exceptions, in Italy and Germany nearly all the 18 considered manufacturing sectors increased the percentage points of their total embodied R&D acquired from KIBS in-between 1995 and 2005. More in particular, in Italy this increase appears relatively more homogenous across the three kinds of KIBS considered than in Germany. Here, the vertical integration of KIBS innovative knowledge into manufacturing has mainly concerned those produced by computer and related activities, especially with respect to technologically close sectors (e.g. sector C30, office, accounting and computing machinery). On the other hand, France and the UK show a completely different picture, with a decreasing reliance of manufacturing on KIBS-embodied R&D over the decade. While 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. Thinking of the increasing weight that KIBS have gained in these economic systems over time, this last result might appear unexpected. However, in interpreting it, one should consider that the kind of knowledge diffusion we are considering is that of the embodiment hypothesis (see Section 2), which attributes a pivotal role to the underlying production transactions. In the case of the UK, the registered decrease does not exclude KIBS having increased their contribution

to manufacturing in a disembodied way, exploiting a degree of development of the relative knowledge-interfaces that in the UK is quite established. To be sure, a sort of substitution in the resort to the two channels can be put forward and would deserve further testing in future research.

For the time being, our analysis focuses instead on the relevance of embodied R&D flows for the innovative performance of manufacturing sectors, as it can be captured by their patent applications. In this last respect, Figure 2 shows again heterogeneity across the four countries in the retained period, when we look at the cumulated number of patent applications in the retained manufacturing sectors. Germany and Italy are extreme cases, among the four, with the highest and lowest numbers of patent applications in the 18 considered sectors, respectively. Still, in both cases, the machinery sector (sector C29) appears the most innovative one, followed by chemicals (sector C24) at a certain distance and by a narrow club of high-tech sectors. On the other hand, the UK and France are somehow in-between in terms of (cumulated) number of patent applications and share the dominant role of chemicals over machinery in the same respect. Even when cumulated patents are considered, their temporal variations across the considered periods remain quite erratic. Overall, however, in the majority of the sectors, they increase from the beginning to the end of period, passing through a slight decrease in the intermediate one.

Insert Figure 2 about here

Looking at the previous two pieces of evidence together, let us consider the econometric test of our main research hypothesis.

Table 4 reports the results of our estimates for Eq.(4). In particular, column (i) considers the vertical integration of KIBS' R&D into manufacturing as a whole. Columns (ii) and (iii) report the estimates obtained when the three KIBS-sectors of the current application are instead considered, that is $KIBS\text{-}RD_j$, $KIBS\text{-}COMP_j$, and $KIBS\text{-}BUS_j$. To be sure, in so doing, some problems emerge given the very low level of vertical integration of *KIBS-RD* for France, which being in fact close to zero, prevents us from obtaining reliable estimates at this disaggregated level. In trying to overcome this problem, we have first left out France from the estimates with respect to all three KIBS of the empirical application (Model (ii)), and then repeated the estimates with all four countries, but leaving *KIBS_RD* out (Model (iii)).

At the aggregated level (Model (i)), our research hypothesis appears confirmed. The larger the R&D that manufacturing sectors acquire through the vertical integration of KIBS, the higher the innovative performance of the sectors themselves. In other words, the flows of R&D coming from KIBS and used by the manufacturing subsystems to satisfy their final demand positively affects the sector ability to innovate. This result is supportive of the theoretical framework we have reviewed in Section 2 about the manifold innovative role that KIBS play in economic systems. In particular, in spite of the structural differences we have detected in the four countries, KIBS appear in all of them an innovation effective carrier of embodied R&D towards manufacturing. In addition, it is interesting to notice that, when KIBS-embodied R&D is plugged into the knowledge production function, *RD_INTRA* loses its significance. This result suggests that, in the considered countries, the only kind of "embodied" R&D that allows 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. On the contrary, 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, attention deserves the significant negative sign that *K_INT* assumes in the "augmented" knowledge production function that we consider. Apparently, by "deepening" their physical capital the manufacturing sectors at word decrease, rather than increasing, their invention capacity: and not, we should stress, their TFP or other efficiency indicators of that kind. Although apparently counter-intuitive, this interpretation is consistent with the findings obtained by other studies on the decreasing innovation returns that equipment investments face with the increase of the industrialisation level of the investing sectors/countries (e.g. De Long and Summers, 1991; Dullek and Foster, 2008). To be sure, in our case it seems that the switch from industrialisation to tertiarisation could have even made these returns negative (Montresor and Vittucci Merzetti, 2011).

The disaggregated analysis of the relationship at stake (Models (ii) and (iii)) reveals some interesting results about the contribution of specific KIBS sectors to manufacturing patenting activity. When *KIBS-RD* are retained along with the other two KIBS – that is, by focusing on the UK, Germany and Italy (Model (ii)) – what emerges is an interesting external variation of the linear innovation mode: the only KIBS whose R&D incorporation makes manufacturing sectors more innovative are those offering R&D services as such. On the

contrary, the knowledge that they accrue by interacting in the production realm with less innovation-dedicated services – that is, business services and ICT – does not significantly help with that. Taking into account the results on *RD_INTRA* (and on *RD_INT* in alternative specifications, available from the authors on request), it seems that in the countries at word, 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 a viable strategy from an innovation point of view.

When we consider all four countries of the empirical application, and then impose an *ad-hoc* misspecification on the model by leaving *KIBS-RD* out, the other two KIBS regain a significant role as innovation predictors for manufacturing. In spite of the possible bias emerging from variables omission, it is interesting to note that the contributions of *KIBS-COMP* and *KIBS-BUS* are significantly different between them,[14] confirming the inner heterogeneity that KIBS have been found to have in the extant literature (see, for example, Consoli and Elche-Hortelano, 2010; Doloreux and Shearmur, 2010). In particular, the impact of the embodied R&D acquired from *KIBS-COMP* is higher than that from *KIBS-BUS*. Thinking of the typical embodiment mechanism that the complementarity between software and hardware realises, 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 want to underscore the pivotal role of the services that business consultants (sectors) provide to manufacturing. However, their innovation contribution could be expected to be higher when the transmission of their knowledge is disembodied, rather than embodied as in the focus of this paper.

Conclusions

The connection between KIBS and innovation is by far an established one. 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 conditions for manufacturing firms to be able to exploit them.

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

In spite of all the existing evidences, however, the multiplicity of channels through which KIBS can contribute to innovation has not been fully explored yet. In particular, while the direct innovative role of KIBS is quite understood, its indirect one still deserves analysis. This is especially so for the extent to which the innovative efforts undertaken by KIBS – typically their R&D expenditures – get 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 issue an extremely relevant one to be addressed.

The present paper contributes to this research need with a new empirical application that has three original elements. First of all, it tries to retain both direct and indirect production relationships between KIBS and manufacturing, by making use of the sub-system methodology. Secondly, it goes beyond the simple mapping of these relationships and directly addresses their actual innovation impact. Thirdly, in order to do that, it combines different data sources 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 we have obtained are quite interesting and have a number of policy implications.

First of all, embodied R&D flows acquired from KIBS actually make manufacturing sectors more innovative. In other words, the innovativeness of manufacturing sectors could also be increased by exploiting the features of the so-called Schumpeter Mark III model and reinforcing the (production) interactive linkage between industry and services. Innovation policies to foster R&D cooperation and technology transfer between the two realms could have a role in that. However, our results also suggest that the increasingly 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) can have an important innovation impact too. The same is thus true for those policies that address the specialisation patterns of countries and/or regions and that in so doing bring about structural changes in their vertically integrated sub-systems.

More generally, our results support the innovative importance of the so-called “rent” kind of R&D spillovers, which occur irrespectively from the public good properties of innovative knowledge and are rather due to the different contractual power of the interactive partners

and the market structure they operate in. In this last respect, industrial policies (e.g. competition ones) find an additional leverage through which they can complement R&D ones in increasing innovation in manufacturing. Indeed, while within-sector R&D needs proper financing, that acquired from KIBS just requires manufacturing firms to face the production and the transaction costs to undertake the underlying economic exchange.

An additional interesting result of our application is the confirmation of the fact that KIBS are different among them, also in their capacity of conveying R&D to manufacturing sectors in such a way to increase their innovation 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 aspect for 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.

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Tables

Table 1 – Descriptive statistics of the variables

Variable	Obs	Mean	Std. Dev.	Min	Max
PATAVE	216	5.2526	1.4535	1.7918	8.6595
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-INTRA	216	5.2022	1.9119	0.0000	9.4448
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
Data are expressed in natural log.					

Table 2 – Pairwise correlation coefficients

	PATAVE	*KIBS*	*KIBS-COMP*	*KIBS-RD*	*KIBS-BUS*	*RD-INT*	*RD-INTRA*	*K_INT*	*L*
PATAVE	1								
KIBS	0.4656*	1							
KIBS-COMP	0.3641*	0.8767*	1						
KIBS-RD	0.0304	0.1382*	-0.0179	1					
KIBS-BUS	0.4347*	0.4728*	0.3042*	-0.2410*	1				
RD-INT	0.5793*	0.2006*	0.2251	-0.1247*	0.1354*	1			
RD-INTRA	0.7894*	0.6086*	0.5330*	-0.0357	0.4224*	0.7693*	1		
K-INT	0.0838*	-0.0342	-0.1031*	-0.073*	0.2099*	0.3487*	0.1723*	1	
L	0.2430*	0.5501*	0.3518*	0.2195*	0.4363*	-0.3627*	0.1334*	-0.4005*	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 - KIBS' R&D acquisitions by manufacturing sectors: 1995-2005

(% change of total intersectoral acquisitions)

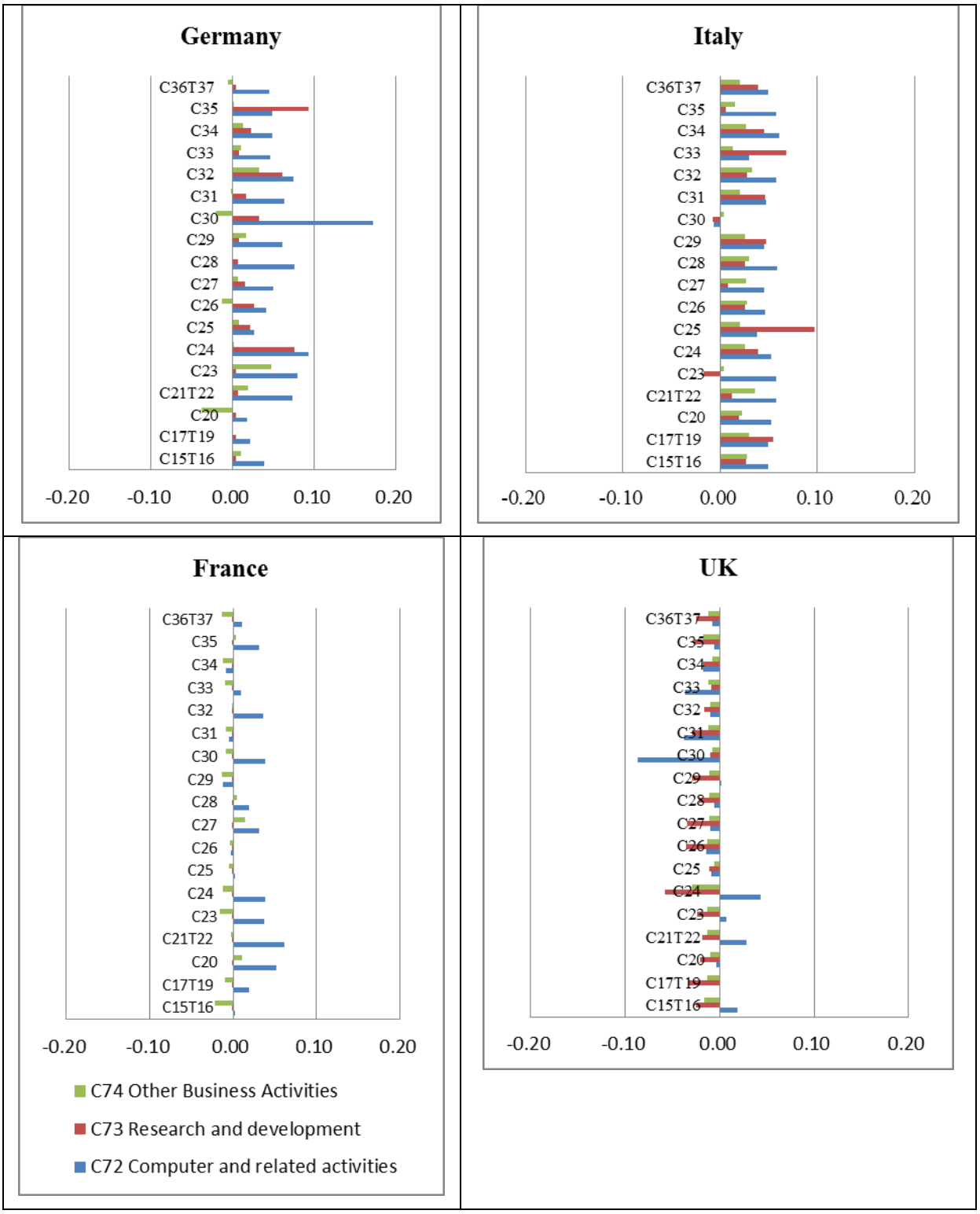


Figure 2 – Cumulated number of patents in manufacturing: 1995-2005

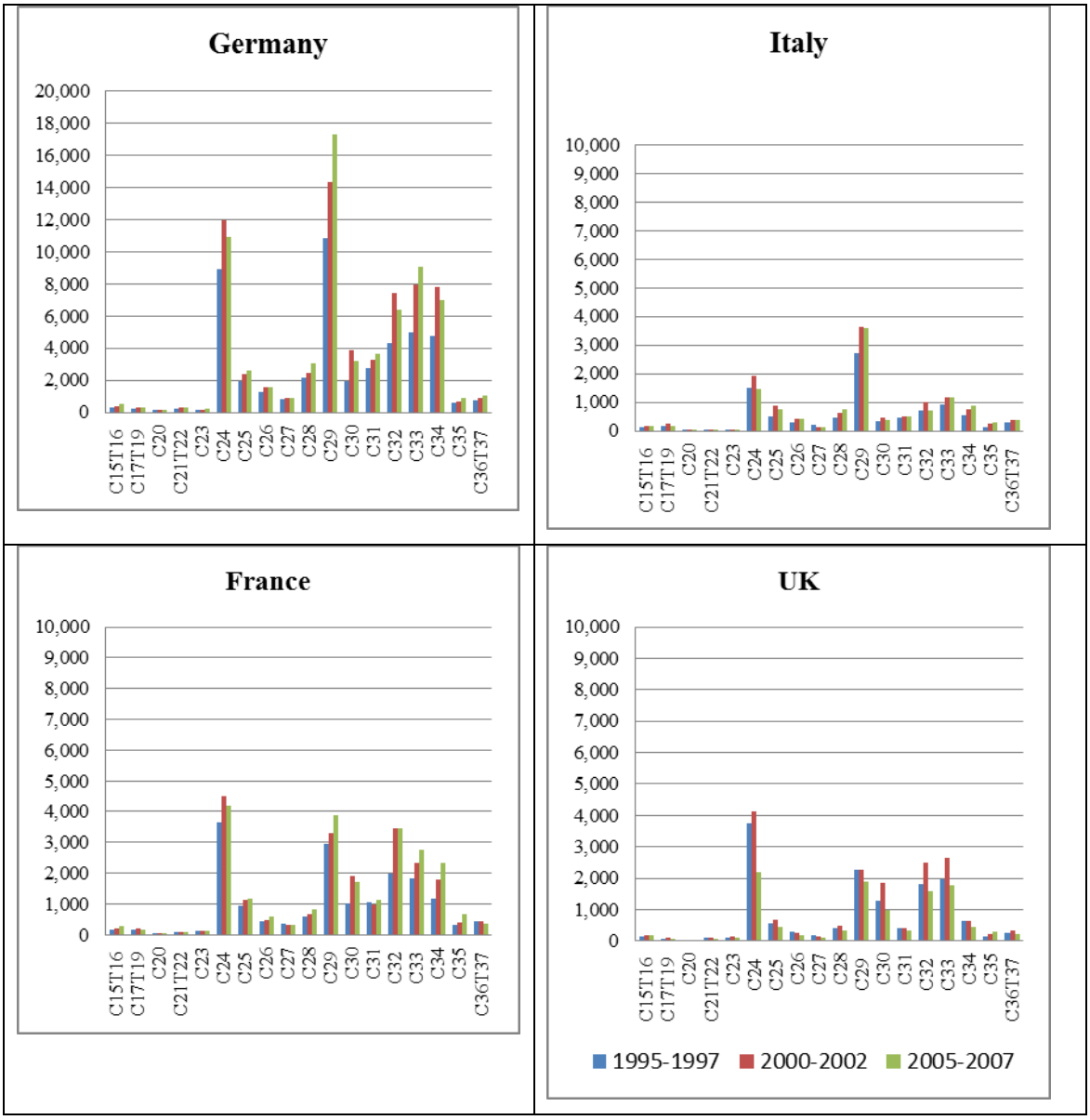


Table 4. Estimates results: Dependent variable *PATAVE*

VARIABLES	(i) Fixed effects robust	(ii) Fixed effects robust (France excluded)	(iii) Fixed effects robust (KIBS-RD excluded)
KIBS	0.191***		
	(0.0387)		
RD-INTRA	-0.0321	-0.0364	-0.0355
	(0.0388)	(0.0423)	(0.0399)
K-INT	-0.129**	-0.165**	-0.138**
	(0.0536)	(0.0647)	(0.0581)
L	-0.0284	-0.194	-0.0684
	(0.193)	(0.162)	(0.172)
D_time1	-0.105**	-0.212***	-0.152***
	(0.0514)	(0.0476)	(0.0481)
D_time2	0.0495	-0.0585	0.0597
	(0.0402)	(0.0524)	(0.0401)
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)
Constant	3.820**	6.810***	5.728**
	(2.621)	(2.416)	(2.418)
Observations	214	160	214
R-squared, within	0.444	0.508	0.496
R-squared, between	0.017	0.039	0.002
R-squared, overall	0.023	0.041	0.003
Number of i_panel	72	54	72
VIF	3.13	3.14	2.87

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

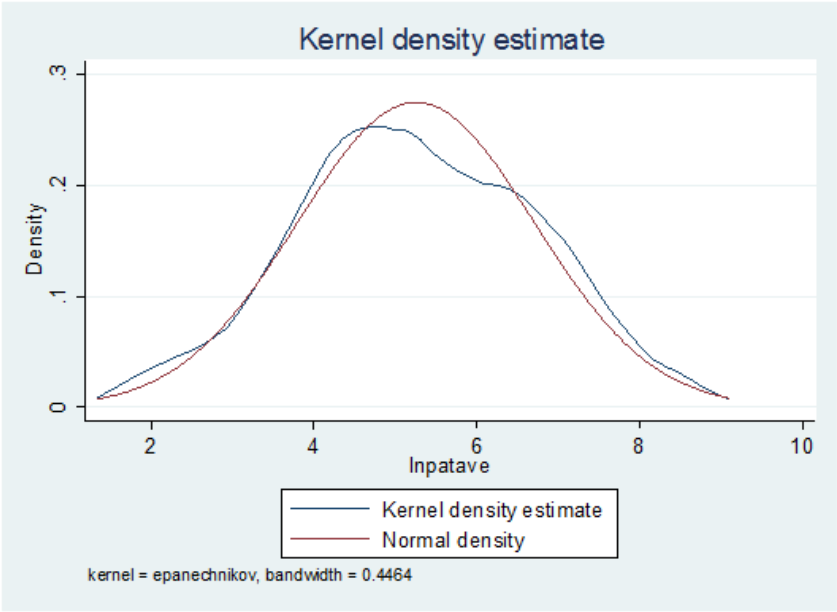
Manufacturing

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

Figure A1: PATAVE distribution



European Commission
EUR26362– Joint Research Centre – Institute for Prospective Technological Studies

Title: Do KIBS make manufacturing more innovative? An empirical investigation for four European countries
Authors: Daria Ciriaci, Sandro Montresor and Daniela Palma

Luxembourg: Publications Office of the European Union

2013- 30 pp. – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1831-9424 (online)

ISBN 978-92-79-34784-9 (pdf)

doi:10.2791/58386

Abstract
The paper aims at estimating the innovation impact of the vertical integration of knowledge intensive business services (KIBS) into manufacturing. By referring to the vertically integrated sectors of an economy, the innovative knowledge, which is transferred directly and indirectly from KIBS to manufacturing in an embodied way, is measured. Its impact on manufacturing innovation is then estimated. By merging OECD data on sectoral R&D and input-output tables with sectoral patent applications from the Pastat dataset, a panel of 18 manufacturing sectors is built up for the 4 largest European countries – France, Germany, Italy and UK – spanning from the mid-90s to the mid-00s. The more innovative sectors are actually those making more intensive and extensive use of R&D embodied into KIBS production flows. In policy terms, strengthening the bridge between KIBS and manufacturing appears as crucial as supporting KIBS activities and service innovations as such.

LF-NA-26362-EN-N

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Publications Office

ISBN 978-92-79-34784-9

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