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Open service innovation and the firm's search for external knowledge

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Abstract

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OPEN SERVICE INNOVATION AND THE FIRM'S SEARCH FOR EXTERNAL KNOWLEDGE

Abstract

The concept of open innovation captures the increasing propensity of firms to look beyond their traditional boundaries of operation. Insofar this phenomenon has largely been studied from the viewpoint of manufacturing businesses while services have received much less attention despite the predominant role they play in advanced economies. In this paper we investigate the open innovation practices of business services and identify whether and how they differ from open innovation in manufacturing. We analyze a unique dataset on open innovation practices amongst UK firms. We find that business services are more active seekers of external knowledge than manufacturers. We show that the production of complex outputs integrating a service component is associated with openness in both services and manufacturing businesses and that IP protection mechanisms support openness in both sectors. When we test for the role of different knowledge sources we find that customers are not more important for business services than for manufacturing firms, and that universities and the public research base are relatively more important than other knowledge sources in the open innovation practices of these knowledge-intensive services. The paper contributes to the theory of innovation by identifying the sectoral and firm-specific drivers of external knowledge sourcing and fills a very significant gap in the open innovation literature through its original quantitative and comparative analyses of open service innovation.

Keywords: Open innovation; service innovation; external knowledge; knowledge search.

1. INTRODUCTION

The ability of firms to search for, absorb and utilize external knowledge and their capacity to leverage or exchange internally-generated knowledge are essential characteristics of successful innovators. This is arguably one of the most important messages to emerge from the relatively long tradition of research on innovation systems (Freeman 1995; Lundval, 1992; Malerba, 2004; Nelson, 1993;), innovation networks (Ahuja, 2000; Burt, 1992; Freeman, 1991; Kogut, 2000; Powell and Grodal, 2005) and inter-organizational learning (Argote & Ingram, 2000; Brown & Duguid, 2000; Cohen & Levinthal, 1990; Coombs, Harvey & Tether 2003; Noteboom, 1999; Pavitt, 1998; Rosenberg, 1982; Rothwell, Freeman, Horsley, Jervis, Robertson & Townsend,1974; von Hippel, 1988).

Access to and use of external knowledge can help firms to generate or better exploit potential sources of competitive advantage. Through collaborative arrangements firms can reduce technological uncertainty, share costs, access complementary assets, enter new markets, or achieve economies of scale and scope along or across value chains (Ahuja, 2000; Cassiman and Veugelers, 2002; Faria et al., 2010; Miotti and Schwald, 2003).

It has been argued that firms are increasingly looking for knowledge outside their organisational boundaries (Chesbrough, 2003; 2006). While it is rather difficult to find consolidated evidence of a radical and widespread regime shift in firms' innovation strategies (Windrum, 2011), the concept of open innovation has been very successful at capturing the interactive nature of innovation processes and in synthesizing the set of strategic behaviors through which firms might develop an outward-looking approach to research and development (R&D) to source at least some knowledge of potential value to the company from the broader environment in which this operates. Vertical disintegration pressures (Langlois, 2003), modularization and outsourcing (Prencipe, Davies, & Hobday, 2003; Sturgeon, 2002), the growth of specialised technology markets (Arora, Fosfuri, & Gambardella, 2002; Brusoni, Prencipe & Pavitt, 2001) and difficulties in appropriating internal investments in intangibles (Chesbrough, 2003a; 2003b) would appear to have strengthened the firms' incentives to increase their reliance on external knowledge for innovation.

Interest in open innovation has been growing very fast in the last few years. Crucially, however, most of the theoretical developments and empirical evidence relate to manufacturing businesses. This is surprising given the predominant role of the service sector in advanced economies. The available evidence shows that services are no less innovative than manufacturing firms but might, in fact, innovate in different ways (Metcalfe and Miles, 1999; Tether, 2001; Tether and Swan, 2003). Tether (2005), for example, reports that services firms are more likely to collaborate with their customers and suppliers, whereas manufacturing firms would rely more on universities. Some recent quantative evidence has revealed the importance of external linkages for service firms' innovative performance (Leiponen, 2005; Love and Mansury, 2007; Love et al., 2010).[1] Despite these significant contributions, however, studies analyzing OI in services are still scarce. Chesbrough's latest work (2011) also responds to this body of evidence and addresses the problem of open innovation in services. Open service innovation is a relatively unexplored area of research where new theoretical contributions and empirical exercises can shed new light on the strategic search behaviors of firms.

In this paper we focus on business services, a segment of the service sector characterized by high growth, productivity and innovation rates (Rubalcaba & Kox, 2007). We study their open innovation practices and show to what extent and in what way these differ from manufacturing

[1] For recent quantitive evidence of open innovation in manufacturing not derived from CIS data, see Lichtenthaler (2007; 2009) and Lichtenthaler and Ernst (2009).

sectors. We analyze a unique dataset generated through an original survey of open innovation practices amongst UK firms. We find that services are more 'open' seekers of external knowledge than manufacturers. Secondly, the production of complex output that integrates a service component is an important driver of openness not only for services but for all businesses. Thirdly, strategic protection mechanisms are no less significant for business services than for manufacturing firms. Moreover, and against expectations, we find that universities and the public research base are relatively more important than customers as a source of external knowledge for business services engaging in open innovation activities. The paper contributes to the theory of open innovation by identifying the sectoral and firm-specific drivers of external knowledge searches and fills a very significant gap in the open innovation literature through its original quantitative and comparative analyses of service innovation.

The paper is structured as follow. In the section that follows we build on the literatures on external knowledge search and open innovation to develop a set of testable hypotheses on the characteristics of open innovation in business services. We then present our data and methods of analysis. After illustrating our results, we discuss them in relation to the prior art, identify the limitations of the study and conclude on the implications of our findings for further research.

2. THEORY AND HYPOTHESES

2.1. Why 'Open Innovation'?

The importance of collaborations (Pisano, 1990), alliances (Ahuia, 2000) or more generally systemic connections (Nelson, 1993) in the process of innovation has long been recognised in the innovation literature and a perfectly 'closed' model of innovation might in fact be quite difficult to find in the long history of technological change (Mowery, 2009). 'Openness' is a matter of degree and might characterize different phases or component of innovation within the same firm (Chesbrough, Vanhaberbeke & West, 2006). Theoretically, there are slightly different interpretations of the concept of open innovation, as Dahlander and Gann (2010), Huizingh (2010) and Lichtenthaler (2011) point out in their recent reviews. This can also be referred to the fact that the notion of open innovation contains many traces of different theoretical constructs, with some overlaps. Among them, there are the concepts of exploration vs. exploitation (March, 1991), absorptive capacity (Cohen & Levinthal, 1990), collective invention (Allen, 1983), innovation sources (von Hippel, 1986) and complementary assets (Teece, 1986).

Despite these possible overlaps and the existence of different interpretations, the concept of open innovation has been useful in integrating, organizing and re-classifying from a strategic perspective a broad set of activities, resources and capabilities aimed to foster innovative combinations of internal and external knowledge inputs with the aim to enhance firm competitiveness[2]. As a core principle, 'openness' implies a rejection of the belief that firms can internally develop all the knowledge they need (Chesbrough, 2006) and a reaction to the so-called 'Not-Invented-Here' syndrome, which can be a powerful barrier to innovation especially in large established firms (Katz & Allen, 1982).

Open innovation requires the capacity to absorb knowledge from multiple sources and in turn share knowledge with external organizations – competitors, clients, suppliers, etc. – in order to generate 1) direct returns from the trade of unused or underutilized intangible assets or 2) indirect returns from the acquisition of higher-quality production inputs, access to shared assets (otherwise too costly), or the diffusion of favorable designs, standards or technology platforms.

The literature distinguishes inbound from outbound activities (Chesbrough & Crowther, 2006; Gassmann & Enkel, 2006). Inbound activities involve access to external innovation sources

[2] For a definition of open innovation along these exact lines, see Chesbrough et al. (2006: 1). For a review and discussion of the way in which the term has been used in the literature, see Dahlander and Gann (2010) and Lichtenthaler (2011).

and the acquisition and absorption of knowledge generated outside the boundaries of the firm. Outbound activities involve the disclosure and sharing of internal knowledge with external organizations, including competitors, suppliers, customers and users, professional advisors, universities and other research partners. Both types of transactions may take place through market (i.e. in- or out-licensing; equity investments, contract R&D) or non-market mechanisms (i.e. personal connections; informal collaboration) and reflect pecuniary (immediate financial returns) as well as non-pecuniary (long-term strategic returns) incentives (Dahlander and Gann, 2010; Lichtenthaler, 2011).

Inbound flows of knowledge can reduce spending on asset-specific R&D if the output of a similar investment already exists and can be effectively accessed at a fraction of the cost of a new firm-specific R&D project. This, however, implies a sufficient degree of absorptive capacity. Alternatively, the search for external knowledge can trigger the renewal of firm's capabilities or help identify new ways of exploiting existing knowledge by sourcing complementary assets from outside. Importantly, the benefits of external search are not unlimited (Dahlander & Gann, 2010) and the management of this set of activities is very challenging (Lichtenthaler, 2011). Firms can over-search and face not only decreasing returns to open innovation but also negative performance effects if they operate beyond optimal levels of 'openness' (Laursen & Salter, 2006). In addition, the attempt to connect unrelated knowledge inputs across organisational boundaries might fail due to high transaction costs, high risks of misalignment of cognitive frameworks, practices or incentives (Ahuja & Kattila, 2001; Sapienza, Parhankangas & Autio, 2004). The risks of disclosure may of course include an unforeseen reduction in the capacity to realize the full benefits of the firms' own investments, technology market frictions or classic asymmetric information problems.

2.2. Why should service innovation differ from manufacturing?

Traditional industrial economics and technologist approaches to innovation used to fundamentally underestimate the role, extent and effects of innovation in services (Djellal & Gallouj, 2011; Metcalfe & Miles, 1999). Services are no longer seen as technologically backward, 'unprogressive' and passive adopters of technology, but both theory development and empirical evidence on the dynamics of the service economy are still lagging behind manufacturing.

The introduction of the European Community Survey (CIS), where the services sectors were included in the early 1990s, greatly contributed to the growth of scholarly work on services partly because it enabled the collection of observations on innovation that were not limited to R&D or patenting. Quantitative analyses based on CIS data showed that overall R&D plays less important a role in services, even though this does not hold true for all services (Evangelista, 2000; Tether, 2003). The traditional distinction between product and process innovations becomes weaker in a service context; because services often consist of processes that are hardly separable from the outcomes they produce (Gallouj & Savona, 2009; Sirilli & Evangelista, 1998). In addition, service innovation tends to imply greater emphasis on organizational and human capital factors relative to more tangible assets.

Service firms have been found to rely heavily on information and communication technologies (Cainelli, Evangelista & Savona, 2006) and non-R&D innovation expenditures (Abreu, Grinevich, Hughes & Kitson, 2009) and seem to use more external knowledge sources than manufacturing (Hipp, 2010; Tether & Tajar, 2008). They appear to collaborate more frequently with their customers and suppliers (Tether, 2005). There is also some evidence that this practice has positive effects on firm innovation performance (Leiponen, 2005; Mansury & Love, 2008; Love et al., 2010).

One striking feature of the service economy is the variety existing between and within the service sector. This encompasses a very broad range of activities with different characteristics (Hughes & Wood, 2000; Miles, 2005; Tether, 2002; Rubalcaba & Kox, 2010), although some studies indicate that the degree of similarity between services and manufacturing increases with the level of knowledge-intensity, so that knowledge-intensive services (Koch & Strotmann, 2008; Leiponen, 2005, Love et al., 2011) will display innovation behaviors similar to those of high-technology manufacturing firms (Hollenstein, 2003; Rodriguez & Camacho Ballesta, 2010). Yet, the empirical evidence provided in the aforementioned studies is not conclusive since they report contrasting results, for example, on the role of specific sources of knowledge and collaboration partners. This further justifies the need to deepen our understanding of whether the search for external knowledge may indeed have different drivers and present different characteristics across sectors of the economy.

2.3. Open innovation in business services

Business services are an extremely important component of the service economy (Rubalcaba & Kox, 2007). They trade intermediate inputs by leveraging human capital, as opposed to physical capital, and overall display rates of innovation not inferior to manufacturing businesses (Tether & Tajar, 2008).

The ‘relational’ nature of their economic activities suggests that the open innovation model is highly suitable to these businesses, although the study of open innovation has insofar been developed from and for manufacturing businesses. The first important question is that if services are ‘relational’ businesses, then we would expect ‘openness’ to be even more important for business services than for manufacturing.

Our first hypothesis is, therefore, that controlling for firm-level characteristics:

Hypothesis 1: Business service firms are more 'open' innovators than manufacturing firms.

Firms are typically classified as services or manufacturers, but evidence is growing that services are becoming an increasingly important dimension of the offer of all firms, including manufacturers, who are expanding the service component of their business models to appropriate value or retain their customer base. Advocates of 'servitization' strategies argue that these enable manufacturers to get closer to their customers, enhancing understanding of users' needs, strengthening relationships and increasing customer loyalty (Vandemerwe & Rada, 1988). Chesbrough (2011) suggests that by integrating a service dimension in their product and process innovation activities, all businesses can gain or sustain competitive advantage. A recent survey of UK businesses has indeed found that 80% of manufacturing firms were offering some type of services (Tether & Bascavusoglu-Moreau, 2011). The offer of complex bundles of new products, processes and services is likely to demand the recombination of different resources, including knowledge inputs, coming from different sources and this can only be achieved by intensifying the search for external knowledge that is necessary to sustain an integrated business model (Chesbrough, 2011).

This leads us to hypothesize that:

Hypothesis 2: The degree of complexity (service-integration) of the innovation output of a firm positively affects its degree of 'openness'.

The ability of firms to search for external knowledge, and also their ability to use it, are closely linked to their ability to absorb this knowledge. Absorptive capacity (Cohen and

Levinthal, 1989) is a key characteristic of firms that successfully seek, obtain and exploit external knowledge, suggesting a complementary relation between internal and external knowledge sources (Cassiman & Veugelers, 2006; Veugelers, 1997; Veugelers & Cassiman, 1999). The ability to capture external knowledge flows is, however, conditioned by knowledge appropriation mechanisms, while the firms' propensity to share knowledge is affected by their ability to protect the value of their investments (Cassiman & Veugelers, 2002). The strength of IP protection regimes of the sector of operation is important because appropriation mechanisms are not all equally well suited to any innovation activity (Hipp & Grupp, 2005; Tether & Tajar, 2008).

It could be argued that formal IP mechanisms might be less important for services than for manufacturing businesses because innovation is embodied in human capital more often than R&D investments (Tether, 2005; Sundbo, 1997). Moreover, the nature of knowledge exchanges which we might expect from a 'relational' business model could in theory be protected by informal strategic mechanisms (Hipp & Grupp, 2005). However, a higher propensity to use external knowledge sources could require more – not less – formal IP protection if firms are to capture the benefits of open innovation activities. If the appropriate legal mechanisms are not in place, it is unlikely that firms can sustain very 'open' business models because they will be more exposed to the risk of leakages and IP abuse. Furthermore, previous work has suggested that the distinction between services and manufacturing with regards to IPR is rather crude, and that there are sectoral differences within services in IP protection related to differences in imitation, R&D intensity and external linkages (Mairesse & Mohnen, 2003).

To subject these arguments to empirical test we formulate the following hypothesis:

Hypothesis 3: IP protection mechanisms will support as high a degree of 'openness' in business services as in manufacturing firms.

The final aspect on which we focus in this paper is the propensity of businesses to co-operate with different partners, on the basis of their relative preferences for the different types of knowledge they are seeking to obtain or to exploit. Typically, engaging with customers and suppliers can help to better specify the market requirement for innovated goods, services or processes and to spread the costs and risks of the innovation process. Interaction with customers, and the co-creation of the firm's output with its customers, has been emphasized as the most important channel of information supporting the adoption of an open service innovation model (Chesbrough, 2011). Prior literature has also highlighted the benefits of interaction with lead users (Hagedoorn, 1993; Von Hippel, 1976; Tether, 2002). This argument should be especially valid for services by virtue of their intangible nature, their process-based business model and the often theorized co-production of their output with customers (Brouthers & Brouthers 2003; Chesbrough, 2011; Miles, 2006).

The literature has placed an emphasis on the importance of different sources of external knowledge, but has overlooked the need to test the importance to the firm of each source relative to the other sources. This distinction is significant because it can provide a synthetic indication of the firms' preferences for external knowledge sourcing for the purposes of innovation. We therefore formulate two hypotheses: the first addresses the absolute importance of customers (4a), the second addresses the importance of customers relative to the other sources (4b).

Hypothesis 4a: The importance of customer positively affects the degree of openness of business services firm more than manufacturing firms.

Hypothesis 4b: The importance of customers relatively to other sources positively affects the degree of openness of business services firm more than manufacturing firms.

Among the sources of knowledge that are key to successful innovation, universities and public research organizations are playing an increasingly prominent role in the management and policy literatures, and the establishment of stronger links with the public research base has not only been pursued by companies as part of their exploration activities, but has been actively encouraged in a variety of regional innovation policies (Perkmann & Walsh, 2007). Firms might engage in collaborative arrangements with universities and research institutions in order to gain access to basic knowledge, either to better exploit their existing capabilities or to explore new avenues for innovation and growth (Bercovitz & Feldman, 2007; Veugelers & Cassiman, 2005). Again, in relation to this aspect of firms' strategic behavior, the research focus is on manufacturing firms rather than on services as the most likely open innovation partners of universities. The typical argument is that manufacturers have the strongest need and can extract the most value from basic R&D whilst services will typically rely on investments in human capital. Systematic comparative evidence on this aspect is also rather scarce. On this basis, we cannot rule out the possibility that services will seek to co-operate with the research base because they want to outsource research activities they do not or cannot carry out on their own or because the exchange of knowledge is an intrinsic part of their service. We formulate again one hypothesis for the absolute importance of this knowledge source (5a) and one for its importance relative to all the other sources (5b):

Hypothesis 5a: The importance of universities and public research organizations positively affects the degree of openness of a manufacturing firm more than a business service firm.

Hypothesis 5b: The importance of universities and public research organizations relatively to other sources positively affects the degree of openness of a manufacturing firm more than a business service firm.

3. DATA AND METHODS

3.1. The survey

The data we use in this paper are drawn from the UK~IRC Open Innovation Survey, specifically designed and launched in 2010 to study the open innovation practices of UK companies[3].

The research team used systematic random sampling measures to draw a sample of 12,000 firms, with between 5 and 999 employees, from Bureau van Dijk's FAME Database, which contains detailed financial company-level information on UK and Irish businesses. The sampling proportions in terms of sector were 65% for manufacturing and 35% for services, plus two additional samples from the pharmaceuticals and clean energy sectors. After carrying out pilot tests in different size groups and sectors, 5 waves of questionnaires were sent out by post between June and November[4]. 1,202 firms completed the survey, leading to a 10% response rate. To check for non-response bias, FAME Data were used again to compare respondents with non-respondents in terms of size, turnover, and year of firm formation. No significant difference was found except for low-tech business services, where respondents had a significantly smaller turnover than non-respondents.

The sample size we use in this study varies between 764 and 829, depending on model specification. Around 162 firms – those who completed the shorter version of the survey – have to be removed from the original sample. A further 200 firms have also been deleted due to incomplete responses (265 in the final specification to account for complete data records). Between the original sample of 1202 firms and our final database we did not find any sample

[3] For details on the survey see Cosh and Zhang (2011). Business services were sampled within SIC classes 64, 65, 66, 70, 72, 73, 74, 85.
[4] For waves 1-3, the original 12-pages long questionnaire was sent out; however, in order to increase the response rate, shorter versions have been sent for the following waves.

attrition bias in terms of firm size, age, firm's largest market, competition intensity, innovation complexity and use of external sources of knowledge. However, our final sample (with no differences between the service and manufacturing sub-samples) is found to have a bias towards more open firms, with higher R&D expenditures and higher share of employees with a degree; and our results should be interpreted bearing this bias in mind.

The final sample shows a reasonable spread across industries with shares of manufacturing 67% (versus 63% in the original sample) and services 33% (versus 37% in the original sample).

3.2.Variables and descriptive statistics

Dependent variable:

The dependent variable in our study is the extent of firms' open innovation (OI) activities. In the survey, firms were asked to indicate the degree of importance of various informal and/or formal activities with external parties, in order to accelerate innovation. These activities are listed in the Appendix (A1). The importance of each activities was evaluated by means of a Likert Scale (0=not used, to 3=highly important). We measure the scope of open innovation activities by adding up these 15 activities and normalizing this sum. As the number of formal activities (10) is higher than the number of informal activities (5) in the survey, however, we weighted the measures accordingly. Firms that did not engage in any formal or informal activities get a score of 0. Firms with higher scores are considered more "open"; this reflects either that a firm engages in more formal/informal activities, that it considers those activities as highly important for innovation, or both. A score of 1 corresponds hypothetically to firms that have engaged in all types of activities and that have scored those activities as highly important, although no such firm exists in our sample. The resulting open innovation variable has a high degree of internal consistency with a Cronbach's alpha of 0.84[5].

The most widely used open innovation activity in our sample (both in the original and the final sample) is engaging directly with lead users. 63% of the firms in our final sample reported to have engaged directly with lead users in the last three years, and 24% scored this engagement as highly important. This is followed by the joint R&D activities (34% of the final sample), sharing facilities (30%) and joint marketing/co-branding and outsourcing/contracting out R&D (29% of the sample). The least used open innovation practice is informally exchanging ideas, with only 15% of the firms in our final sample reporting it.

When we look at the differences between services and manufacturing, descriptive statistics reveal that business services are more engaged in open innovation activities as well as in formal collaborations than manufacturing firms, and these differences are statistically significant at a 95 percent level[6]. There are considerable differences between the manufacturing and services firms in our sample regarding the OI practices they actively pursue. Although engaging with lead users is the most widespread OI activity in both sectors, manufacturing firms tend to participate in joint R&D projects, whereas services firms participate mainly in joint-marketing/co-branding activities.

Independent variables:

Our key independent variables relate to the complexity of innovation output, the appropriability regime and the sources of knowledge. The complexity variable has been

[5] A simpler measure, open innovation breadth (see Laursen and Salter (2006), Leiponen and Helfat (2010) among others) has also been constructed (Cornbach's alpha = 0.85) and used to check for robustness of our results.

[6] T-test results are not reported here but are available upon request from the authors.

constructed as a combination of the different types of innovation listed in the Appendix (A2). It ranges from 0 to 5, according to the number of different types of innovation launched in the last three years, conditional on having introduced new or significantly improved service product and/or new method to produce and deliver the service product. 80% of our final sample has been engaged in some kind of innovative activities, however only 8% report more than 4 types of innovation. Although a slightly higher share of manufacturers report innovation, we do not find any statistical difference between the two sectors.

The appropriability regime has been introduced in the regression at the sectoral level (SIC 2 digit). The survey asked firms about the importance of different methods to protect their innovations, using a Likert Scale (0=not used, to 3=highly important). Following Cassiman and Veugeulers (2006), we distinguish between the effectiveness of IP protection (patents) and strategic protection methods. Strategic methods of protection include secrecy, complexity of design and lead-time advantage over competitors. Effectiveness of IP protection is defined as the industry average of the firm-level scores of importance. Likewise, the effectiveness of strategic protection is defined as the industry average of the scores of importance of the three strategic protection methods as perceived by the firms. On average, firms that are engaged in open innovation activities score both formal and informal methods of protection as more important, compared to firms that are not engaged in open innovation activities.

Regarding the different sources of information, we are particularly interested in the role of customers and users, and of the universities, higher education institutes and public sector research organizations. In order to test our hypothesis 4a (5a), we use the scores or importance of customers and users (universities and other higher education and research organizations) as perceived by the firms. Furthermore, in addition to this absolute measure of the importance of these different types of information sources, we also want to assess their relative importance for hypotheses 4b and 5b. For this purpose, we construct a ratio of the importance of customers and users (universities and other higher education and research organizations) over the importance of all the other sources of knowledge. As expected, customers and users represent the most widely used knowledge sources, with 91% of our sample confirming them as a source of information, and 31% scoring them as highly important. Meanwhile, only 45% of our sample report having used universities and higher education institutes as a source of information. These shares are very similar between manufacturing and services sectors.

Control Variables:

We introduce a measure of research and development (R&D) activities, measured as the logarithm of firms' R&D expenditure and a measure of knowledge intensity, measured by the percentage of employees with a first and/or higher degree, in order to control the effect of R&D and knowledge on firm's innovative performance. Firm size and age may affect innovative performance; we thus include the logarithm of number of employees, and firm age and its square term to account for potential non-linearities[7]. We also take into account firms' largest market in terms of its sales revenue and the intensity of competition as perceived by the firm.

3.3.Modeling and estimation strategy:

We test our hypothesis using an ordinary least squares (OLS) estimations. In order to evaluate the difference between services and manufacturing sectors, we introduced a dummy variable which is equal to 1 if the firm belongs to a service sector and 0 otherwise. By interacting our independent variables with the service sector dummy, we are able to assess the specificity of

[7] We also introduced this latter variable as categories of age (not reported), in order to assess any potential impact of a particular age on engaging in open innovation activities, but the results did not differ significantly.

our service firms. We tested for multicolinearity by calculating the variance inflation factors (VIFs). The VIF values for all variables are well below the threshold criterion of 10, suggesting that there is no excessive multicolinearity in the data (Kleinbaum, Kupper & Muller, 1988). The definition of variables, descriptive statistics and tables can be found in the Appendix B. (Tables B1, B2 and B3).

3.4. Robustness Checks:

We performed two different robustness checks. Firstly, we checked the robustness of our econometric specification by using a fractional logit model (Papke & Wooldridge, 1996; 2008), which can be applied since our dependent variable ranges between 0 and 1. The results between the two estimation methods were very similar. For the sake of clarity, and given the complexities associated with the interaction terms in non-linear model, we present here the OLS model.

The second robustness check relates to the dependent variable. We constructed a breadth measure for open innovation activities, similar to the one used in well-known prior studies (Laursen & Salter, 2006; Leiponen, 2005). The results obtained with this new dependent variable are again very similar to those presented in the paper.[8]

Given the differences in the number of observations between different specifications, we also re-estimated the first Table (first 6 models) with the reduced sample of 764 observations (Appendix C, Table C1).

[8] The results for these additional estimations are available from the authors upon request.

4. RESULTS

Table 1 shows the set of OLS models we use to test our first three hypotheses and Table 2 shows the results of the inclusion of the knowledge sources effects (hypotheses 4 and 5). The first model (Base model) includes the baseline control variables. The second model introduces the dummy variable ‘Service’. Model 3 includes the complexity variable to test the effect of the firm’s innovation output mix (product-process-service). In Model 4 this is interacted with the sector dummy. Similarly, Model 5 introduces the appropriation mechanism variables, and Model 6 includes their interactions with the sector dummy.

INSERT TABLE 1 ABOUT HERE

In the first column (Model 7) of Table 2 we show results for the variables indicating the importance of customers/users and universities/higher education/public research sector. The interactions between the role of each knowledge source with the sector dummy are included, respectively, in models 8 and 9. The fully saturated model follows in the next column (10). Following the same line, in Table 3 we present results on the relative importance of the different sources of external knowledge.

INSERT TABLE 2 AND 3 ABOUT HERE

Among the control variables, firm size is positively related to openness, while the effects of age (also in its squared specification), largest market of operation and the intensity of perceived competition are not significant. R&D expenditures are instead an important driver of openness. Human capital is also significant, although it exerts a weaker effect. These results should not be discounted as completely predictable since the lack of resources faced by smaller firms might have incentivized the search for external knowledge. In addition, the greater flexibility of SMEs in adapting to changing external environment might have proved very useful in this set of activities. These baseline results are, however, broadly in line with prior findings that showed that among the firm-level characteristics associated with 'openness', cooperation tends to increase with the size and R&D intensity of the firm (Veugelers, 1997; Fritsch and Lukas, 2001; Negassi, 2004). On the basis of their larger resource bases, larger firms face lower search and management costs and expect to benefit more from collaborative agreements.

Our first hypothesis posited that business services were more active seekers of external knowledge than manufacturing firms given the interactive nature of their core activities. The results we obtain from Model 2 confirm that services are indeed more 'open' businesses than manufacturing. Hypothesis 2 predicted that the inclusion of a service component in the output mix of any firm positively affected the firm's openness because of the need to gather and recombine different knowledge inputs, which had to be acquired through a broader set of search activities. We also find strong support for this hypothesis (Model 3). Not unexpectedly, this effect is reinforced by the firm being mainly a service business, as shown in the estimation of (interaction) model 4.

Hypothesis 3 defied the expectation that the use of legal IP protection mechanisms would be less important for business services than for manufacturing businesses on the ground that services are people-based activities which would benefit more from informal (or 'strategic', following Cassiman and Veugelers, 2006) protection mechanisms. The effect of IP protection on the whole sample is indeed positive and significant, in line with literature. But controlling for strategic protection mechanisms, this effect is even slightly stronger for business services than for manufacturing, in contrast with the general assumption often made about the use of IPR in service innovation.

Hypothesis 4a stated that the importance of customers is associated with a higher degree of openness for services than for manufacturing firms because services typically co-create their output with their clients. Conversely, hypothesis 5a posited that universities and the public research base would be more important for manufacturing than for business services in predicting the degree of openness of firms. Our results show that indeed both sources of knowledge are positively associated with the degree of open innovation activities for the whole sample (Table 2, Model 7). Contrary to our expectations, however, customers do not seem to be a more important source of knowledge for business service firms (Model 8). It is actually universities and the public research base that are found to be an important source of external knowledge for these services as far as innovation is concerned (Model 9).

Hypotheses 4b (5b) stated that *relative to other knowledge sources* the importance of customers (universities and the public research base) is associated with a higher (lower) degree of openness for business services than for manufacturing firms. From the viewpoint of open innovation, universities and the public research base, not customers, seem to be the most important source of external knowledge (Table 3, Model 11). Interestingly in this respect, and against our expectations, customers are relatively less important for business services that manufacturing while universities and the public research base are relatively (if weakly) more important for the former than for the latter (interaction models 12 and 13).

These counter-intuitive results might require some additional comment. Our results do not show that customers are unimportant. Instead, they show that customers are relatively less important than other sources, more specifically universities and the public research base, especially for business services, for the purposes of innovation. The absolute – as opposed to relative – importance of the two sources is in fact positively and significantly associated with the degree of openness of firms (Table2, Models 7). But if we were to limit our analysis to these indicators we would fail to capture the order of preference with which firms might engage in open innovation activities. This is relevant because the search for external knowledge is not costless and firms make strategic decisions that explicitly or implicitly take into account the opportunity costs of any choice of partners relative to all the available alternatives[9].

Figures 1-4 chart the interaction effects of the interaction models 4, 6, 8, 9, 12 and 13, and provide clear illustrations of our results. Table 4 summarizes the hypotheses and the outcome of estimations.

INSERT FIGURES 1-4 ABOUT HERE

INSERT TABLE 4 ABOUT HERE
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5. DISCUSSION AND CONCLUSION

Successful innovation is increasingly dependent on the effective recombination of knowledge inputs across firm boundaries. Inter-firm knowledge flows have the potential to improve the firm's existing output or production processes, for example, by disclosing knowledge to partners, users or suppliers and incorporating valuable feedback (Henkel, 2006); or they can generate direct returns from underutilized intangible resources that can be traded on technology markets (Arora et al., 2001; Fosfuri, 2006).

There are, however, important differences across sectors of the economy in the extent to and the way in which firms use open innovation strategies to gain or maintain competitive

[9] In interpreting this result, as we have already emphasised, it is important to bear in mind the significant proportion of R&D-intensive services in our sample. Note as well that the R&D performed by services does not necessarily have technological nature.

advantages and these differences have important implications for the strategic use of external knowledge sources. In this paper we extend our theoretical understanding of the open innovation model to take into account macro-sectoral specificities. In particular, we make a substantial contribution to the development of the emergent research on open service innovation (Chesbrough, 2011).

Existing analyses of innovation survey data have revealed that there is considerable variation in the way in which different sectors innovate. These analyses could only address a limited set of questions given the broad coverage of the questionnaire on which they are based. Typically, these studies work with the observation of how many and what types of collaborations firms use, but cannot address the problems of what open innovation activities they are engaged in and in what way.

As to the empirical evidence that is available on the open innovation paradigm, the number of case studies on the topic has been growing considerably, but these typically focus on manufacturing firms, with an emphasis on large companies in high-tech sectors. Only recent contributions (Love et al. 2011; Love et al. 2010; Gassmann et al. 2010; Chesbrough, 2011) constitute rare exceptions that help redirect the necessary attention services, a fundamental component of advanced economies by both value added and employment.

From a methodological viewpoint, this study provides novel quantitative evidence on open service innovation. Case study evidence is extremely important, but is also difficult to systematize and generalize given the very different takes on open innovation found across cases. Furthermore, our evidence is comparative and we are able to look at the same time at the characteristics of manufacturing and business service sectors. Even though it is based on cross-sectional data, which cautions against making strong claims on causality, it provides a unique opportunity to observe the conduct of open innovation activities in a fairly large sample of businesses. Moreover, our results are robust to different specifications of both our dependent variable and the estimation technique.

Overall, among the firm-level characteristics associated with 'openness', our results confirm that cooperation tends to increase with R&D intensity (Fritsch & Lukas, 2001; Negassi, 2004; Veugelers, 1997). Human capital intensity is also positively associated with openness, as expected by both innovation theory and resource-based perspectives.

The relational nature of services is reflected in their openness and so is the complexity of the firm's offering defined as the service-integration of its innovation output (Chesbrough, 2011). The more complex the innovation, and the higher the degree of technology intensity, the more likely that firms will seek external knowledge (Bayona, Garcia-Marco & Huerta, 2001; Piga & Vivarelli, 2004; Tether, 2002). Our findings are also compatible with the view that service innovation tends to be recombinative or 'architectural' than purely technological in nature (de Vries, 2006). Furthermore, more openness requires appropriate formal IP protection, which proves to be more important than strategic appropriation mechanisms. This is as true for business services as it is for manufacturing firms.

The relational nature of services does not only imply interactions, or co-creation of output, with customers, as it is often assumed in the service literature (Vargo, Maglio & Akaka, 2008). Although customers remain a very important source of knowledge both for business services and manufacturing firms, the former seem to be driven towards potentially higher marginal benefits generated from engaging with universities and the public research base, in contrast with the results of previous studies based on the general service sector and/or on older data (Tether, 2002; Leiponen, 2005). Our results might indicate a development over time in the patterns of collaboration of firms, a trend reflected in the growing institutional expectation that universities improve the impact of their research by intensifying their collaboration with industry.

Finally, the question must be asked whether openness translates into superior market performance and whether and under what circumstances there are differences in the performance of firms with different characteristics. While this is outside the scope of this contribution, it certainly constitutes an important avenue for further research.

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TABLES

Table 1: Determinants of OI Activities

	(1)	(2)	(3)	(4)	(5)	(6)
Size	0.007**	0.007*	0.005	0.005	0.005	0.006*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age squared	0.000	0.000	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Largest market	-0.001	0.002	0.003	0.003	0.001	0.001
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Competition intensity	0.000	-0.001	-0.003	-0.003	-0.004	-0.004
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D expenditures	0.020***	0.021***	0.020***	0.020***	0.019***	0.020***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Human capital	0.001***	0.000**	0.000**	0.000**	0.000**	0.000**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Service Dummy (S)		0.039***	0.037***	0.023*	0.030**	0.099
		(0.01)	(0.01)	(0.01)	(0.02)	(0.10)
Service integration			0.014***	0.010***	0.010***	0.014***
			(0.00)	(0.00)	(0.00)	(0.00)
Service integration X (S)				0.014**	0.013*	
				(0.01)	(0.01)	
Effectiveness of IP Protection					0.030**	0.015
					(0.01)	(0.02)
Eff. of Strategic Protection					-0.009	0.007
					(0.02)	(0.02)
IP protection X (S)						0.035*
						(0.03)
Strategic protection X(S)						-0.053
						(0.05)
Constant	0.068***	0.048**	0.039*	0.046**	0.011	-0.003
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)
Number of observations	829	829	829	829	820	820
F-test	31.15	28.43	27.90	25.40	22.02	20.34
R-Squared	0.21	0.22	0.23	0.24	0.24	0.24

* $p < .10$, ** $p < .05$, *** $p < .01$. Two-tailed tests. Standard errors (robust to heteroskedasticity) are in parentheses.

Table 2: OI Activities and Scores of Customers and Universities

	(7)	(8)	(9)	(10)
Size	0.003	0.003	0.004	0.004
	(0.00)	(0.00)	(0.00)	(0.00)
Age	-0.000	-0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Age squared	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Largest market	-0.003	-0.003	-0.003	-0.003
	(0.01)	(0.01)	(0.01)	(0.01)
Competition Intensity	-0.000	-0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
RD Expenditures	0.014***	0.014***	0.014***	0.014***
	(0.00)	(0.00)	(0.00)	(0.00)
Human Capital	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Service Integration	0.011***	0.011***	0.011***	0.011***
	(0.00)	(0.00)	(0.00)	(0.00)
Effectiveness IP Protection	0.019*	0.019*	0.013	0.013
	(0.01)	(0.01)	(0.01)	(0.01)
Effectiveness Strategic Protection	0.005	0.005	0.013	0.012
	(0.02)	(0.02)	(0.02)	(0.02)
Importance Score of Customers	0.021***	0.018***	0.021***	0.020***
	(0.00)	(0.01)	(0.00)	(0.01)
Importance Score of Universities	0.073***	0.073***	0.058***	0.058***
	(0.01)	(0.01)	(0.01)	(0.01)
Service Dummy (S)	0.046***	0.032*	0.027**	0.023
	(0.01)	(0.02)	(0.01)	(0.02)
Importance of Customers X (S)		0.007		0.002
		(0.01)		(0.01)
Importance of Universities X (S)			0.037***	0.036**
			(0.02)	(0.02)
Constant	-0.034	-0.030	-0.040	-0.038
	(0.05)	(0.05)	(0.05)	(0.05)
Number of observations	789	789	789	789
F-Test	34.10	31.75	33.27	31.02
R squared	0.38	0.38	0.39	0.39

** p < .10, ** p < .05, *** p < .01. Two-tailed tests. Standard errors (robust to heteroskedasticity) are in parentheses.*

Table 3: OI Activities and Relative Importance of Customers and Universities

	(11)	(12)	(13)	(14)
Size	0.004	0.006*	0.005	0.005
	(0.00)	(0.00)	(0.00)	(0.00)
Age	-0.000	-0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Age squared	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Largest market	0.000	0.002	-0.001	0.000
	(0.01)	(0.01)	(0.01)	(0.01)
Competition Intensity	-0.000	-0.003	0.001	0.001
	(0.00)	(0.01)	(0.01)	(0.00)
RD Expenditures	0.017***	0.018***	0.018***	0.017***
	(0.00)	(0.00)	(0.00)	(0.00)
Human Capital	0.000**	0.001***	0.000*	0.000**
	(0.00)	(0.00)	(0.00)	(0.00)
Service Integration	0.012***	0.012***	0.013***	0.012***
	(0.00)	(0.00)	(0.00)	(0.00)
Effectiveness IP Protection	0.021*	0.024**	0.021*	0.016
	(0.01)	(0.01)	(0.01)	(0.01)
Effectiveness Strategic Protection	0.002	-0.001	0.006	0.008
	(0.02)	(0.02)	(0.02)	(0.02)
Relative importance of Customers	-0.113***	-0.086***		-0.060**
	(0.02)	(0.03)		(0.03)
Relative importance of Universities	0.362***		0.315***	0.285***
	(0.09)		(0.10)	(0.11)
Service Dummy (S)	0.054***	0.090***	0.036**	0.073***
	(0.01)	(0.02)	(0.02)	(0.02)
Rel. importance of Customers X (S)		-0.146***		-0.116***
		(0.05)		(0.05)
Rel. importance of Universities X (S)			0.266*	0.170
			(0.18)	(0.18)
Constant	0.020	0.018	-0.009	0.007
	(0.05)	(0.05)	(0.05)	(0.05)
Number of observations	764	772	765	764
F-test	24.38	23.00	23.38	21.72
R squared	0.29	0.27	0.29	0.30

** $p < .10$, ** $p < .05$, *** $p < .01$. Two-tailed tests. Standard errors (robust to heteroskedasticity) are in parentheses.*

Table 4: Summary of hypotheses:

Hypothesis	Key variable	Expected sign	Results
1	Openness of services	+	Supported
2	Innovation complexity	+	Supported
3	IP protection mechanism	+	Supported
4b	Relative importance of customers	+	Not Supported
5b	Relative importance of universities and the research base	**-**	Not Supported

FIGURES

Figure 1: Complexity; Distinction between Services and Manufacturing

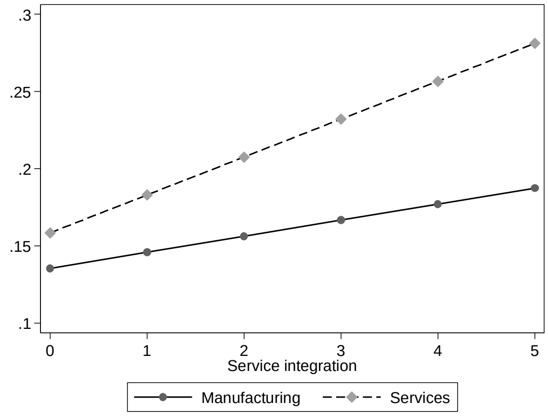


Figure 2: Effectiveness of IP & Strategic Protection; Distinction between Services and Manufacturing

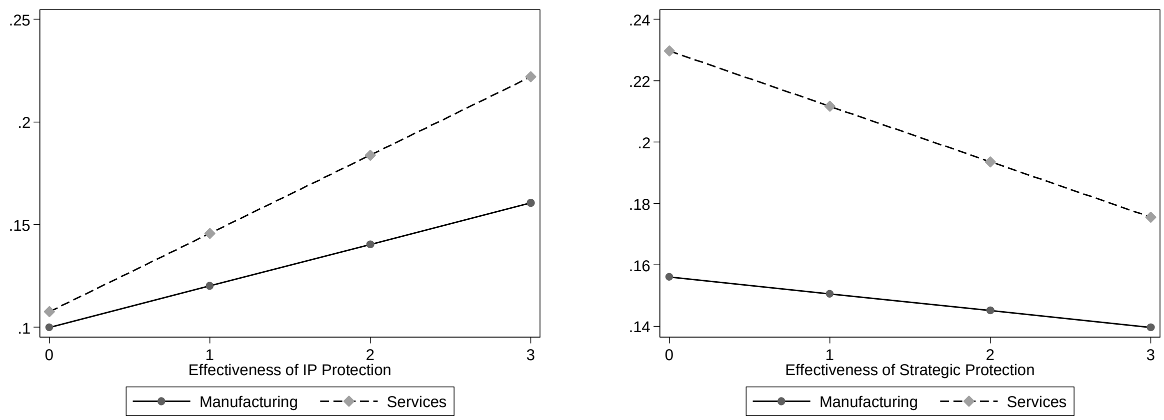


Figure 3: Importance of Customers and Universities: Distinction between Services and Manufacturing

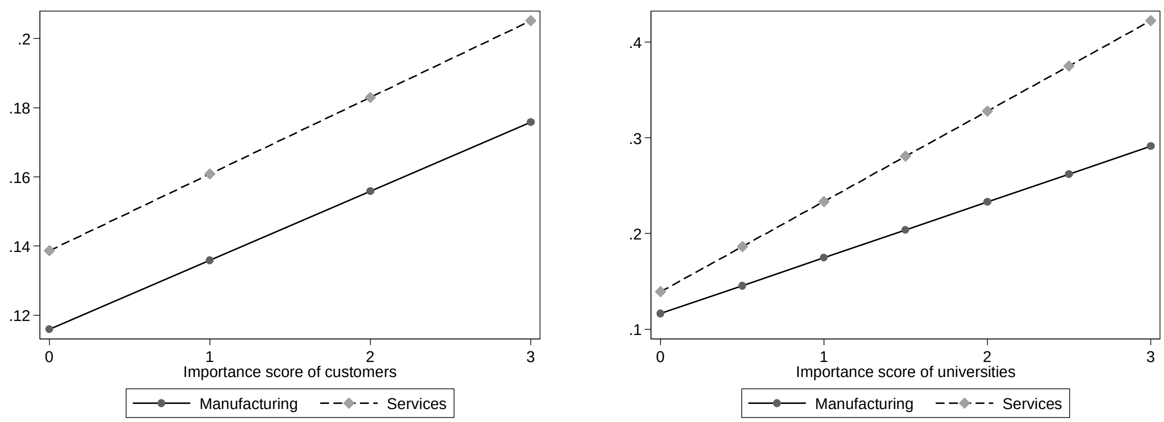
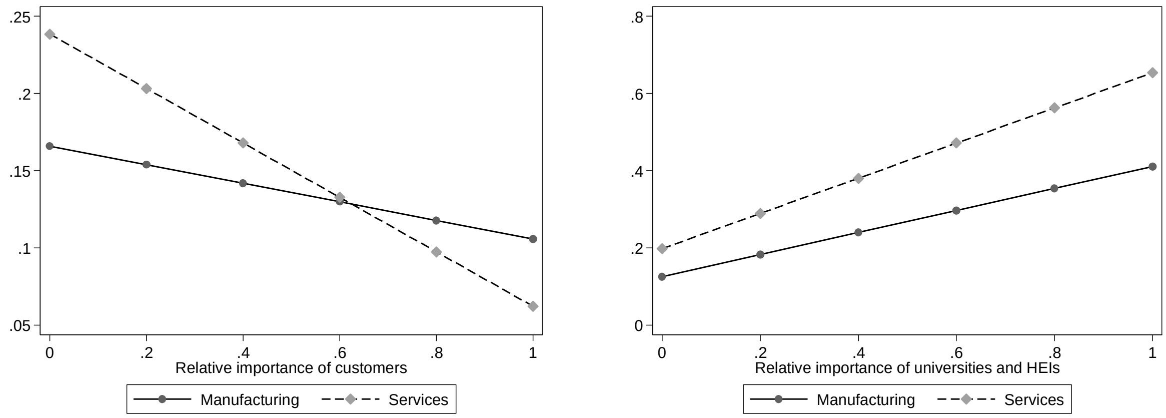


Figure 4: Relative importance of Customers and Universities: Distinction between Services and Manufacturing



APPENDIX A

A1: Open Innovation Practices as listed in the OI Survey

Informal (non-contractual) activities:
Engaging directly with lead users and early adopters
Participating in open source software development
Exchanging ideas through submission websites and idea “jams”, idea competitions
Participating in or setting up innovation networks/hubs with other firms
Sharing facilities with other organizations, inventors, researchers etc
Formal (contractual) activities:
Joint R&D
Joint purchasing of materials or inputs
Joint production of goods or services
Joint marketing/co-branding
Participating in research consortia
Joint university research
Licensing in externally developed technologies
Outsourcing or contracting out R&D projects
Providing contract research to others
Joint ventures, acquisitions and incubations

A2: Innovation types as listed in the OI Survey

Technologically new or significantly improved manufactured product
Technologically new or significantly improved methods of producing manufactured product
Technological improvements in supply, storage or distribution systems for manufactured product
New or significantly improved service product
New method to produce and deliver your service product

APPENDIX B

Table B1: Description of Variables

Size	Logarithm of number of employees
Age	Firm age
Largest market	Largest market in terms of revenue: 1 – local ; 2 – regional; 3 – national; 4 - international
Competition intensity	Number of serious competitors as perceived by the firm
R&D Expenditures	Log of R&D Expenditures (+1)
Human capital	Proportion of the firm's employees that were educated to degree level or above.
Complexity of Innovation	Number of different types of innovation introduced by the firm, conditional on having introduced a new or significantly improved service product and/or new methods to produce and/or deliver the service.
Effectiveness of IP Protection	Means of scores of importance of patent protection' use among the firms in 2 digit industry.
Effectiveness of Strategic Protection	Means of scores of importance of the use of strategic protection methods among the firms in 2 digit industry.
Relative importance of customers	Importance of customers and users as source of knowledge divided by the total of importance scores of all other sources
Relative importance of universities	Importance of universities, higher education institutes and public sector research organisations as source of knowledge divided by the total of importance scores of all other sources
Importance score of customers	Importance of customers and users as source of knowledge as scored by the firm
Importance score of universities	Importance of universities, higher education institutes and public sector research organisations as source of knowledge as scored by the firm

Table B2: Descriptive statistics

		Mean	Sd	Min	Max
	OI Breadth	4.08	3.65	0.00	15.00
	OI Depth	0.77	1.32	0.00	10.00
1	OI Activities	0.17	0.15	0.00	0.82
2	Size	3.53	1.37	0.00	10.24
3	Age	22.26	19.39	1.00	125.00
4	Largest market	3.32	0.71	1.00	4.00
5	Competition intensity	1.56	0.88	0.00	4.00
6	R&D expenditures	3.05	2.85	0.00	11.63
7	Human capital	29.07	33.18	0.00	100.00
8	Complexity of innovation	0.92	1.45	0.00	5.00
9	Effectiveness of IP Protection	2.14	0.48	1.00	4.00
10	Effectiveness of Strategic Protection	2.55	0.36	1.00	3.41
11	Relative importance of Customers	0.23	0.16	0.00	1.00
12	Relative importance of Universities	0.05	0.07	0.00	0.50
13	Importance score of customers	1.92	0.93	0.00	3.00
14	Importance score of universities	0.55	0.72	0.00	3.00

Table B3: Correlation Table

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1													
2	0.13												
3	-0.05	0.26											
4	0.19	0.11	0.02										
5	-0.03	0.10	0.01	-0.03									
6	0.42	0.36	0.07	0.40	-0.09								
7	0.24	-0.33	-0.24	0.21	-0.04	0.16							
8	0.14	0.12	-0.03	-0.04	0.10	0.05	-0.06						
9	0.15	0.05	0.15	0.26	-0.02	0.28	0.01	-0.02					
10	0.06	0.10	0.14	0.21	-0.05	0.28	-0.16	0.01	0.66				
11	-0.15	-0.08	-0.04	0.01	-0.01	-0.05	0.14	-0.08	-0.14	-0.11			
12	0.32	0.08	0.00	0.17	-0.08	0.26	0.20	-0.02	0.13	0.00	-0.23		
13	0.24	0.11	0.02	0.11	0.00	0.17	0.06	0.06	0.02	0.06	0.43	-0.04	
14	0.48	0.09	0.00	0.18	-0.04	0.31	0.19	0.03	0.16	0.03	-0.30	0.77	0.15

APPENDIX C: ROBUSTNESS CHECKS

C.1. Robustness Check with Reduced (Final) Sample for the 1st Table

	(1)	(2)	(3)	(4)	(5)	(6)
Size	0.007*	0.006*	0.005	0.004	0.005	0.006*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age squared	0.000	0.000	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Largest market	-0.001	0.002	0.003	0.003	0.001	0.000
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Competition intensity	0.001	0.000	-0.001	-0.002	-0.002	-0.003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D expenditures	0.020***	0.021***	0.020***	0.020***	0.019***	0.019***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Human capital	0.001***	0.001**	0.001***	0.001***	0.000**	0.000**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Service Dummy (S)		0.044***	0.042***	0.032**	0.040***	0.107
		(0.01)	(0.01)	(0.02)	(0.02)	(0.11)
Service integration			0.013***	0.010***	0.010***	0.013***
			(0.00)	(0.00)	(0.00)	(0.00)
Service integration X (S)				0.010	0.010	
				(0.01)	(0.01)	
Effectiveness of IP Protection					0.035***	0.018
					(0.01)	(0.02)
Eff. of Strategic Protection					-0.013	0.005
					(0.02)	(0.02)
IP protection X (S)						0.043*
						(0.03)
Strategic protection X(S)						-0.059
						(0.05)
Constant	0.072**	0.050*	0.040*	0.045*	0.012	-0.000
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)
Number of observations	764	764	764	764	764	764
R-squared	0.21	0.23	0.24	0.24	0.25	0.25

** p < .10, ** p < .05, *** p < .01. Two-tailed tests. Standard errors (robust to heteroskedasticity) are in parentheses.*