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Exploiting Knowledge Flows: Openness and the innovative performance of business services

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Abstract

Innovation requires a capacity to seek, absorb and utilize external knowledge, and an ability to develop, leverage or exchange internally-generated knowledge. Internally to the firm, it requires the structuring of information channels within and across hierarchical or divisional levels. Externally, it implies choices and costs in selecting and managing interactions and collaborations. The way in which these two types of organisational choices jointly contribute to firm performance has been substantially under-researched. Based on an original survey of open innovation practices amongst UK firms, this paper addresses the impact of external and internal openness, and the role of formal vs. informal knowledge sourcing practices (and their interaction) on the innovative performance of business services. Not only external but also internal openness positively affect the innovative performance of firm. Among different types of knowledge exchange mechanisms, informal practices are especially effective in business services. On the contrary, joint engagement in formal and informal activities decreases the firm's innovative performance, a result which points to the occurrence of diseconomies of scale and managerial attention constraints. In-depth analyses of different groups of firms generate further insights into how the benefits of openness vary substantially with firm size.

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EXPLOITING KNOWLEDGE FLOWS:

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Abstract:

Innovation requires a capacity to seek, absorb and utilize external knowledge, and an ability to develop, leverage or exchange internally-generated knowledge. Internally to the firm, it requires the structuring of information channels within and across hierarchical or divisional levels. Externally, it implies choices and costs in selecting and managing interactions and collaborations. The way in which these two types of organisational choices jointly contribute to firm performance has been substantially under-researched. Based on an original survey of open innovation practices amongst UK firms, this paper addresses the impact of external and internal openness, and the role of formal vs. informal knowledge sourcing practices (and their interaction), on the innovative performance of business services. Not only external but also internal openness positively affect the innovative performance of firm. Among different types of knowledge exchange mechanisms, informal practices are especially effective in business services. On the contrary, joint engagement in formal and informal activities decreases the firm's innovative performance, a result which points to the occurrence of diseconomies of scale and managerial attention constraints. In-depth analyses of different groups of firms generate further insights into how the benefits of openness vary substantially with firm size.

Key Words:

Open innovation; Innovative performance; Business services.

INTRODUCTION

Innovation requires a capacity to seek, absorb and utilize external knowledge, and an ability to develop, leverage or exchange internally-generated knowledge. This a prominent theme in the literature on 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), innovation networks (Ahuja, 2000; Burt, 1992; Freeman, 1991; Kogut, 2000; Powell and Grodal, 2005) and – at a higher level of aggregation – innovation systems (Freeman 1995; Lundvall, 1992; Malerba, 2004; Nelson, 1993). While the exchange of knowledge among agents is partly an emergent property of networks, from the viewpoint of the firm this it is not a resource-free activity and requires substantial organizational efforts (Chesbrough, 2006). Internally, it requires the structuring of information channels within and across hierarchical or divisional levels. Externally, it requires cognition, choices and costs in selecting and managing interactions and collaborations (Foss, 2005).

The emphasis on the notion of open innovation (Chesbrough, 2003; 2006) has popularized some important aspects of the problem of the external organization of the firm. 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 & Veugelers, 2002; ; Miotti & Schwald, 2003; de Faria, Lima & Santos, 2010). Open innovation requires the capacity to absorb knowledge from multiple sources and in turn share knowledge with external organizations, including competitors, clients and suppliers.

Although the role of external 'openness' and its impact on firms' innovation and performance has been extensively studied in the previous literature, the role of 'internal openness' in this context has received less attention (Love et al. 2011). The opening up of innovation processes poses a challenge for the extant internal organization of the firm (Chesbrough, 2006; Colombo, Laursen, Magnusson, & Rossi-Lamastra, 2011). For example, an increase in the relative importance of intangible and tacit resources may induce a gradual shift of power from management to employees (Tsoukas, 1996) and firms can be better off moving away from hierarchical structures and adopting less formalized coordination mechanisms (Foss, Laursen & Pedersen, 2011). The interaction of external and internal openness, however, as well as their individual and joint impact on innovation performance, is still poorly understood (Colombo et al., 2011).

This paper addresses this gap by exploring the impact of external and internal openness on the innovative performance of firms. The premise of this paper is that firms differ both in the way in which they facilitate internal knowledge flows and the way in which they search for, access and use knowledge across organizational boundaries. Moreover, when they engage in knowledge exchanges with the external environment, firms have different preferences for a variety of mechanisms through which these exchanges can take place. In particular, a firm might engage in knowledge exchanges through formal or informal means. The choice of formal or informal mechanisms is likely to affect innovative performance in different ways conditional on firm characteristics and its sector of operation.

In this study we investigate the effects that this set of strategic decisions exerts on the innovative performance of firms. Our empirical focus is on business services, a low capital-intensive sector of the economy that relies on the organization of knowledge flows within and across boundaries to gain and sustain competitive advantage (Bessant & Rush, 1995; Hargadon & Sutton, 1997; Howells, 2006).

The data for this analysis is drawn from an original survey specifically designed and launched in 2010 to study the open innovation practices of UK companies [ANONYMIZED FOR SUBMISSION]. We first distinguish between the performance effect of internal knowledge flows and external ones. Our analyses reveal strongly significant and positive effects for both. We then distinguish between the formal and informal mechanisms that are used to access external knowledge, and find striking differences: the former exert no noticeable effect on the innovative performance of business services while the latter exert strong positive effects. Interestingly, pursuing both informal and formal practices seem to decrease the share of innovative sales, which can be interpreted as an indication of diseconomies of scale or managerial attention constraints. Finally, these effects appear to vary substantially across size classes.

This paper contributes to the theory of the knowledge-based firm by relating internal and external, and formal and informal knowledge flows with innovative performance. It highlights the effects of complementary and alternative mechanisms through which knowledge is created, absorbed, leveraged and exchanged within and across firm boundaries. The empirical contribution of the paper is an original quantitative analyses of micro-level behaviors for which there has traditionally been scarcity of data for applied research. Furthermore, the paper extends our understanding of a sector of the economy – business services – which is still under-researched despite its very substantial, and increasing, contribution to economic growth both by employment and value added.

The paper is organized as follows: Section 2 reviews the literature and develops testable hypotheses. Section 3 describes the data and the variables and the empirical methodology. Section 4 presents the results and Section 5 concludes.

THEORY AND HYPOTHESES

External knowledge flows and internal openness

The ability to exploit external knowledge has been theorized as a significant driver of innovative performance (Cohen & Levinthal, 1990: 128). This is not only because of the combinatorial properties of innovation (Katila & Ahuja, 2002) but also because the original creators of innovative ideas might not be the best users of these ideas when the challenge becomes the commercial development of, and extraction of value from, novel products or processes (Arora et al. 2002). The open innovation literature contends that firms are increasingly looking outside their organizational boundaries to improve their innovative performance (Chesbrough, 2006).

Scholars of innovation have investigated the role of collaborations (Pisano, 1990), alliances (Ahuia, 2000) and more generally systemic connections (Nelson, 1993) in the pursuit of novel sources of competitive advantage. Access to and use of external knowledge can enable firms to de-risk technology development and thus reduce technological uncertainty. They can allow firms to share costs, gain complementary assets, enter new markets, and realize economies of scale and scope in research (Ahuja, 2000; Cassiman & Veugelers, 2002; de Faria et al., 2010; Miotti & Schwald, 2003). Clearly the management of external knowledge flows is a non trivial task and the implementation of open innovation activities requires specific capabilities and resources (Lichtenthaler, 2011). Among the possible risks is the possibility that firms misdirect or misalign resources (Ahuja & Kattila, 2001; Sapienza, Parhankangas & Autio, 2004), and that they exceed optimal levels of 'openness', overstretch limited resources, including managerial attention (Ocasio, 1997), thus actually decreasing innovative performance (Laursen & Salter, 2006).

While controlling for non-linear effects, we hypothesize that:

HP1: External know*ledge flows exert a positive effect on firm' innovative* performance.

The organization of external knowledge flows is one side of a more extensive system of knowledge exchanges. This includes the firm's internal patterns of communication, a specific form of routines (Nelson & Winter, 1982) through which firms exchange knowledge within organizational boundaries (Allatta & Singh, 2011). This internal organization of knowledge is a major source of competitive advantage and one of the most important areas of strategic decision-making (Kogut & Zander, 1992; Nonaka, 1994). The sharing of knowledge exerts a positive influence, for example, on team performance (Reagans & Zuckerman, 2001; Rulke & Galaskiewicz, 2000; Sparrowe et al., 2001) and has been related to the management of the division of labor in complex products, where different individuals might contribute to different subcomponents (Baldwin & Clark, 2000).

We define 'internal openness' as the ability of firms to share and distribute knowledge within its organizational boundaries. Internal openness reflects the organizational design of the firm and depends on its hierarchical structure, degree of co-operation among employees and informality of communication patterns (Bunderson & Boumgarden, 2010). Although there is a risk that excessive knowledge sharing reduces cognitive variety and thus limits the creative potential of the firm (Burt, 1992; McFadyen & Cannella, 2004), we posit that overall internal openness positively influences the innovative performance of firms because it can align objectives, create a shared vision of tasks and responsibilities and hence facilitate problem solving for the purposes of innovation. We therefore hypothesize that:

HP2: Internal openness exerts a positive effect on firms' innovative performance.

It can also be argued that external knowledge flows and the internal openness of firm may induce synergetic effects on the firm's innovation performance: the full value of the knowledge that is brought into the firm from the external environment can be best exploited when it is shared and fully understood in different parts of the organization. The benefit of internal openness should more than compensate for the risk that a high frequency of internal co-operation, leading to an inward-looking organization, reduces the propensity to accept external knowledge inputs (Burt, 1992; Ibarra, 1992; Oh et al., 2004; Bunderson & Boumgarden, 2010). We therefore test for positive interaction effects and hypothesize that:

HP3: Internal openness enhances the effects of external knowledge flows on innovative performance.

Formal and Informal Knowledge Flows

Although the vast majority of existing contributions on firms' external search has been focused on formal agreements with different partners, a great deal of information exchanges is in fact informal: firms can engage directly with users, participate in innovation networks, or share un-codified know-how with other firms. Informal networks do not involve any contractual relationship between partners and tend not to be designed as means to generate output in the form of a patent or a prototype (Grimpe & Hussinger, 2008). In informal arrangements collaboration is based on mutual trust and moral obligations rather than legally binding contracts (Appleyard, 1996; Leibeskind et al., 1996; Van Aken & Weggemen, 2000).

Compared to formal arrangements, informal collaborations are relatively overlooked, mainly because these can take a number of forms that leave no paper trail and are therefore difficult to capture (Hagedoorn et al., 2000). With the exception of Bonte and Keilbach (2005), the small number of studies that have considered informal partnerships has focused

on intra-industry knowledge sharing (see for example Schrader, 1991; Appleyard, 1996). Yet, there is some evidence that firms often prefer informal cooperative arrangements (Bonte & Keilbach 2005) and report that informal exchanges are the most important type of cooperation in which they chose to engage (Harabi, 1998). This preference for informal collaborations over formal ones may be partly explained by the costly and time-consuming nature of the formal contracts. Informal technology exchanges, for example through contacts, meetings or conferences, give a firm the opportunity to browse for relevant technological knowledge without mobilizing substantial human or financial resources. Some of these activities are rather easy to create, but may constitute great opportunities for companies – especially smaller companies – to tap into the "world's knowledge base" (Van Aken & Weggemen, 2000).

Importantly, informal exchanges may enable the firm to access tacit knowledge surrounding formalized technological know-how (Grimpe & Hussinger, 2008). Previous work on industry-university linkages shows that the highest proportion of the knowledge that is 'transferred' through informal links has tacit nature (Faulkner and Senker, 1995) and that formal and informal flows of knowledge are in fact complementary (Grimpe and Hussinger, 2008). It has been shown that it is the unplanned nature of informal interactions that may be conducive to future successful collaborations and/or to innovations (Kreiner and Schultz, 1993), although collaboration in informal innovation networks is typically not aimed at short-term innovation but rather at technology exchange, learning and the generation and testing of new ideas (Van Aken and Weggement, 2000). On these premises, we hypothesize that:

HP4: Informal activities will have a higher positive impact on firms' innovative performance relative to formal activities.

Beyond the direct effect of informal activities on innovation, informal searches may also increase the firms' performance indirectly by leading to more formal types of collaborative agreements (Kreiner and Schultz, 1993), as observed by Freeman: "Behind every formal network, giving it the breadth of life, are usually various informal networks" (Freeman, 1991: 503). Not only informal search activities can act as a catalyst for more formal collaborations, these informal and personal networks can also ensure the latter's success, helping to overcome internal barriers and resistance to external knowledge as manifested through the so-called not-invented-here and/or not-sold-here syndromes (Katz and Allen, 1982). We therefore expect that:

HP5: Informal search activities will strengthen the relationship between formal external search and innovative performance.

DATA AND VARIABLES

Empirical Setting

The empirical setting of this study is the business services sector. This provides an ideal context for an analysis of knowledge flows from an innovation perspective given its intangible sources of competitive advantage and its high rates of innovation. Far from the marginal role they have long been attributed in both the economics and management literatures, business services are one of the most valuable segments of the service economy and include some of the most important activities in terms of growth rates, employment and innovation (Metcalfe & Miles, 1999; Rubalcaba and Kox, 2007; Djellal & Gallouj, 2011). Business services provide intermediate inputs, from the most part labour- rather than capital-intensive, to other businesses (Miles et al. 1995). They include a variety of subsectors characterized by varying degrees of technological intensity. These range from the substantial utilization of science and technology assets by R&D services, to the relatively low

technological content of the output of legal or employment services output (Evangelista, 2000; Hughes and Wood, 2002; Tether, 2002; Tether and Tajar, 2008, von Nordenflycht, 2010).

Business services are intensive users of external knowledge sources (Hipp, 2010; Tether & Tajar, 2008) with high frequency of interaction with customers and suppliers (Tether, 2005; Leiponen, 2005). The 'relational' nature of service businesses makes them highly suitable to the adoption of 'open' innovation strategies. This provides a good fit for the brokering role or intermediation function that have been attributed to these businesses in relation to the value chain – or more broadly the innovation system – in which they operate (Bessant and Rush, 1995; Hargadon and Sutton, 1997; Howells, 2006). The relevance of the open innovation model for service businesses has recently been brought to the fore (Chesbrough, 2011). However, the availability of evidence on the effects of knowledge sourcing on the performance of business services is seriously limited by the fact that only the sources, but not the types, of knowledge exchanges have been captured in empirical research based, for example, on Innovation Survey data (Mansury & Love, 2008; Love et al., 2010).

Data

The data for this analysis are drawn from the [ANONYMIZED FOR SUBMISSION], specifically designed to study the open innovation practices of UK companies. A systematic random sampling method was used to draw a sample of 12,000 firms from Bureau van Dijk's FAME Database, which contains detailed financial company-level information on UK and Irish businesses. The survey was sent to firms between 5 and 999 employees, in order to fill the gap on small and medium sized firms' open innovation practices. 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. 1,202 firms completed the survey, leading to a 10% response rate. Checks for non-response bias did not reveal any significant problem [ANONYMIZED FOR SUBMISSION].

The final sample of business service firms has 442 observations. Missing value problems reduce the size of sample to 265 firms with complete responses. Between the original sample and our final database we do not find any sample attrition bias in our key variables[1] (share of innovative sales, R&D intensity, internal and external openness, firm size and age), although there is an indication of a bias towards more knowledge intensive firms and results should be interpreted bearing this in mind.[2]

Variables:

Our dependent variable is the firm's innovative performance. The survey asked about the firms' total sales revenue in the last financial year derived from new and/or significantly improved products and/or services introduced within the last three years. This widely used measure of innovative performance reflects both the companies' ability to introduce new products as well as these latter's commercial success (Laursen and Salter, 2006; Leiponen and Helfat, 2011; Love, Roper and Vahter, 2011). On average, 71% of the firms in our sample introduced new products and services, and 31% reported increased sales due to these new product and/or services (See Table A.1 in the Appendix for descriptive statistics.). 50%

[1] When the data appeared normally distributed, a 2-sample t test; otherwise, a Wilcoxon-Mann-Whitney test has been used to test for sample attrition bias. The results of these tests are available from the authors upon request.

[2] In our final sample, firms have on average 63% of their employees with a higher degree compared to 33% in the rest of the sample.

of these innovations are reported to be new to the market by the innovating firms (both in the whole and in the final samples).

The key explanatory variables in our study are firms' external knowledge flows and its internal openness. Internal openness is measured on a scale of items related to the role of co-operation, flat hierarchies and informal management styles, on a Likert-scale of 1 to 5.

Firms were also asked to indicate the degree of importance of a number of informal and/or formal activities with external parties for the purposes of innovation. The list of the open innovation activities are presented in the Appendix (A3).

Both measures are normalized sums of the amount of relevant dimensions/activities. The openness variables thus constructed have a high degree of internal consistency (Cronbach's alpha = 0.69 and 0.84 respectively). Two additional measures of external knowledge flows have been constructed, by distinguishing between informal (Cronbach's alpha = 0.70) and formal (Cronbach's alpha = 0.82) activities. The most widely used informal search activity is as expected "engaging with lead users". 66% of our sample reports to have engaged with lead users and early adopters, while 26% ranks this activity as highly important. Among the formal search activities, "joint-marketing and/or co-branding" seems to be widely used by business services firms with 35% of the sample reporting it, followed by "licensing in externally developed technologies" (29%) and "joint R&D" (28%). However, the most important contractual activity is "providing contract research to others", with 9% or our sample scoring it as highly important, followed by 8% scoring "joint R&D".

Previous research has highlighted that there might be limits to the benefits of openness (Ahuja, 2000; Katila & Ahuja, 2002). Empirical studies have indeed found a negative effect of over-searching on firms' innovative performance (Laursen & Salter, 2006; Leiponen & Helfat, 2011, Love et al., 2011). In order to take into account this potential non-

linear relationship between openness and innovative performance, we include into our regression the square terms of internal openness and external search activities.

As further controls, we introduce a measure of research and development (R&D) activities, the logarithm of firms' R&D expenditure and a measure of knowledge intensity, percentage of employees with a first and/or higher degree, to control the effect of R&D and knowledge intensity 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-linearity.

Estimation Method:

The share of innovative sales is a proportion whose values are bound between zero and one hundred percent by definition; we have hence a double censored dependent variable. Accordingly, we use a fractional logit model (Papke & Wooldridge, 1996), which can deal with the proportional nature of dependent variables. Although the two-limit tobit model has been widely used to estimate the determinants of innovative sales in previous work (Laursen & Salter, 2006; Leiponen & Helfat, 2010, among others), it has been argued that the fractional logit model is more appropriate given that censoring does not occur because the dependent variable is unobservable (Falk, 2008; Ebersberger, 2010).

We also control for the potential sample selection bias by estimating a first stage probit model on the decision of engaging in open innovation activities. We construct the inverse Mills ratio from the first stage selection estimation and include it as an explanatory variable in the second stage estimation. The selection equation includes size, age, R&D expenditures, knowledge intensity and a measure of the effectiveness of IP protection at the industry level.

Robustness checks:

As a robustness check, and in order to allow the comparison of our results with previous studies, we also apply a Tobit analysis (Greene, 2000). The results can be found in the Appendix (Table A.4.).

RESULTS

Table 1 presents the baseline model (1) and the relevant tests for our hypotheses (Models 2 to 6). The Inverse Mills ratio, obtained from the first stage equation is significant for all the specifications, confirming the existence of the selection bias.[3] Among the control variables, we find that knowledge intensity is positively related to innovative performance, as expected. However, we do not find any statistically significant impact of firm size and R&D expenditures. The non-significant coefficient on the R&D variable is explained by the first stage selection equation. Existing evidence on the effect of size on innovative performance appears to be mixed; while some studies find a positive effect (for example, Laursen & Salter, 2006; Love et al., 2011), others have found a non-significant effect (Leiponen & Helfat, 2011). We also find a negative impact of firm age. Although the results point to a U-shaped relationship between age and innovative performance, the square term of age is only seldom significant. Furthermore, the turning point of the non-linear relation is around 55 years, an age reached only by 2% of our sample.

INSERT TABLE 1 ABOUT HERE
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[3] The first stage selection model (not reported but available upon request) reveals that engaging in open innovation activities is mainly explained by firms' internal R&D expenditures.

Our first hypothesis posited that external knowledge flows will be positively associated with innovative performance, and is confirmed by Model (2). We find that a unit increase in external openness is associated with a 3.6% increase in innovative sales. Model (2) also incorporates the squared term of the external openness variable in order to evaluate the potential non-linearity previously found in the literature. Our results corroborate the findings of prior contributions; innovative performance has an inverted U-shaped relationship with firms' external search activities (Laursen & Salter, 2006; Leiponen & Helfat, 2011; Love et al., 2011). When a particular level of openness is reached, firms' external search activities provide decreasing returns for innovative sales. The tipping point of this non-linear relationship is around 0.4. A closer look to the data shows that around 90% of our sample has an index of external openness inferior or equal to 0.4. We can therefore conclude that only a small fraction of business service firms suffer from the decreasing returns of openness. This result is also in line with previous research on manufacturing firms (Leiponen and Helfat, 2011; Love et al., 2011).

The second hypothesis concerned the impact of internal openness on innovative performance. We find that firms that are "internally" more open perform better than those that are not (Model 3). A unit increase in internal openness enhances innovative sales by around 7%. The squared term of the internal openness variable is found positive but not significant. We conclude therefore that there is no non-linear relationship between internal openness and innovative performance, and exclude the square term of internal openness from subsequent models.

Our third hypothesis addressed the possible effect of the interaction between internal and external openness on service firms' performance. Contrary to our expectations, we find a significant and negative moderator effect of internal openness on external knowledge flows (Model 4), suggesting a potential substitution effect between internal and external openness.

This result hints at the presence of distinct sets of organizational mechanisms governing knowledge flows within and across organizational boundaries.

Results for hypothesis 4, which explored comparisons between the impact of informal and formal external searches on innovative performance, are presented in Model (5). Only informal search strategies are positively associated with innovative sales: we find that a unit increase in informal OI activities is associated with around 5% increase in innovative sales, confirming hence our hypothesis.

Model (6) explores in depth the moderator effect of internal openness on informal and formal external search. We find that the negative moderator effect found in Model (4) is mainly due to formal activities.

Finally, Model (7) tests our last hypothesis on the performance effect of engaging simultaneously in informal and formal external search activities. We find a negative impact on innovative performance. Overall, business service firms seem to benefit much more from informal search activities than formal collaborative agreements and from their internal openness.

We now want to have a closer look at the possible variation of these effects across firm size classes. Non-linear effects across size distributions are not picked up by the size variable as a control due to our two-stage estimation procedure. In order to investigate these potential non-linearities between size, R&D and search activities, we run a further robustness check and split our sample by size classes.

As we have mentioned earlier, the sample includes small and medium sized firms for which quantitative studies on external sources of knowledge are rather scarce (the few exceptions to our knowledge are studies from van de Vrande, Vareska, Jong & Vanhaverbeke, 2009; Lee, Park, Byungun & Park, 2010; Brunswicker & Vanhaverbeke, 2011) despite SMEs' crucial role in innovation networks. Constraints on financial and

technological assets make external knowledge sources highly relevant for SMEs (Baum et al. 2000). At the same time, it can be argued that there are substantial size-related differences between SMEs in the impact of internal and external sources of knowledge, and their interactions on innovative performance.

We identify three size classes; micro-firms with less than 9 employees, small firms with 10 to 50 employees and medium firms with more than 50 employees. The results of these specifications are presented in Tables 2, 3 and 4 respectively.

INSERT TABLE 2 ABOUT HERE

For micro enterprises (Table 2), we find a positive and significant impact of R&D expenditures (and note that the inverse mills ratio is not significant). External openness has the expected non-linear effect; the negative impact of OI activities occurs for an external openness index of around 0.3, affecting around 29% of micro-firms, a higher ratio compared to the whole sample. Internal openness has a positive effect on innovative performance, but it has no moderating effect on external openness. As expected, informal external search activities are found to increase innovative performance. Internal openness has no moderating effect on formal and informal external search activities. Interestingly, the positive impact of R&D investments disappears when we take into account internal openness, whereas the positive impact of internal openness disappears when we distinguish between formal and informal activities. Our results hint to potential complementarities between internal R&D investments, internal openness and informal open innovation activities for micro-firms but more in-depth analyses are needed to disentangle the nature of these relationships and verify to what extent these are due to resource constraints.

INSERT TABLE 3 ABOUT HERE

Results are quite different for small firms (Table 3). In this subsample we do not find a non-linear relationship between external openness and innovative performance, and external openness has a positive impact. Furthermore, the internal openness variable is also insignificant. The innovative performance of small firms seems closely related to the extent of their external openness, and both formal and informal external search activities are positively associated with innovative performance, with formal activities having a stronger impact than informal ones. However, simultaneously engaging in formal and informal activities produces negative effect on innovative performance.

INSERT TABLE 4 ABOUT HERE

Finally, medium sized firms emerge as those who benefit the most from open innovation activities. With a squared term positive and significant, the results suggest increasing returns to external search activities. Internal openness is also significant and positive, even though a negative effect is found for the interaction between internal and external openness. The positive effect of open innovation activities seem to only relate to informal activities. This positive effect is increased by internal openness, suggesting a complementary relationship between this and informal external search. Conversely, we find a negative interaction effect between internal openness and formal search, which suggests a degree of attrition between formal open innovation activities and organisational arrangements that favors internal co-operation, flat hierarchies and informal management styles.

CONCLUSION

Firms differ in the way in which they facilitate internal knowledge flows and in the way in which they search for, access and use knowledge. In this paper, we investigate the performance effect of the strategic decisions regarding the mechanisms of knowledge exchange, both within and across organizational boundaries. Through an original survey of UK firms, we explore a particular set of firms – business services – which prior literature characterizes as knowledge integrators and intensive users and producers of innovation. These characteristics qualify business services as an ideal setting to evaluate firms' exploitation of knowledge flows.

We find that both internal and external knowledge flows are associated with firms' innovative performance. However, the empirical results hint to a potential substitution between these two types of knowledge flows, suggesting a distinct set of organizational mechanisms governing knowledge flows within and across organizations.

As far as different mechanism of accessing to external knowledge, we find that only informal practices are positively associated with innovative performance. As observed by Hamel, Doz and Prahalad (1989, p: 136) "Many of the skills that migrate between companies are not covered in the formal terms of collaboration. Top management puts together strategic alliances and sets the legal parameters for exchange. But what actually gets traded is determined by day-to-day interactions of engineers, marketers, and product developers". Previous research points to time and cost constraints to explain firms' choice of informal over formal means of knowledge exchange (Bonte and Keilbach, 2005); these constraints may also cancel out the potential positive effect on innovative performance.

Contrary to our expectations, we do not find evidence on the indirect performance effect of informal knowledge flows. On the contrary, engaging simultaneously in both informal and formal search activities seem to decrease firm's innovative performance. Again,

different sets of organizational skills may be needed to govern different types of knowledge flows. Finally, our in-depth analysis of size effects reveals considerable heterogeneity. The positive effect of external openness seems very much related to the firm size with larger SMEs benefiting substantially more from external knowledge flows.

Overall, this paper contributes to the theory of the firm by relating internal and external, and formal and informal knowledge flows with innovative performance. It highlights the firm's need for complementary and alternative mechanisms in the organization of knowledge that leads to superior performance. It also contributes to the deepening our understanding of a sector – business services – which despite its increasing contribution to economic growth and employment is still severely under-researched with respect to manufacturing businesses. A focus on small and medium size enterprises also constitutes advancement over the state-of-the-art because the majority of studies on open innovation focus on large firms, while only a minority of studies provides systematic quantitative evidence on a sufficient scale.

The study and the data upon which it is based have, of course, also some limitations. The survey instrument through which the data were generated was designed to gather quantitative evidence on open innovation practices and lacks information on the nuances of organisational behaviors as well as detailed information, for example, on individual-level incentives to share knowledge within and across firm boundaries. In addition, given the cross-sectional nature of the data, our study cannot provide conclusive evidence on a causal relationship between knowledge flows, openness and innovative performance. It does, however, provide novel and original evidence based on a unique dataset on the links between the organization of knowledge and innovative performance. A dynamic approach to this problem, based on the availability of panel data, certainly is an important avenue for future research.

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TABLES AND FIGURES

Table 1. Performance effect, External Search and Internal Openness

	1	2	3	4	5	6	7
Size	-0.0207	-0.018	-0.0134	-0.0143	-0.0193	-0.0194	-0.0155
	(0.017)	(0.017)	(0.018)	(0.018)	(0.017)	(0.017)	(0.018)
Age	-0.011***	-0.011***	-0.010***	-0.009***	-0.010***	-0.009***	-0.001***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Age Squared	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Knowledge intensity	0.0021***	0.0019***	0.0019***	0.0019***	0.0019***	0.0019***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R&D expenditures	-0.0132	-0.0116	-0.0154	-0.0108	-0.0193	-0.0122	-0.0144
	(0.0305)	(0.0320)	(0.0339)	(0.0340)	(0.0313)	(0.0306)	(0.0320)
OI activities		0.360***	0.558***	0.562***			
		(0.188)	(0.187)	(0.187)			
OI squared		-1.279**	-1.099**	-1.031**	-0.685	-0.502	0.743
		(0.584)	(0.584)	(0.567)	(0.604)	(0.565)	(1.120)
Internal openness			0.662***	0.712***	0.542***	0.646***	0.569***
			(0.218)	(0.230)	(0.223)	(0.233)	(0.226)
Internal openness * OI Activities				-1.591*			
				(1.202)			
Formal OI activities					0.0184	-0.00288	-0.0890
					(0.188)	(0.181)	(0.201)
Informal OI activities					0.499***	0.491***	0.525***
					(0.124)	(0.123)	(0.131)
Internal Op.* OI Formal Act.						-2.822**	
						(1.524)	
Internal Op.* OI Informal Act.						1.294	
						(1.542)	
Formal OI * Informal OI							-1.375*
							(0.943)
Inverse Mills	-1.253**	-1.055**	-1.071*	-0.992*	-1.169**	-1.056**	-1.088**
	(0.498)	(0.527)	(0.562)	(0.565)	(0.528)	(0.522)	(0.541)
Observations	265	265	265	265	265	265	265
Log-Likelihood	-116.2	-113.4	-111.3	-111.0	-109.4	-108.4	-108.9
Chi-square	91.20	116.4	119.7	118.2	139.0	139.6	136.5

Marginal effects. Standard errors in parentheses. *p<.10, ** p<.05, ***p<.01.
(Two-tailed tests for controls, one-tailed tests for hypothesized variables.)

Table 2. Performance effect, External Search and Internal Openness: Micro-Firms

	1	2	3	4	5	6	7
Size	0.0824	0.0791*	0.0707	0.0708	0.0461	0.0689	0.0458
	(0.0711)	(0.0610)	(0.0579)	(0.0573)	(0.0599)	(0.0666)	(0.0595)
Age	-0.0160	-0.0161	-0.0163	-0.0163	-0.0155	-0.0139	-0.0140
	(0.0103)	(0.0111)	(0.0108)	(0.0109)	(0.00946)	(0.00948)	(0.00985)
Age Squared	0.0001	0.0001	0.0002	0.0002	0.0002*	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Knowledge intensity	0.00199	0.00173	0.00182	0.00181	0.00167	0.00156	0.00162
	(0.00132)	(0.00134)	(0.00137)	(0.00137)	(0.00141)	(0.00145)	(0.00137)
R&D expenditures	0.0665*	0.0689	0.0607	0.0610	0.0709*	0.0721*	0.0735*
	(0.0500)	(0.0538)	(0.0540)	(0.0552)	(0.0525)	(0.0549)	(0.0525)
OI activities		1.159***	1.067***	1.065***			
		(0.332)	(0.341)	(0.339)			
OI squared		-3.519***	-3.302***	-3.281***	-2.486**	-2.435**	-0.763
		(1.227)	(1.190)	(1.253)	(1.225)	(1.099)	(1.714)
Internal openness			0.553*	0.556*	0.394	0.623*	0.452
			(0.411)	(0.425)	(0.451)	(0.443)	(0.469)
Internal openness * OI Activities				-0.111			
				(2.273)			
Formal OI activities					0.290	0.359	0.151
					(0.355)	(0.330)	(0.379)
Informal OI activities					0.660***	0.562***	0.678***
					(0.223)	(0.237)	(0.248)
Internal Op.* OI Formal Act.						-4.141	
						(3.475)	
Internal Op.* OI Informal Act.						4.487	
						(4.086)	
Formal OI * Informal OI							-1.661
							(1.476)
Inverse Mills	-0.120	0.138	0.126	0.129	0.135	0.194	0.147
	(0.506)	(0.537)	(0.526)	(0.535)	(0.518)	(0.547)	(0.510)
Observations	87	87	87	87	87	87	87
Log-Likelihood	-33.99	-30.47	-29.81	-29.81	-29.09	-28.54	-28.85
Chi-square	37.73	57.54	56.88	60.34	66.80	65.79	67.61

Marginal effects. Standard errors in parentheses. *p<.10, ** p<.05, ***p<.01.
(Two-tailed tests for controls, one-tailed tests for hypothesized variables.)

Table 3. Performance effect, External Search and Internal Openness: Small Firms

	1	2	3	4	5	6	7
Size	0.0357	0.0233	0.0274	0.0231	0.0281	0.0253	0.0147
	(0.0919)	(0.0878)	(0.0878)	(0.0894)	(0.0888)	(0.0908)	(0.0894)
Age	-0.0185**	-0.024***	-0.023***	-0.023***	-0.023***	-0.023***	-0.023***
	(0.00906)	(0.00964)	(0.00971)	(0.0100)	(0.00953)	(0.00983)	(0.00958)
Age Squared	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Knowledge intensity	0.00187	0.00169	0.00162	0.00162	0.00165	0.00170	0.00188
	(0.00114)	(0.00115)	(0.00117)	(0.00115)	(0.00115)	(0.00114)	(0.00117)
R&D expenditures	-0.0170	-0.0330	-0.0333	-0.0339	-0.0305	-0.0303	-0.0323
	(0.0528)	(0.0518)	(0.0517)	(0.0517)	(0.0556)	(0.0554)	(0.0550)
OI activities		0.926***	0.897***	0.871***			
		(0.366)	(0.375)	(0.374)			
OI squared		-1.723	-1.663	-1.377	-1.593	-1.307	0.710
		(1.604)	(1.619)	(1.728)	(1.715)	(1.902)	(2.142)
Internal openness			0.247	0.259	0.228	0.231	0.208
			(0.401)	(0.404)	(0.396)	(0.394)	(0.393)
Internal openness * OI Activities				-1.316			
				(2.955)			
Formal OI activities					0.554*	0.528*	0.328
					(0.340)	(0.358)	(0.371)
Informal OI activities					0.337**	0.343**	0.488**
					(0.197)	(0.196)	(0.221)
Internal Op.* OI Formal Act.						-0.742	
						(2.227)	
Internal Op.* OI Informal Act.						-0.976	
						(2.321)	
Formal OI * Informal OI							-2.683**
							(1.192)
Inverse Mills	-1.554**	-1.639**	-1.641**	-1.657**	-1.592**	-1.594**	-1.552
	(0.893)	(0.893)	(0.887)	(0.889)	(0.957)	(0.954)	(0.948)
Observations	93	93	93	93	93	93	93
Log-Likelihood	-40.53	-38.83	-38.75	-38.73	-38.74	-38.70	-38.29
Chi-square	42.64	52.11	51.89	51.86	52.67	52.12	62.33

Marginal effects. Standard errors in parentheses. *p<.10, ** p<.05, ***p<.01.
(Two-tailed tests for controls, one-tailed tests for hypothesized variables.)

Table 4. Performance effect, External Search and Internal Openness: Medium Firms

	1	2	3	4	5	6	7
Size	-0.0402	-0.0361	-0.0411	-0.0315	-0.0538*	-0.0455	-0.0536
	(0.0426)	(0.0447)	(0.0438)	(0.0427)	(0.0386)	(0.0373)	(0.0385)
Age	-0.0034	-0.0018	0.0005	0.00003	-0.0001	-0.0002	-0.0001
	(0.00379)	(0.00370)	(0.00379)	(0.00374)	(0.00379)	(0.00373)	(0.00380)
Age Squared	0.0000	0.0000	-0.0000	-0.0000	-0.0000	-0.00000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Knowledge intensity	0.00160	0.00143	0.00137	0.00108	0.00111	0.00105	0.00107
	(0.0011)	(0.0010)	(0.0010)	(0.0010)	(0.0009)	(0.0009)	(0.0009)
R&D expenditures	0.0261	0.0303	0.00749	0.0269	-0.00950	0.0147	-0.0101
	(0.0384)	(0.0363)	(0.0384)	(0.0396)	(0.0365)	(0.0328)	(0.0371)
OI activities		0.185	0.188	0.224			
		(0.284)	(0.261)	(0.254)			
OI squared		1.044*	1.116*	1.063*	1.378**	1.293**	0.818
		(0.777)	(0.752)	(0.731)	(0.786)	(0.668)	(3.103)
Internal openness			0.861***	0.952***	0.815**	1.026***	0.802**
			(0.347)	(0.375)	(0.351)	(0.409)	(0.351)
Internal openness * OI Activities				-3.030**			
				(1.649)			
Formal OI activities					-0.281	-0.363*	-0.265
					(0.304)	(0.276)	(0.306)
Informal OI activities					0.424**	0.477**	0.432**
					(0.226)	(0.206)	(0.240)
Internal Op.* OI Formal Act.						-6.605***	
						(2.682)	
Internal Op.* OI Informal Act.						3.763*	
						(2.580)	
Formal OI * Informal OI							0.516
							(2.754)
Inverse Mills	-0.344	-0.0911	-0.588	-0.127	-1.115	-0.575	-1.124
	(0.898)	(0.890)	(0.906)	(0.901)	(0.893)	(0.803)	(0.898)
Observations	85	85	85	85	85	85	85
Log-Likelihood	-38.54	-37.53	-36.39	-36.04	-35.85	-34.95	-35.85
Chi-square	33.58	52.86	59.80	73.51	78.64	114.0	78.16

APPENDIX

A1. Descriptive Statistics (N=265)

	Mean	S.D.	Min.	Max.
Share of innovative sales	30.58	34.22	0.00	100.00
OI activities	0.17	0.16	0.00	0.73
Informal OI activities	0.21	0.19	0.00	1.00
Formal OI activities	0.15	0.18	0.00	0.83
Internal openness	0.61	0.10	0.17	0.83
Size	3.15	1.53	0.00	8.04
Age	13.89	12.54	1.00	107
Knowledge intensity	48.52	38.81	0.00	100.00
R&D expenditures	2.64	2.89	0.00	10.24
Innovators (1/0)	0.71	0.45	0.00	1.00
Radical innovators	0.51	0.50	0.00	1.00

A.2. Correlation Table

		1	2	3	4	5	6	7	8
1	Share of innovative sales								
2	OI activities	0.35							
3	Informal OI activities	0.40	0.79						
4	Formal OI activities	0.26	0.94	0.54					
5	Internal openness	0.28	0.16	0.24	0.09				
6	Size	0.10	0.13	0.14	0.09	-0.01			
7	Age	-0.07	0.08	0.05	0.08	-0.12	0.16		
8	Knowledge intensity	0.17	0.08	0.04	0.08	0.03	-0.33	-0.11	
9	R&D Expenditures	0.49	0.39	0.32	0.36	0.17	0.31	0.08	0.03

A3: 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

Table A.4. Performance effect, External Search and Internal Openness – Tobit Analysis

	1	2	3	4	5	6	7
Size	-2.350*	-2.159	-1.807	-1.823	-2.220	-2.008	-1.925
	(1.797)	(1.820)	(1.855)	(1.866)	(1.795)	(1.787)	(1.874)
Age	-1.073***	-1.062***	-0.961***	-0.959***	-0.966***	-0.917***	-0.936***
	(0.365)	(0.368)	(0.370)	(0.370)	(0.363)	(0.362)	(0.367)
Age Squared	0.00708**	0.00704**	0.00672**	0.00668**	0.00675**	0.00634**	0.00668**
	(0.00347)	(0.00337)	(0.00329)	(0.00329)	(0.00324)	(0.00322)	(0.00323)
Knowledge intensity	0.200***	0.179***	0.177***	0.177***	0.178***	0.170***	0.177***
	(0.0577)	(0.0579)	(0.0564)	(0.0565)	(0.0543)	(0.0544)	(0.0546)
R&D expenditures	-1.232	-0.898	-0.790	-0.731	-1.046	-0.652	-0.665
	(3.103)	(3.164)	(3.241)	(3.217)	(2.996)	(2.924)	(3.086)
OI activities		54.78***	46.92***	46.77***			
		(16.81)	(17.08)	(17.17)			
OI squared		-104.2**	-84.36*	-82.67*	-35.16	-25.73	46.26
		(58.48)	(58.14)	(58.81)	(58.27)	(56.84)	(103.6)
Internal openness			53.59***	53.32***	43.58***	47.96***	44.38***
			(17.61)	(17.82)	(17.76)	(18.21)	(17.77)
Internal openness * OI Activities				-23.27			
				(108.4)			
Formal OI activities					-5.901	-5.454	-10.97
					(17.38)	(16.96)	(17.70)
Informal OI activities					46.75***	43.88***	46.88***
					(11.45)	(11.53)	(11.51)
Internal Op.* OI Formal Act.						-197.0*	
						(142.3)	
Internal Op.* OI Informal Act.						148.7	
						(121.1)	
Formal OI * Informal OI							-79.35
							(86.79)
Inverse Mills	-123.5***	-102.0**	-95.93**	-95.01**	-102.8**	-95.18**	-95.88**
	(51.04)	(52.52)	(54.05)	(53.72)	(50.67)	(49.96)	(52.43)
Observations	265	265	265	265	265	265	265
Log-Likelihood	-1265.0	-1259.1	-1254.8	-1254.7	-1249.2	-1247.9	-1248.8

Marginal effects for the expected value of the innovative sales conditional on being uncensored. Standard errors in parentheses.
*p<.10, ** p<.05, ***p<.01 (Two-tailed tests for controls, one-tailed tests for hypothesized variables.)