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

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The concept of open innovation captures the increasing propensity of firms to work across their traditional boundaries of operation. 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. This paper focuses on open innovation in services, both as a subsector of the economy and as a component of the activities of manufacturing firms. We study the open innovation practices of business services firms and then consider the implications for open innovation of the adoption of a service inclusive business model by manufacturing firms. Our analyses are based on a unique dataset with information on open innovation activities amongst UK firms. Overall, engagement in open innovation increases with firm size and R&D expenditure. Business services are more active open innovators than manufacturers; they are more engaged in informal relative to formal open innovation practices than manufacturers; and they attach more importance to scientific and technical knowledge than to market knowledge compared to manufacturing firms. Open innovation practices are also associated with the adoption of a service inclusive business model in manufacturing firms and service-integrated manufacturers engage in more informal knowledge-exchange activities. The paper contributes towards a reconceptualisation of open innovation in service businesses and a deeper evidence-based understanding of the service economy.

1. Introduction

Firms are increasingly looking for knowledge outside their organisational boundaries (Chesbrough, 2003a, 2006) and are developing more outward-looking strategic approaches to research and development to source at least some knowledge of potential value from the broader environment in which they operate. Vertical disintegration pressures (Langlois, 2003), modularisation and outsourcing (Prencipe et al., 2003; Sturgeon, 2002), the growth

strengthened firms' incentives to increase their reliance on external knowledge for innovation.

The importance of external knowledge has been discussed at length in the innovation literature,[3] but interest in open innovation (OI) has been growing very fast especially in the last few years (Gassmann, 2006; Dahlander and Gann, 2010; Huizingh, 2010). 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,

(Leiponen, 2005, 2012; Love and Mansury, 2007; Love et al., 2010) while the link between openness and the adoption of a service business model in manufacturing firms is also coming to the fore (Chesbrough, 2011). Despite these significant contributions, however, studies that analyse OI in services are still scarce. Open service innovation is a relatively unexplored area of research where novel theoretical and empirical investigations can shed new light on the strategic search behaviours of firms.

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[3] This is arguably one of the most important messages to emerge from the relatively long tradition of research on innovation systems (Lundvall, 1992; Nelson, 1993; Freeman, 1995; Malerba, 2004).

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In this paper, firstly we focus on business services, a segment of the service sector characterised by high growth, productivity and innovation rates (Rubalcaba and Kox, 2007). Business services are a diverse group of businesses which include IT support services, design, architecture and engineering consultancies, R&D services, advertising, marketing and other traditional professional services such as legal services and management consultancy. Amongst them we find prominent examples of business models structured to search broadly for external knowledge and to leverage internally generated knowledge.

IDEO is a well-known case of a company whose knowledge-brokering activities are key to its business model and a fundamental source of competitive advantage. Born as a product development company, IDEO now offers a much broader range of consulting services for applications as diverse as health and medical devices and services, energy, food and beverage, education, mobile and digital technologies, and innovation in the public sector. The company thrives on knowledge exchanges with clients, suppliers and the science base in the search for innovative solutions.[4] Active intermediation between users and developers of new knowledge also characterises the operation, for example, of the technology consultancies that have greatly contributed to the growth of the Cambridge (UK) cluster, arguably the most successful technology cluster in Europe. Service companies such as Cambridge Consultants, the Technology Partnership (TTP), PA Technology and Sagentia engage in intense, and typically highly focused, interactions with their local and international clients and research base.[5] But interactions between services and specialist external knowledge sources are found at the cutting edge in many different subsectors, including more traditional businesses such as restaurants. The Catalan restaurant El Bulli, named for several years amongst the world best restaurants and famed as a radical innovator in the sector, developed over time as one component of a broader platform of activities which included upstream collaborations with the science base as well as downstream interactions, amongst others, with food manufacturers and the hospitality sector.[6]

Interestingly, a service approach to business is not limited to subsectors of the economy that are classified as services in standard industry statistics. Services are also economic activities that can be performed by product-based businesses. Several manufacturing firms are significantly expanding the range of services they provide in combination with their core products as a way to enhance value creation and customer retention opportunities. Companies such as IBM, Xerox, and Rolls Royce now derive growing shares of their total revenues from service activities, although they are not considered as service businesses, and they often develop their service profile by partnering with external knowledge sources.

In this paper we study the open innovation practices of business services and show to what extent and in what way these differ from those in manufacturing sectors. Secondly, we take into account the service offer of manufacturing firms and we explore the implications of adopting a service business model for the open innovation profiles of manufacturing firms. We analyse a unique dataset generated through an original survey of open innovation practices amongst UK firms conducted at the UK Innovation Research Centre in 2010. We find that business services are more open users of external knowledge than manufacturers. We show that they are more intensive users of informal relative to formal open innovation practices than manufacturers. In addition, we uncover the importance of scientific knowledge vis-à-vis market knowledge in business services relative to manufacturing firms. When we consider the service activities of manufacturing firms we find that a higher degree of openness, enabling the search and recombination of more diverse knowledge inputs, is associated with the adoption of a service inclusive business model. Finally, and consistently with our prior findings, we show that the degree of service integration is positively associated with engagement in informal knowledge-exchange activities. Overall, the paper contributes to the theory of open innovation by postulating new aspects of the sectoral and firm-specific characteristics of external knowledge searches.

2. Exploring open service innovation: theory and evidence

2.1. How does 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 (Metcalfe and Miles, 2000). The service sector is no longer seen as a technologically backward, ‘unprogressive’ and passive adopter 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 Innovation Survey (CIS), where individual service 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.

A number of stylised facts distinguish service from manufacturing innovation.

Quantitative analyses based on CIS data show for example that overall R&D plays a less important role in services, even though this does not hold true for all services (Evangelista, 2000; Tether, 2003).[7] The traditional distinction between product and process innovations becomes weaker in a service context since services often consist of processes that are hardly separable from the outcomes they produce. In addition, service innovation tends to imply greater emphasis on organisational and human capital factors relative to more tangible assets (Gallouj and Savona, 2009; Sirilli and Evangelista, 1998; Hipp and Grupp, 2005).

Service firms have been found to rely heavily on information and communication technologies and non-R&D innovation expenditures and seem to use more external knowledge sources than manufacturing (Cainelli et al., 2006; Tether and Tajar, 2008; Hipp, 2010). They also appear to collaborate more frequently with their customers and suppliers (Tether, 2005). There is some evidence that this practice has positive effects on firm innovation performance (Leiponen, 2005; Mansury and Love, 2008; Love et al., 2010). One striking feature of the service economy certainly is the variety existing between and within individual service sectors. This encompasses a broad range of activities with different characteristics (Miles, 2005; Tether, 2002; Rubalcaba and Kox, 2007), 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 (Leiponen, 2005; Love et al., 2011) will display innovation behaviours similar to those of high-technology manufacturing firms (Hollenstein, 2003; Rodriguez and Ballesta, 2010).[8] Yet, some uncertainties persist. There are, for example, conflicting results on the role of specific types of

[4] Hargadon and Sutton (1997), Kelley and Littman (2001) and Hargadon (2003).
[5] Probert et al. (2013), Kirk and Cotton (2012).
[6] Chesbrough (2011).

[7] With the exception of the recent paper by Leiponen (2012), who finds that R&D activities play a similar role in both service and manufacturing innovation.
[8] In a cluster analysis of the innovation activities of Finnish and Danish firms, Leiponen and Drejer (2007) show that the differences between manufacturing and service firms within clusters are a matter of degree as service firms do not tend to cluster together but alongside manufacturing firms.

knowledge and collaboration partners and the need remains to deepen our understanding of whether the search for external knowledge may indeed have different drivers and present different characteristics across the manufacturing and service sectors of the economy.

2.2. Open innovation in business services

Business services are an extremely important component of the service economy (Rubalcaba and Kox, 2007) and are intensive traders of knowledge inputs (Metcalfe and Miles, 2000; den Hertog and Bilderbeek, 2000; Gallouj, 2002). They tend to add value by leveraging human capital, as opposed to physical capital, and display rates of innovation not inferior to manufacturing businesses, typically the highest recorded in the service sector (Tether and Tajar, 2008). They have been described in the literature as key innovation intermediaries, or 'brokers', that excel at connecting together innovative ideas developed by different individuals and organisations (Bessant and Rush, 1995; Hargadon and Sutton, 1997; Howells, 2006), and at translating new knowledge generated by the science base into commercialisable inputs (Tether and Tajar, 2008).

The highly interactive and relational nature of their economic activities suggests that the open innovation model may be particularly important for these firms. Firms can choose between engaging in contractual arrangements as a formal framework for cooperation, or they can engage in informal exchanges. These include direct unstructured interaction with collaborators, participation in innovation networks, or sharing of un-codified know-how with other firms. In these types of activities collaboration tends to be based on mutual trust and moral obligations rather than legally binding contracts (Appleyard, 1996; Liebeskind et al., 1996; Van Aken and Weggeman, 2000). We therefore provide evidence on the choice between formal and informal governance mechanisms. These may differ between businesses services and manufacturing firms. We can expect, for example, that the intangible nature of services does not favour highly formalised contractual solutions (Fitzsimmons and Fitzsimmons, 2000). Instead, their interactive nature can give rise to relational solutions (Vargo et al., 2008), favouring informal over formal arrangements. Business services may also be more difficult to control and monitor on delivery, given the intangibility, simultaneity and people-oriented character of many activities (Brouthers and Brouthers, 2003).

Resource based theory suggests that the choice of partners for collaboration depends on their potential to provide additional complementary inputs (Miotti and Sachwald, 2003). On this basis the literature has distinguished between science-based and market-based partners as sources of scientific/technical knowledge and market knowledge respectively (Danneels, 2002; Du et al., 2012). The order of preference with which firms might engage in open innovation activities is relevant also because the search for external knowledge is not costless. Firms make strategic decisions that explicitly or implicitly take into account the opportunity costs of any choice of partners relative to available alternatives. We therefore examine the important issue of the choice of type of open innovation partner.

Engaging with market-based partners such as 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 emphasised as the most important channel of information supporting the adoption of an open service innovation model (Chesbrough, 2011), while prior literature has highlighted the benefits of interaction with lead users (von Hippel, 1976; Hagedoorn, 1993). Firms might, instead or in addition, engage in collaborative arrangements with universities and research institutions in order to gain access to basic knowledge, either to better exploit their existing capabilities across a wide range of functional management domains, including HR, finance and marketing (Hughes and Kitson, 2012), or to explore new avenues for innovation and growth (Bercovitz and Feldman, 2007; Veugelers and Cassiman, 2005). Furthermore, growing interactions with the public research base are compatible with the expectations that are placed in the management and policy literatures on the economic potential of 'the entrepreneurial university' (Etzkowitz, 2002; Audretsch and Phillips, 2007) and might have become easier over time through the implementation of policies aimed at facilitating access and simplifying negotiation processes (Perkmann and Walsh, 2007).

Engaging with market-based partners can be especially useful for services by virtue of their intangible nature, their process-based business model and the often theorised co-production of their output with customers (Brouthers and Brouthers, 2003; Chesbrough, 2011; Miles, 2005). On the other hand, universities and public research institutes may be more suitable partners for manufacturing firms rather than services because they can extract the most value from their R&D activities whilst services will typically rely more on investments in human capital. Previous research based on CIS data has indeed found that providers of scientific knowledge are on average less important as a source of information for service innovators than for manufacturing innovators (Arundel et al., 2007; Tether, 2005).

2.3. Open service innovation in manufacturing firms

Firms are typically classified as being either in services or in manufacturing, but evidence is growing that service provision is becoming an increasingly important dimension of the offer of manufacturing firms, who are expanding the service component of their output (Chesbrough, 2011). Seen in this light, services are no longer the remit of specialist service providers, but become instead characteristics of a broader business model adopted by manufacturing firms to capture additional value or retain their customer base. It has been reported that the share of service sales is as high as 31% for an average manufacturing firm (Fang et al., 2008) while a recent survey of UK businesses has found that 80% of manufacturing firms are offering some type of services (Tether and Bascavusoglu-Moreau, 2011).

The growing literature on business model innovation (see for example Teece, 2010; Chesbrough, 2010; Gambardella and McGahan, 2010; Zott et al., 2011) emphasises the need to investigate how firms develop, deliver and appropriate value and how firms can change the architecture of their businesses to adapt to new environments, and sustain competitive advantages or generate extra profits. Teece (2010) argues that changes in the firm's organisational and financial design aimed to improve the capability of firms to turn customer needs into profits are at least as important as technological innovation. The integration of a service component into the firms' range of activities can be a powerful mechanism of value creation (Wise and Baumgartner, 1999): advocates of 'servitisation' strategies argue that services enable manufacturers to get closer to their customers, enhancing understanding of users' needs, strengthening relationships and increasing customer loyalty (Vandermerwe and Rada, 1988). The offer of complex bundles of products, processes and services, however, poses specific challenges to the organisation of the knowledge base of the firms. It is likely to demand the recombination of different resources (Kogut and Zander, 1992) including knowledge inputs, coming from different sources and this can push firms to intensify the search for external knowledge that may be necessary to sustain an integrated business model (Chesbrough, 2011). It is therefore important to explore whether the adoption of a service business model by manufacturing firms is associated with a higher degree of openness.

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. 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.[9] 1202 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 (Cosh and Zhang, 2011).

In the European Community Innovation Survey (CIS), widely used in the majority of prior quantitative studies (Laursen and Salter, 2006; Leiponen and Helfat, 2010; Leiponen and Drejer, 2007; Leiponen, 2012; Tether, 2002, among others), firms are asked about the importance of different sources of information/cooperation for their innovation related activities. While also including these questions, the survey we use collected information on firms' open innovation *practices*. Data on such activities are not obtained in the CIS datasets. The term 'open innovation' was not used anywhere in the survey in order to avoid potential respondent bias, but firms were specifically asked about the different types of informal and formal activities they had engaged in with external parties to accelerate innovation. Therefore, while comparable to the previous empirical literature, this paper uses a richer dataset to directly explore the firms' open innovation activities and their antecedents.

The sample size we use in this study varies between 788 and 819 across estimations, due to missing values. Exclusion because of missing values resulted in our final sample having a slight overall bias towards more open firms, with higher R&D expenditures and human capital. However, and crucially for our purposes, there were no differences in this respect between our services and manufacturing subsamples and no other differences between our initial and final samples. The latter shows a reasonable spread across industries with shares of manufacturing 67% (vs. 63% in the original sample) and services 33% (vs. 37% in the original sample).[10]

Table 1 displays the industry distribution of our sample. In keeping with prior studies we also report as descriptive statistics measures of the breadth and depth of open innovation across sectors.[11] OI breadth is defined as the number of open innovation activities firms engage in. OI depth is defined as the extent to which firms make intensive use of the different activities. Overall, we find that firms engage in four open innovation activities on average. R&D services ($n = 50$) exhibit a higher level of openness, as well as scoring OI activities as highly important, followed by chemicals and chemical products ($n = 84$), indicating that firms in knowledge intensive services and medium-high technology manufacturing are more engaged in open innovation activities.[12] Although there is some variation within the business service sector, manufacturing firms are more heterogeneous in terms of the breadth and depth of openness. Given this heterogeneity, in what follows, we distinguish the high-tech manufacturing sub-sample within the whole sample of manufacturing businesses.

3.2. Variables and descriptive statistics

3.2.1. Dependent variable

The dependent variable in our study is the extent of firms' OI *activities*. In the survey, firms were asked to indicate the degree of importance of various activities conducted with external parties in order to accelerate innovation. Our measures of open innovation are therefore based on qualitatively different and wider information than previous empirical studies of CIS survey data. The latter are based on observations of the importance of different partners (customers, suppliers, universities, etc.) as sources of external knowledge. We, instead, are able to observe the number, partners *and* type of open innovation activities performed by firms. The full list of 15 activities is reported in Appendix A (Table A1). These take into account both formal (contractual) and informal (non-contractual) activities. The importance of each activity is evaluated by means of a Likert Scale (0 = not used, to 3 = highly important). In the first instance we measure the scope of open innovation activities by adding up the normalised scores for all activities and divide them by the total number of activities.[13] Firms that did not engage in any activity get a score of 0. Firms with higher scores are considered to be more open. Hypothetically a score of 1 is given 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. In order to identify the firms' preferences for formal or informal activities we then construct two separate measures for informal (Cronbach's alpha = 0.68) and formal practices (Cronbach's alpha = 0.80). Table 2 presents the use of OI activities for the whole sample, as well as business services, manufacturing, and high-tech manufacturing sub-samples.[14] The most widely used open innovation activity in our sample (both in the original and the final sample) is engaging directly with lead users. 61% 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 joint R&D activities (34% of the final sample), sharing facilities (30%) and joint marketing/co-branding and

[9] For waves 1–3, the original 12-pages long questionnaire was sent out; then in order to increase the response rate, shorter versions were used in subsequent waves.

[10] We further explore the risk of response bias in our data by performing a wave analysis of responses. Those requiring more prompts may be hypothesised to be closer in characteristics to non-respondents than early respondents. Since our data were collected in five waves it is possible for us to test whether there are systematic differences in our variables across waves and whether these are associated with the timing of response. One-way ANOVA analyses and post hoc tests with Bonferroni correction revealed no significant differences between survey waves in any of our open innovation variables. In line with the sample attrition tests already reported, multinomial logistic regressions of dependent and independent variables against the survey wave only revealed a significant difference in human capital for waves four and five (but with discordant signs), and R&D expenditure for wave one. These tests confirm that non-respondent bias is not a major cause for concern in our analyses.

[11] The concepts of breadth and depth have been widely used in the previous literature with regard to firms' search activities (Laursen and Salter, 2006; Leiponen and Helfat, 2010, amongst others).

[12] As we prove in our econometric analyses and related robustness checks, the inclusion of these R&D services is not a source of bias for the results.

[13] To normalise the scores of each item we divide each score by 3 (maximum possible value) to bring the scores within a 0–1 range.

[14] The classification of sectors is based on the most detailed information level available in the dataset and reflects the FAME standard classification of firms. High-Tech manufacturing includes classes: 33.3, 32.1, 32.3, 33.1, 24.41, 33.2, 32.2, 30.02, 33.4, 35.3, 30.01, 24.42.

Table 1
Sectoral distribution of the sample.

NACE	Industry	*N*	Share (%)	OI breadth	OI depth
21–22	Mnf. of pulp, paper, printing and publishing	3	0.38	3.75	1.00
24	Mnf. of chemicals, chemical products and man-made fibres	84	10.66	4.88	0.97
25	Mnf. of rubber and plastic products	4	0.51	5.25	0.25
26	Mnf. of other non-metallic mineral products	19	2.41	3.37	0.37
27	Mnf. of basic metals	28	3.55	3.11	0.32
28	Mnf. of fabricated metal products, except machinery and equipment	93	11.8	2.97	0.42
29	Mnf. of machinery and equipment n.e.c.	58	7.36	3.02	0.47
30	Mnf. of office machinery and computers	17	2.16	3.94	1.12
31	Mnf. of electrical machinery and app. n.e.c.	81	10.28	3.79	0.72
32	Mnf. of radio, television and communication equip. and app.	26	3.3	4.50	0.62
33	Mnf. of medical, precision and optical inst., watches and clocks	69	8.76	4.34	0.77
34	Mnf. of motor vehicules, trailers and semi-trailers	18	2.28	3.33	0.39
35	Mnf. of other transport equipment	21	2.66	3.76	0.29
36	Mnf. of furniture, manufacturing n.e.c.	3	0.38	2.33	0.00
37	Recycling	4	0.51	3.25	1.00
64	Post and communication	26	3.3	4.50	0.92
72	Computer and related activities	71	9.01	4.48	0.79
73	R&D	50	6.35	6.71	1.76
74	Other business activities	113	14.34	3.58	0.89
	Total	788	100	3.91	0.73

Table 2
Open innovation practices by sector groups.

Use of OI activities (0/1)	Whole sample			B. Services		Manufacturing		High-tech manuf	
	Mean	sd	Count	Mean	sd	Mean	sd	Mean	sd
Engaging directly with lead users and early adopters	0.61	0.49	788	0.7	0.46	0.57	0.5	0.68	0.47
Participating in open source software development	0.22	0.42	788	0.29	0.45	0.19	0.39	0.2	0.4
Exchanging ideas through submission websites and idea “jams”, idea competitions	0.16	0.36	788	0.23	0.42	0.12	0.32	0.16	0.36
Participating in or setting up innovation networks/hubs with other firms	0.24	0.43	788	0.33	0.47	0.2	0.4	0.22	0.42
Sharing facilities with other organisations, inventors, researchers, etc.	0.30	0.46	788	0.32	0.47	0.30	0.46	0.37	0.48
Joint R&D	0.34	0.47	788	0.30	0.46	0.36	0.48	0.37	0.49
Joint purchasing of materials or inputs	0.17	0.38	788	0.13	0.34	0.19	0.39	0.14	0.34
Joint production of goods or services	0.24	0.43	788	0.22	0.41	0.25	0.43	0.21	0.41
Joint marketing/co-branding	0.29	0.45	788	0.37	0.48	0.26	0.44	0.25	0.43
Participating in research consortia	0.22	0.42	788	0.28	0.45	0.20	0.4	0.27	0.45
Joint university research	0.25	0.44	788	0.25	0.43	0.26	0.44	0.32	0.47
Licensing in externally developed technologies	0.23	0.42	788	0.29	0.46	0.2	0.4	0.27	0.45
Outsourcing or contracting out R&D projects	0.29	0.45	788	0.3	0.46	0.29	0.45	0.44	0.50
Providing contract research to others	0.18	0.38	788	0.21	0.41	0.16	0.37	0.22	0.42
Joint ventures, acquisitions and incubations	0.27	0.44	788	0.31	0.46	0.24	0.43	0.27	0.44

outsourcing/contracting out R&D (29% of the sample). The least used open innovation practice is informally exchanging ideas, with only 16% of the firms in our final sample reporting it.

When we look at the differences between business services and manufacturing, descriptive statistics reveal that business services are more engaged in non-contractual open innovation activities than manufacturing firms.[15] However, these differences disappear when we restrict our sample to high-tech manufacturing, with the exception of participating in or setting up innovation networks with other firms. Regarding contractual open innovation activities, we see that business services are more similar to high-tech manufacturers in their formal search activities, than to the whole manufacturing sample. High-tech manufacturing firms more often participate in joint R&D projects and joint university research, whereas business services firms seem to privilege joint-marketing/co-branding activities.[16]

We also look at the characteristics of firms depending on the relative importance of formal and informal OI activities they are engaged in. For descriptive purposes, we classify firms in four groups (Table 3): low informal/low formal activities (48.1% of firms), low informal/high formal activities (8%), high informal/low formal activities (10.8%), and high informal/high formal activities (12.3%). 170 firms in our sample do not engage in any open innovation activities. Although statistically different, the average firm size is rather similar amongst the different categories. The average firm age is around 21–23 years in all categories except the low formal/high informal group, where the average firm age is around 18 years, and this difference is not statistically significant across categories. Younger firms are more likely to engage in informal OI activities. R&D expenditures and human capital vary considerably. As it is reasonable to expect, firms with relatively higher R&D expenditures and shares of highly skilled human capital belong to high informal/high formal category, followed by low informal/high formal (Table 3).

3.2.2. *Independent variables*

Our estimations contain indicators for a broad set of firm characteristics, including indicators for the firm being a business service firm, the sources of knowledge, and the adoption of a service business model. Descriptive statistics are presented in Table 4, again for the whole sample, business services, manufacturing and high-tech manufacturing sub-samples.

Regarding the different sources of information, we are particularly interested in the importance of market-based partners relative

[15] *t*-Test results (not reported but available from the authors upon request) shows that these differences are statistically significant at a 95 percent level.

[16] Based on *t*-tests (not reported, but available from the authors upon request) none of these differences between the two subsamples are statistically significant.

Table 3
Distribution of firms by their engagement in formal and informal OI.

Firm type	Obs.	(%)	Size	Age	R&D exp.	Human capital
No OI	170	20.76	3.09	22.51	1.03	25.91
Low formal and low informal	394	48.11	3.49	22.33	2.74	26.31
Low informal and high formal	65	7.94	3.66	21.81	4.39	38.2
Low formal and high informal	89	10.87	3.48	18.12	3.23	32.97
High informal and high formal	101	12.33	3.97	23.52	4.67	43.09

*The differences between categories are significant at the 99% level, except for the Age variable.

Table 4
Descriptive statistics.

	Whole sample				B. Services		Manufacturing		High-tech. manuf.	
	Mean	sd	Min	Max	Mean	sd	Mean	sd	Mean	sd
OI activities	0.16	0.15	0	0.87	0.20	0.17	0.15	0.14	0.18	0.14
Informal OI activities	0.18	0.18	0	1	0.23	0.20	0.16	0.16	0.19	0.16
Formal OI activities	0.14	0.17	0	0.97	0.16	0.18	0.13	0.16	0.16	0.17
Size	3.50	1.39	0	10.24	3.06	1.6	3.71	1.22	3.59	1.22
Age	22.13	19.27	1	125	13.93	14.15	26.16	20.17	23.81	16.63
Largest market	3.32	0.72	1	4	3.27	0.76	3.35	0.7	3.60	0.56
Competition intensity	1.54	0.88	0	4	1.57	0.95	1.53	0.84	1.44	0.81
R&D expenditures	2.84	2.82	0	11.62	2.59	2.93	2.97	2.76	3.99	2.76
Human capital	29.44	33.47	0	100	55.43	37.03	16.65	22.40	26.89	26.71
Effectiveness of IP protection	2.14	0.48	1.59	4	1.92	0.54	2.25	0.4	2.51	0.24
Service innovation integration	0.9	1.43	0	5	0.94	1.29	0.88	1.5	0.88	1.5
Share of service in total revenue	33.44	40.86	0	100	69.63	39.02	14.10	25.99	10.92	20.95
Market-based knowledge	1.86	0.98	0	3	1.87	1	1.85	0.96	1.96	1
Science-based knowledge	0.53	0.71	0	3	0.58	0.8	0.5	0.67	0.63	0.72

to science-based partners. In order to test their effect on openness we use the score of the importance of 'customers and users' and the score of the importance of 'universities, other higher education and research organizations', as perceived by the firms. 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 institutions as a source of information. These shares are very similar between manufacturing and business services sectors, although high-tech manufacturing firms show a higher score for both knowledge sources.

In order to test for the effect on open innovation activities of the adoption of a service business model by manufacturing firms, we operationalise the service integration concept by using two indicators: the first measures the share of services in the total revenue of the firm; the second measures the integration of a service component in the firm's innovation output (the 'innovation types' used to construct this variable are listed in Appendix A, Table A2).[17] The survey questionnaire asks about the percentage of firms' total revenue accounted for goods, services and others. Overall, the share of product sales is around 63% and the share of services sales 33% on average. Indeed, we find considerable heterogeneity at the subsector level. The share of service revenues accounts for 69% of total revenues in business services, whereas it accounts respectively for 10% and 15% of the total revenue in low-tech and high-tech manufacturing firms.[18]

We then take into account the composition of firms' innovation output. The variable we construct 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, either for the number of innovations, or for the complexity of innovation.

We include in the estimations an indicator for R&D activities, measured as the logarithm of firms' internal R&D expenditure and an indicator of human capital, measured by the percentage of employees with a first and/or higher degree. Although business services and manufacturing as a whole display very similar levels of R&D expenditures, high-tech manufacturing firms are more R&D intensive, as expected. On the other hand, business services have the most highly trained human capital, as should also be expected. Firm size and age may affect openness; we thus include the logarithm of number of employees, and firm age and its square term to account for potential non-linearities.[19] Overall, manufacturing firms are larger and older than business services. We also take into account a firms' largest market in terms of its sales revenue and the intensity of competition as perceived by the firm. Firms in both sectors operate mainly at the national and international level (with respectively 46% and 44% of the firms), and the geographical distribution of their largest market does not differ significantly between the sectors. The intensity of competition also shows a very similar pattern.

Finally we test for the effectiveness of the IP appropriation regime. The ability to capture external knowledge flows is conditioned by knowledge appropriation mechanisms, because firms

[17] Note that these innovation types encompass a broader set of characteristics that the CIS. This also explains the higher percentage of innovative firms in our sample relative to the latest available CIS survey results (2011).

[18] Low-tech manufacturing firms seem to rely more on service revenues than high-tech manufacturing firms. This may signal the kind of services offered by the manufacturing businesses: recent surveys have indicated that the most widely offered services by manufacturing firms are training, delivery, spare parts, customer helpdesks, and installation (Tether and Bascavusoglu-Moreau, 2011; Baines et al., 2009).

[19] We also introduced this latter variable as categories of age (not reported), in order to assess any potential effect of a particular age group on engaging in open innovation activities. Results did not differ significantly.

Table 5
Total, informal and formal OI activities.

	Total OI activities (1)	Total OI activities (2)	Informal OI activities (3)	Formal OI activities (4)	Informal OI activities (5)	Formal OI activities (6)
Size	0.008*	0.008*	0.007	0.01**	0.006	0.010**
	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
Age	−0.001	−0.0004	−0.001	−0.0008	−0.0005	−0.0004
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age squared	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Largest market	−0.0002	0.002	−0.010	0.009	−0.006	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Competition intensity	−0.0009	−0.002	−0.0001	−0.002	−0.002	−0.003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D expenditures	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Human capital	0.0007***	0.0004*	0.0007***	0.0007***	0.0002	0.0005*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Effectiveness of IP protection	0.01	0.03**	−0.02	0.05***	0.0003	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Bus. service dummy (BSD)		0.05***			0.06***	0.04**
		(0.01)			(0.02)	(0.02)
Constant	0.04	−0.008	0.2***	−0.08**	0.10**	−0.1***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Number of observation	819	819	819	819	819	819
R-squared	0.20	0.21	0.15	0.19	0.16	0.19
F	26.66	25.60	18.46	23.06	18.11	21.19
Log-likelihood	473.53	480.19	311.25	394.12	318.35	397.13
AIC	−929.05	−940.39	−604.50	−770.24	−616.69	−774.27

One-tailed tests were conducted for the main variables and two-tailed tests for the other effects. Standard errors (robust to heteroskedasticity) are in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

may be willing to share knowledge only if they can protect the value of their investments (Cassiman and Veugelers, 2002; Laursen and Salter, 2012). In addition, the effectiveness of IP protection can also reflect technological opportunities available to firms whose effects need to be taken into account in our estimation. The appropriability regime enters 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 Veugelers (2006), we measure the effectiveness of IP protection as the industry average of the firm-level scores of importance. On average, firms that engage in open innovation activities score both formal and informal methods of protection as more important, compared to firms that do not engage in open innovation. As expected, business service sectors exhibit a lower score of importance of IP protection compared to manufacturing sectors.

3.3. Modelling and estimation strategy

We conduct our empirical analyses by means of ordinary least squares (OLS) estimations. In order to evaluate the difference between business services and manufacturing sectors, we introduce a dummy variable which is equal to 1 if the firm is a business service firm and 0 otherwise. By interacting key variables with the dummy variable, we are able to assess the specificity of our business 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 et al., 1988). The definition of variables and correlation table are reported in Appendix A (Tables A3 and A4).

Because our data are self-reported and collected via a cross-sectional research design through a single questionnaire, common method variance may cause systematic measurement error and bias the estimates. We performed Harman's one-factor test to verify the risk of common method effect. The unrotated principal component factor analysis and the principal component analysis with varimax rotation revealed the presence of five distinct factors with eigenvalue greater than 1.0, rather than a single factor. The three factors together accounted for 73 percent of the total variance; the first (largest) factor did not account for a majority of the variance (24%). Thus, no general factor is apparent and we conclude that our results are not affected by this problem.

4. Results

Table 4 shows the set of OLS models we use to analyse the business services' degree of engagement in open innovation, and their reliance on formal vs. informal activities, relative to manufacturing businesses. Table 5 reports results of the analysis of the effects of market vs. science based knowledge. Table 6 shows the results of the analysis of the role of service-integration in manufacturing businesses. We adopt a hierarchical estimation strategy. In the first table (Table 5), under Model 1we present the baseline estimation's results. The second model introduces the dummy variable 'Business service'. Models 3 and 4 distinguish between informal (3) and formal (4) open innovation activities. Models 5 and 6 introduce the business service dummy. Table A5 in Appendix A presents the same results for the sample of business services and high-tech manufacturing firms.

In Table 6, Models 1 and 2 introduce market and science-based sources of knowledge. Interactions between the roles of each knowledge source with the business sector dummy are included in Models 3, 4, 5 and 6. In Table A6 in Appendix A we restrict our sample to high-tech manufacturing firms alongside business services.

In the first two columns (Models 1 and 2) of Table 7 we present the baseline model for the manufacturing sample, respectively for informal (Model 1) and formal (Model 2) open innovation activities. Service integration in the sales and in the innovative output is

Table 6
OI activities, market and scientific knowledge.

	Informal OI activities (1)	Formal OI activities (2)	Informal OI activities (3)	Formal OI activities (4)	Informal OI activities (5)	Formal OI activities (6)
Size	0.002	0.006	0.002	0.006	0.003	0.007
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age	−0.0007	−0.0005	−0.0007	−0.0005	−0.0007	−0.0005
	(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	−0.01	0.007	−0.01	0.007	−0.01	0.007
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Competition intensity	0.0007	−0.0004	0.0007	−0.0003	0.001	−0.0001
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D expenditures	0.02***	0.01***	0.02***	0.01***	0.02***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Human capital	0.00002	0.0002	0.00002	0.0002	0.00003	0.0002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Effectiveness of IP protection	−0.001	0.05***	−0.001	0.05***	−0.005	0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Market-based knowledge	0.03***	0.01**	0.03***	0.009*	0.03***	0.01**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Science-based knowledge	0.06***	0.09***	0.06***	0.09***	0.04***	0.08***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Bus. service dummy (BSD)	0.06***	0.03**	0.06**	0.02	0.04**	0.02*
	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)
Market-based knowledge X (BSD)			0.002	0.006		
			(0.01)	(0.01)		
Science-based knowledge X (BSD)					0.05***	0.02
					(0.02)	(0.02)
Constant	0.06	−0.1***	0.07	−0.1***	0.08***	−0.1***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Number of observation	788	788	788	788	788	788
R-squared	0.26	0.35	0.26	0.35	0.27	0.35
F	25.79	32.28	23.80	29.55	24.66	29.84
Log-likelihood	352.53	463.45	352.54	463.64	357.41	464.37
AIC	−681.05	−902.89	−679.08	−901.28	−688.82	−902.75

One-tailed tests were conducted for the main variables and two-tailed tests for the other effects. Standard errors (robust to heteroskedasticity) are in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

included, respectively, in models 3 and 5 as predictors of informal openness, and in Models 4 and 6 as predictors of formal openness.

As shown in Table 5, firm size is positively related to openness, while the effects of age (also in its squared form), largest market of operation and the intensity of perceived competition are not significant. R&D expenditures are closely associated with openness. Human capital is also significantly associated in the baseline model, although the relationship is weaker. In the baseline model the IP Protection variable is not significant. The lack of resources faced by smaller firms might incentivize the search for external knowledge. In addition, the greater flexibility of SMEs in adapting to changing external environment might prove beneficial for 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 base, larger firms face lower search and management costs and expect to benefit more from collaborative agreements.

Results from Model 2 clearly show that business services are more active seekers of external knowledge than manufacturing firms. Models 3 to 6 address the relationship between being a business services firm and engaging in informal and formal open innovation activities. First of all we observe that in the basic specification for all firms (Models 3 and 4), effectiveness of IP protection is associated with formal open innovation activities (Model 4) and not with informal ones (Model 3). Firm size also seems to matter more for formal activities (Model 4). Models 5 and 6 confirm that business services are more active seekers of both formal and informal external knowledge, but service businesses are relatively more engaged in informal open innovation activities (Model 3). The coefficient of the business service dummy is higher in Model 3 compared to Model 4, and significant at 99% (compared to 95%).[20]

We then consider the role of market-based partners compared to science-based partners. In Table 6, Models 1 and 2 show that the importance of both market-based and science-based knowledge is positively associated with open innovation activities. For both informal and formal activities, however, science-based partners are more important than market-based partners. Moreover, market-based partners do not seem to be a more important source of knowledge for business service firms, as the interaction term is statistically not significant (Models 3 and 4). Furthermore, we find that science-based partners are a more important source of external knowledge as far as informal open innovation activities are concerned (Model 5), whereas there is no statistically significant difference between business services and manufacturing firms with regards to formal open innovation activities. Contrary to expectations, business services are attracted by informal science-based collaborators more than manufacturing (as well as high-tech

[20] As a robustness check we also interacted the R&D variable with the business service dummy to rule out the possibility that the association between business services and openness may be an artefact of R&D intensity rather than due to the characteristics of services firms. The interaction term was not statistically significant, confirming our findings.

Table 7
Determinants of OI activities and service integration.

	Informal OI activities (1)	Formal OI activities (2)	Informal OI activities (3)	Formal OI activities (4)	Informal OI activities (5)	Formal OI activities (6)
Size	−0.006	−0.002	−0.006	−0.002	−0.007	−0.003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Age	−0.0008	0.00002	−0.0007	0.00009	−0.0007	0.0001
	(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	0.003	0.0004	0.008	0.004	0.01	0.005
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Competition intensity	0.009	0.004	0.008	0.003	0.005	0.002
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D expenditure	0.02***	0.01***	0.02***	0.01***	0.02***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Human capital	0.0003	0.0005	0.00009	0.0004	0.0002	0.0004
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Effectiveness of IP protection	−0.02	0.04**	−0.006	0.05***	−0.007	0.05***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Market-based knowledge	0.04***	0.01**	0.04***	0.01**	0.04***	0.01**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Science-based knowledge	0.03***	0.08***	0.03***	0.08***	0.03**	0.08***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Share of service in total revenue			0.0008***	0.0005**	0.0007**	0.0004*
			(0.00)	(0.00)	(0.00)	(0.00)
Service integration					0.01***	0.008**
					(0.01)	(0.00)
Constant	0.06	−0.07	0.01	−0.1**	0.0007	−0.1**
	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)
Number of observation	409	409	409	409	409	409
R-squared	0.26	0.34	0.27	0.35	0.29	0.35
F	15.80	19.48	15.07	18.18	14.90	16.90
Log-likelihood	225.80	287.30	229.53	289.15	234.36	291.21
AIC	−429.60	−552.59	−435.06	−554.29	−442.72	−556.42

One-tailed tests were conducted for the main variables and two-tailed tests for the other effects. Standard errors (robust to heteroskedasticity) are in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

manufacturing)[21] firms. Corroborating evidence is emerging that services firms can benefit from the diversity of external knowledge flows as much as manufacturing firms (Leiponen, 2012). This may indicate that in an advanced service economy firms increasingly seek basic knowledge as a source of competitive advantage and tend to do so informally rather than formally.

With regards to the relationship between open innovation and service integration amongst manufacturing businesses, we find strong evidence that the adoption of a service business model is positively related to firm openness. This may relate to the need to gather and recombine different knowledge inputs acquired through a broader set of search activities (Table 7: Models 3 and 4). The inclusion of a service element in the firm's offer is positively and significantly associated with openness. But the clearest evidence is found for our measure of service integration in the firm's innovative output. In line with our finding on the service businesses' relative preference for informal knowledge exchange mechanisms (Models 5 and 6), we also show that adoption of a service business model in product-based firms is more closely associated with their engagement in informal practices compared to formal ones. This provides further evidence of the strong link existing between the integration of service activities in manufacturing businesses and the characteristics of open service innovation.

4.1. Robustness checks

We performed several robustness checks.[22] Firstly, we tested the robustness of our results to the choice of the econometric specification. As our dependent variable has values ranging between 0 and 1, we can treat it as a double censored dependent variable and run estimations using Tobit (Greene, 2000), or we can treat it as a proportional dependent variable and use a fractional logit model (Papke and Wooldridge, 1996). The results of these two estimation methods are very similar to the results shown in the paper. In the interest of clarity, and given the complexities associated with the interpretation of interaction terms in non-linear models, we present and discuss the OLS model.

The second robustness check focused on the dependent variable. We computed a breadth measure for open innovation, similar in construction to the one used in well-known prior studies (Laursen and Salter, 2006; Leiponen and Helfat, 2010; Leiponen, 2012), but different in its components, which are our activities-based measures rather than measures based on knowledge sources. The results obtained with this new dependent variable are very similar to our main results. Final robustness checks have been performed by removing the R&D services sector from our sample to test whether our findings are unduly affected by the presence and characteristics of these businesses (e.g. high R&D expenditures). As expected since these factors are always systematically controlled

[21] Table A6 in Appendix A shows that these results hold when we restrict the comparison to business services and high-tech manufacturing firms.

[22] These are all available from the authors upon request.

for in our prior estimations, there are no major changes in the main findings.[23] Results hold also when we exclude from the sample the top quartile of the distribution of firms by R&D spending.

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 underutilised 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 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 an emergent research programme on open service innovation (Chesbrough, 2011). Firstly, we do so by focusing on business services, where access, use and exchange of knowledge play a key role in value creation. Secondly, we consider the adoption of a service business model by manufacturing firms and look at its association with the degree of openness of firms.

Existing analyses of innovation survey data have revealed that there is considerable variation in the way in which different sectors innovate. Typically, studies based on the CIS work with the observation of how many and what types of collaborators/sources firms use. However, they cannot address the questions which our data can of what open innovation activities they engage in, to what extent 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., 2010, 2011; Chesbrough, 2011) constitute rare exceptions that help redirect the necessary attention to services, a fundamental component of advanced economies by both value added and employment.

From a methodological viewpoint, this study provides novel quantitative evidence which is an essential complement to the emergent case study work on open service innovation. Furthermore, our evidence is comparative and we are able to look at the same time at the characteristics of manufacturing and business service sectors, and then also focus on the product vs. service output of firms. The study has, of course, limitations. It is an intensive study of services – business services – characterised by high innovation rates. This choice is appropriate because these firms are arguably the most active open service innovators. This does not mean that traditional services cannot and should not derive considerable advantages from the adoption of open innovation solutions, but these are very unlikely to be the same solutions adopted, for example, by R&D-intensive firms. Secondly, the study is based on cross-sectional data, an aspect which cautions against making strong claims on causality without the assistance of panel data. But despite these limitations, this study provides a unique opportunity to observe the conduct of open innovation activities in a fairly large sample of businesses. It includes novel and original evidence on an important characteristic of advanced economies: their service profile. Finally, its results are robust to different specifications of both our dependent variable and estimation technique.

Among the firm-level characteristics associated with openness, our results confirm that cooperation tends to increase with R&D intensity (Fritsch and 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. Effectiveness of IP protection is positively associated with formal, but not informal, open innovation practices. The relational nature of services is reflected in their higher degree of openness relative to manufacturing firms, with a preference for informal over formal practices relative to manufacturers. The literature on services often emphasises interactions, or co-creation of output, with customers (Bettencourt et al., 2002; Vargo et al., 2008). Interestingly, however, we find that although customers remain a very important source of knowledge, as far as innovation is concerned and on a comparative basis, business services seem to be sensitive to potentially higher marginal benefits generated from engaging with universities and the public research base. Compared to prior empirical studies, our results might indicate a development over time in the patterns of collaboration of UK firms. On the one hand, this may be facilitated by the growing institutional expectation that universities improve the impact of their research by intensifying their collaboration with industry. On the other hand, this may reflect the dynamism of a sector that is among the most productive and internationally competitive of the whole UK economy. Or to look at this from a different angle, the importance of interactions with customers may still be under-emphasised in analyses of manufacturing sectors where market knowledge could be more important because manufacturing innovation may be, on average, more expensive and errors more costly.[24] In any event our findings suggest that further theoretical work on the purpose and nature of activities with different partners is a potentially fruitful area for research. So too is the nature of the link between open innovation activities and the choice between informal and formal modes of mediating such activities. They also suggest that new theorising is required on the form and nature of the knowledge exchanges firms may undertake with the science base, with possible extensions of conceptual models that are not limited to purely technological and scientific knowledge (Hughes and Kitson, 2012).

When we consider services as economic activities instead of groups of firms identified by standard industry classifications, the data are consistent with the view that manufacturing firms are also part of the service economy. In line with Chesbrough (2011) we find that in manufacturing businesses open innovation practices are associated with the adoption of a service business model, as indicated by service sales revenues and the integration of a service component in the firm's innovation output. The more complex the innovation, and the broader the knowledge input that is required, the more likely that firms will seek external knowledge (Bayona et al., 2001; Piga and Vivarelli, 2004; Tether, 2002). These findings are also compatible with the view that service innovation tends to be recombinative or 'architectural' rather than purely technological in nature (De Vries, 2006). In addition, and consistently with our prior finding, the association of service integration amongst manufacturing businesses is stronger with the degree of

[23] The R&D service sector plays an important role in open innovation, and may present analytical challenges in a comparative setting. The exclusion of our R&D service firms ($n = 50$) from our sample does not, however, fundamentally change the story. The only notable difference is a lack of association between the business service dummy and formal OI practices and a significant effect in the interaction between market-based knowledge and the business service dummy, as we would expect. Importantly, business services remain more active open innovators, more engaged in non-contractual practices, and with a preference for informal collaborations with the university baserelative to manufacturing firms.

[24] We thank an anonymous referee for this observation.

engagement in informal activities than with engagement in formal activities.

Of course, an important question remains as to whether openness translates into superior market performance and whether, where and under what circumstances in the service economy. This analysis is outside the scope of this contribution. It is of course a primary avenue for further research, but one that cannot be undertaken without an in-depth understanding of the ex ante distribution of open innovation behaviours across firms. Our findings provide solid foundations for further reconceptualisations of open innovation in service businesses and for new analyses of the changing boundaries of the firm in the service economy.

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Appendix A.

See Tables A1–A6.

Table 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 organisations, 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

Table 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

Table A3
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 internal R&D expenditures (+1)
Human capital	Proportion of the firm's employees that were educated to degree level or above
Effectiveness of IP protection	Means of scores of importance of patent protection' use among the firms in 2 digit industry
Market-based knowledge	Importance of customers and users as source of knowledge as scored by the firm
Science-based knowledge	Importance of universities, higher education institutes and public sector research organisations as source of knowledge as scored by the firm
Service integration in 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
Service integration in output	Share of total revenue accounted for the services

Table A4
Correlation table.

		1	2	3	4	5	6	7	8	9	10	11	12
1	OI activity												
2	Size	0.15											
3	Age	−0.03	0.26										
4	Largest market	0.22	0.11	0.02									
5	Competition intensity	0.01	0.14	0.02	−0.05								
6	R&D expenditures	0.44	0.37	0.11	0.41	−0.08							
7	Human capital	0.24	−0.33	−0.25	0.20	−0.05	0.12						
8	IP protection	0.16	0.06	0.17	0.25	−0.02	0.29	0.00					
9	Market-based knowledge	0.29	0.15	0.04	0.11	0.04	0.20	0.00	0.02				
10	Science-based knowledge	0.49	0.07	0.00	0.17	−0.02	0.30	0.19	0.16	0.17			
11	Service integration in innovation	0.19	0.15	−0.02	−0.03	0.12	0.08	−0.04	0.01	0.07	0.04		
12	Service integration in output	0.09	−0.22	−0.26	−0.16	0.07	−0.17	0.44	−0.31	−0.03	0.03	0.02	
13	Bus. service dummy	0.16	−0.24	−0.30	−0.05	0.01	−0.07	0.57	−0.32	−0.01	0.07	0.00	0.65

Table A5
Determinants of OI activities – high-tech manufacturing sample.

	Total OI activities (1)	Total OI activities (2)	Informal OI activities (3)	Formal OI activities (4)	Informal OI activities (5)	Formal OI activities (6)
Size	0.02**	0.01**	0.02**	0.01**	0.01**	0.01**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Age	−0.001	−0.0003	−0.001	−0.001	−0.0002	−0.0003
	(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	0.004	0.010	−0.006	0.01	−0.001	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Competition intensity	−0.006	−0.008	−0.006	−0.005	−0.008	−0.007
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D expenditures	0.02***	0.02***	0.02***	0.01***	0.02***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Human capital	0.0006***	0.0004	0.0005***	0.0007***	0.0003	0.0004
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Effectiveness of IP protection	0.02	0.04**	−0.02	0.05***	0.005	0.08***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Bus. service dummy (BSD)		0.06***			0.06***	0.07***
		(0.02)			(0.02)	(0.02)
Constant	0.03	−0.08	0.2***	−0.1*	0.06	−0.2***
	(0.05)	(0.06)	(0.06)	(0.05)	(0.07)	(0.07)
Number of observation	419	419	419	419	419	419
R-squared	0.16	0.18	0.12	0.17	0.13	0.18
F	10.79	11.24	7.03	10.28	6.87	10.30
Log-likelihood	211.89	216.65	129.82	173.03	132.67	177.43
AIC	−405.79	−413.30	−241.64	−328.06	−245.34	−334.85

One-tailed tests were conducted for the main variables and two-tailed tests for the other effects. Standard errors (robust to heteroskedasticity) are in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table A6
OI activities, market and scientific knowledge – high-tech manufacturing sample.

	Informal OI activities (1)	Formal OI activities (2)	Informal OI activities (3)	Formal OI activities (4)	Informal OI activities (5)	Formal OI activities (6)
Size	0.01	0.01**	0.01	0.01***	0.01***	0.01**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Age	−0.0006	−0.0005	−0.0006	−0.0005	−0.0006	−0.0005
	(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	−0.008	0.01	−0.008	0.01	−0.008	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Competition intensity	−0.002	−0.002	−0.002	−0.002	0.0001	−0.001
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D expenditures	0.02***	0.010***	0.02***	0.010***	0.02***	0.010***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Human capital	0.0000	0.0002	0.0000	0.0002	0.0000	0.0002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Effectiveness of IP protection	−0.002	0.06***	−0.002	0.06***	−0.008	0.06***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Market-based knowledge	0.03***	0.02***	0.03***	0.03***	0.03***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Science-based knowledge	0.07***	0.09***	0.07***	0.09***	0.03	0.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Bus. service dummy (BSD)	0.06***	0.07***	0.07**	0.09***	0.02	0.05**
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)
Market-based knowledge X (BSD)			−0.003	−0.01		
			(0.02)	(0.01)		
Science-based knowledge X (BSD)					0.06***	0.03
					(0.03)	(0.02)
Constant	0.03	−0.2***	0.03	−0.2***	0.07	−0.2***
	(0.07)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
Number of observation	399	399	399	399	399	399
R-squared	0.25	0.36	0.25	0.36	0.26	0.36
F	13.25	19.25	12.23	17.83	13.07	17.39
Log-likelihood	156.52	215.02	156.54	215.40	159.97	216.00
AIC	−289.04	−406.04	−287.07	−404.80	−293.95	−406.01

One-tailed tests were conducted for the main variables and two-tailed tests for the other effects. Standard errors (robust to heteroskedasticity) are in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

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