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READY TO BE OPEN? EXPLAINING THE FIRM LEVEL BARRIERS TO BENEFITING FROM OPENNESS TO EXTERNAL KNOWLEDGE

ABSTRACT

This paper provides new theory and evidence about the benefits of openness on a firm's innovation performance and, more importantly, the specific firm-level contingencies under which those benefits are more (or less) likely to be observed. Building on Dyer and Singh's (1998) relational view, we suggest that a firm's lack of resources and absorptive capacity, as well as its use of secrecy, are significant barriers to benefiting from openness to external knowledge. Using responses from 12,152 firms to the fourth and fifth UK versions of the Community Innovation Survey (CIS) we generate findings consistent with our hypotheses.

KEYWORDS: external knowledge sourcing, innovation performance, open innovation, secrecy, absorptive capacity.

INTRODUCTION

In the last decade, studies of how organizations identify and gain access to relevant knowledge created by other organizations (and the subsequent impact on innovation performance) have proliferated, in part due to the publicity enjoyed by the open innovation concept (Chesbrough 2003, Trott and Hartmann, 2009). Dozens of books, several special issues (e.g. Baden-Fuller, 2004; West et al., 2014) and numerous academic articles (e.g. West and Bogers, 2014) have been written on the topic, and many companies have explicitly adopted and applied the principles of open innovation to the way they conduct their innovation activities. This openness to external knowledge, it is argued, is particularly necessary in an era of increasingly complex technological development, higher uncertainty surrounding research and development (R&D), increasingly costly R&D projects, and shorter innovation cycles (Arora et al., 2001; Hagedoorn, 2002; Laursen and Salter, 2006).

It has long been assumed that openness to external knowledge increases a firm's innovation performance by enhancing combinatory search, adding new elements to a firm's knowledge base, and therefore improving the possibility of finding novel linkages (e.g. Dahlander and Magnusson, 2008; Gemser and Leenders, 2011; Katila and Ahuja, 2002; Rosenkopf and Nerkar, 2001). However, there is still an important conceptual debate, and contradictory empirical results, about the actual innovation benefits of openness to external knowledge and the contextual conditions (both external and firm-specific) under which those benefits are likely to transpire (e.g. Almirall and Casadesus-Masanell, 2010; Andriopoulos and Lewis, 2010, Lazzarotti et al., 2011; Enkel and Lenz, 2009; Trott and Hartmann, 2009). As a result, we believe more empirical investigations are necessary to verify the effect of openness on a firm's innovation output and economic performance.

This paper contributes to the debate on open innovation and helps to clarify the conditions under which openness to external partners is good for innovation performance. We aim at extending an emergent stream of research (e.g. Garriga et al., 2013) that uses the resource-based view (Wernerfelt, 1984; Barney, 1991) to highlight how a firm's resources (or lack thereof) have an impact on its ability to benefit from external knowledge. More precisely, we build on the well-known relational view (Dyer and Singh, 1998), which itself incorporates ideas from the resource-based view, to identify the specific attributes of the firm that should be expected to enhance (or harm) the efficacy of its external knowledge sourcing strategy. This focus allows us to examine new aspects of how not only the firm's resources but also its strategic use of knowledge protection mechanisms (i.e. secrecy) may impact the internalization and application of external knowledge.

We argue first that resources are required to enable linkages to be formed and to provide partners with the "ability to identify and evaluate potential complementarities" (Dyer and Singh, 1998: 663). As previous research has shown, a firm's resources available for research and development (R&D) are fundamental to enabling firms to benefit from external knowledge (Garriga et al., 2013). In this paper, we focus on one such resource, namely the financial resources in the focal firm that enable it to invest in innovation-oriented activities. If the firm lacks the necessary financial resources, its capacity to make use of external knowledge to innovate based on knowledge recombinations will be compromised (Galunic and Rodan, 1998; Rodan and Galunic, 2004).

Second, we consider the knowledge-sharing routines that enable the firms in a relationship to learn from one another, and we focus specifically on the absorptive capacity of the focal firm (Cohen and Levinthal, 1990) as manifested in the availability of qualified personnel working for

it. To the extent that value is created in external relationships, it emerges largely through the skill and experience of these individuals (Rao and Drazin, 2002:491). This argument builds on the relational view and also on the recent research stream on the microfoundations of absorptive capacity (e.g. Lewin, Massini and Peeters, 2011, Volberda, Foss and Lyles, 2010) suggesting that individuals are often the key to enabling inter-organizational innovation (Ritala, Armila and Blomqvist, 2009).

Third, there is the need for effective governance in external relationships, in terms of both the formal and informal mechanisms through which individuals work together (Dyer and Singh, 1998). We focus on informal governance mechanisms (while controlling for formal protection mechanisms like patenting), and we develop the argument that the use of secrecy by the focal firm may make its partners less likely to trust it and more (reciprocally) likely to treat their own knowledge strategically. The net result, we suggest, is that a secretive orientation is a double-edged sword: it helps to protect existing knowledge assets but is actually damaging to the firm's ability to enjoy innovation benefits from its relationships with external firms.

In sum, we develop a theoretically-grounded set of arguments about the firm-level conditions under which external knowledge sourcing is conducive to innovation. To test our arguments we use a database of 12,152 responses to the fourth and fifth UK versions of the Community Innovation Survey (CIS). These provide strong support for the arguments developed above. A series of sensitivity and robustness checks enhance confidence in and interpretability of our results.

Our contribution is to define some of the boundary conditions around sourcing external knowledge and provide new empirical evidence not only about the benefits of openness on a firm's innovation performance, but more importantly about some specific firm-level

contingencies under which those benefits are more (or less) likely to be observed.

The rest of the paper is organized as follows. The theoretical background and hypotheses are presented in the next section. A section on our methods follows. We subsequently present the results of our regressions and robustness checks. Contributions, managerial implications and directions for future research are discussed in the concluding section.

THEORY AND HYPOTHESES

The Benefits of Openness to External Knowledge

There is a long tradition of research on the relationship between openness to external knowledge and innovation performance (e.g. Arora, 1997; Chesbrough, 2010; Dahlander and Magnusson, 2008; Lamoreaux and Sokoloff, 2003). Attempts to access external knowledge among organizations of all sizes have increased substantially in the last two decades (Arora and Gambardella, 2010; Hagedoorn, 2002; Kale and Singh, 2009), and this more 'open' approach to innovation has become increasingly important to overall innovation strategy.

Recent research has demonstrated the importance of external knowledge sourcing for organizational innovativeness (Van Wijk et al., 2008). According to Katila and Ahuja (2002, p. 185) there are two reasons why openness to external knowledge is important: first, it enriches the in-sourcing firm's knowledge pool by adding distinctive new variations, offering a wider range of choices to solve problems (March, 1991); second, it boosts innovation by enhancing combinatory search (e.g. Fleming and Sorenson, 2001; Nelson and Winter, 1982). From an innovation perspective, external knowledge has the potential to provide the organization with possibilities for novel actions, and the process of constructing novel actions often entails finding new uses or new combinations of disparate ideas (Hargadon and Fanelli, 2002, p. 292). The benefits of accessing knowledge beyond the firm's boundaries are not only the addition of

distinct new knowledge to a firm's repertoire, thus overcoming the familiarity trap (Cassiman and Veugelers, 2006; Cohen and Levinthal, 1990; Laursen and Salter, 2006), but also the possibility of challenging a firm's internal routines and paradigms (Lei et al., 1996).

If most scholars agree on the potential benefits of openness, the actual realization of such potential (and internal and external contingencies affecting it) is still an open question empirically. Although some previous studies have shown that external technology sourcing increases innovative output (e.g. Ahuja, 2000; Gemser and Lenders, 2011; Leiponen and Helfat, 2009; Rosenkopf and Nerkar, 2001; Rothaermel and Hess, 2007; Van Wijk et al., 2008), more recently a number of authors have suggested that openness has its limits and that more evidence of its relationship with innovation is required (e.g. Almirall and Casadesus-Masanell, 2010; Trott and Hartmann, 2009). We hypothesize that:

Hypothesis 1: Openness to external knowledge is positively associated with the in-sourcing firm's innovation performance.

Firm-Level Barriers to Benefiting from External Knowledge

While on average we expect the relationship between openness to external knowledge and innovation performance to be positive, we would expect to see a range of outcomes. Intuitively, it seems likely that some firms have the ability and motivation to access and apply insights from their external relationships while others do not.

In this paper, we argue that the firm's ability to fully benefit from its external relationships is a function of the specific resources, capabilities and governance mode used in those relationships. Our perspective builds particularly on the relational view of Dyer and Singh (1998:

660), who identified three important determinants of value that are relevant to our empirical setting[i].

First there are the complementary resources that enable linkages to be formed and provide the "ability to identify and evaluate potential complementarities" between partners (Dyer and Singh, 1998: 663). We focus on one such resource, namely the financial resources in the focal firm that enable it to invest in innovation-oriented activities.

Second, there are knowledge-sharing routines that enable the firms in a relationship to learn from one another. As Dyer and Singh (1998: 665) observe, an important element of this is the absorptive capacity of the focal firm (Cohen and Levinthal, 1990), which we operationalize in terms of the availability of qualified personnel.

Third, there is the need for effective governance to ensure the "willingness of alliance partners to engage in value creation initiatives" (Dyer and Singh, 1998: 669). While the notion of governance is often interpreted in terms of formal rules and contracts, we focus here on informal mechanisms such as trust and reciprocity that shape behavior in relationships. Such safeguards "are more effective than third-party enforcement mechanisms at maximizing value-creation initiatives" (Dyer and Singh, 1998: 670).

In the remainder of this section, we develop specific arguments for how each of these three factors moderates the overall relationship between openness and innovation outputs.

Availability of financial resources. It is recognized that innovation is a costly process requiring substantial resource commitments (Gulati et al., 1994; Levinthal, 1998; Levinthal and March, 1981; Parkhe, 1993). Past research has highlighted both the positive and negative impact of the availability of financial slack and innovation (Greve, 2003; Nohria and Gulati, 1996). On

the one hand, it has been argued that financial slack is fundamental to innovation as it releases funds for innovation that would not be available in a context of scarcity. As Klueter, Monteiro and Dunlap (2013) put it, the availability of financial resources supports the innovation process indirectly by influencing the decision context in which resource allocations for innovative projects are undertaken (Greve, 2003; Nohria and Gulati, 1996) and by allowing the in-sourcing firm to continue to commit financial resources to develop the knowledge sourced externally, rather than being driven by short-term performance pressures (Greve, 2003). On the other hand, Nohria and Gulati (1996:1249) suggested that with increasing financial slack projects with high risk may be funded "simply to indulge agents for whom these are pet projects" and this lack of discipline in resource allocation can be detrimental to innovation. In addition, it has also been shown that firms with more financial slack may be less open to external innovation while firms with less abundant financial More recently, Katila and Shane (2005) hypothesized that the availability of financial resources would be conducive to innovation but failed to find empirical support.

While the direct effect of financial slack on innovation performance is still subject to conceptual debate and requires further empirical evidence (Greve, 2003; Katila and Shane, 2005, Nohria and Gulati, 1996), we believe the availability of financial resources is very important to allow firms to benefit from the knowledge they tapped from external partners, allowing them to translate and apply that knowledge internally. Where financial resources are constrained we would expect firms to face difficult trade-offs in allocating resources between competing demands, one likely scenario being to favor internal R&D (because it is better understood) rather than trying to find new applications for externally sourced knowledge (Jeppesen and Lakhani, 2010).

Similarly, firms which lack financial resources have fewer opportunities to discover new ways to use internal R&D and external knowledge simultaneously. Even though complementarities between internal R&D and external knowledge may exist (Cassiman and Veugelers, 2006; Veugelers, 1997), the in-sourcing firm may lack the funding to explore such complementarities and hence to tangibly benefit from the external knowledge. The challenges imposed by financial constraints are particularly acute today as R&D costs in many industries (e.g. pharmaceuticals) have been increasing considerably (e.g. DiMasi, Hansen and Grabowski, 2003; DiMasi, 2014). Taken together, these arguments form the foundation of our second hypothesis:

Hypothesis 2: The lack of financial resources by a focal in-sourcing firm mitigates the positive effects of openness to external knowledge on its innovation performance.

Availability of Qualified Personnel. In addition to financial resources, innovation based on external knowledge requires dedicated and qualified personnel in the in-sourcing firm. Previous research has demonstrated the importance of absorptive capacity (Cohen and Levinthal, 1990), usually proxied as R&D intensity, total R&D expenditure, or even overall firm size (Li and Vanhaverbeke, 2009; West and Bogers, 2013) in allowing firms to better utilize external knowledge (e.g. Grimpe and Kaiser, 2010). While not disputing the importance of internal R&D to enable the in-sourcing firm to benefit from external knowledge (and controlling for it in our empirical models), this paper shifts the focus to some of the microfoundations of absorptive capacity (Lewin, Massini and Peeters, 2011, Volberda, Foss and Lyles, 2010). More specifically, we examine how a lack of qualified personnel dedicated to innovation in the in-sourcing firm can be an important barrier to benefiting from openness (Grimpe and Sofka, 2009; Tether and Tajar,

2008). Individuals can be seen as breathing life into formal connections between organizations and the "entrepreneurial networks" between actors in various organizations are often the key issue in enabling innovation from external knowledge sourcing activities (Ritala et al., 2009).

We argue that having the personnel capable of using and transforming external knowledge into new products (not only scientists, but also other managers involved in the innovation process) allows the in-sourcing firm to fully benefit from that knowledge. Firms can only attend to a few unique innovation problems, especially in the context of absorbing and using external knowledge and qualified managers are critical in this process (Ahuja and Lampert, 2001; Klueter et al., 2013; Ocasio, 1997). In addition, Ritala et al. (2009) recognize that critical issues in forming and running innovation networks with external partners are often related to key individuals (e.g., boundary spanners, gatekeepers, champions, or scouts). Similarly, Lewin et al. (2011) highlight that individual boundary spanners have a central role in determining the effectiveness of external knowledge sourcing. Without this qualified personnel, it will be less likely that external scouts and internal "sellers" (Dutton and Ashford, 1993; Dutton et al., 2002) are able to identify the appropriate external knowledge and then defend and promote such external knowledge within the organization to the point of enabling the launch of a new product. Hence:

Hypothesis 3: The lack of qualified personnel by a focal in-sourcing firm mitigates the positive effects of openness to external knowledge on its innovation performance.

Informal governance mechanisms. Effective governance plays an important part in enabling firms to create and capture value through their external relationships and, as Dyer and Singh (1998) acknowledge, firms have a range of formal and informal mechanisms at their

disposal for doing this. Because the focus in this paper is on innovation outputs, we are particularly interested in the appropriability mechanisms firms use to protect their knowledge assets, and these range from formal mechanisms such as trademarks, copyrights and patents (Levin, Klevorick et al. 1987; Cassiman and Veugelers 2002) to informal or "strategic" approaches such as secrecy. Among other differences, some scholars highlight that when using formal mechanisms firms are obliged to disclose and codify their technological activities, making public their capabilities and knowledge, while using secrecy relies on the ability of firms to keep their secrets, indeed, secret (Denicolò and Franzoni, 2004; Laursen and Salter, 2006; Liebeskind, 1997, p. 624).

While we acknowledge there is an important debate in the literature with some researchers proposing that formal mechanisms hinder knowledge flows among innovation partners, with others claiming that patents represent a useful "currency" for partnering and hence may favor openness (e.g. see Alexy et al, 2009; Bogers, 2011; Hertzfeld, Link and Vonortas, 2006; Murray and Stern, 2007), our focus in this paper is on informal safeguards, specifically the use of secrecy as a knowledge protection mechanism (we do control for the effect of formal protection in our empirical models though).

Our expectation is that secrecy, while effective as a way of protecting valuable knowledge, sends a mixed message about the type of relationship the firm wants to have with its external partners. The social interaction between individuals who are committed to share and develop knowledge together is critical to new knowledge creation (Nonaka, 1994). We therefore suggest that effective partnerships rely to a large degree on reciprocity and trust (e.g. Dodgson, 1993; Gambetta, 1988; Hausler et al., 1994; Krishnan et al., 2006; Zaheer et al., 1998). Reciprocity is the expectation from one partner that a favor it provides to the other will

subsequently be returned, and the moral obligation of the other to uphold this implicit deal (Axelrod, 1984; Gouldner, 1960; Kogut, 1989). Trust is the expectation that one partner will not exploit the vulnerabilities of the other when faced with an opportunity to do so (Krishnan et al., 2006) and has been shown to be important in achieving efficient and equitable outcomes in inter-firm partnerships (Ring and Van de Ven, 1994). While reciprocity and trust are intuitively viewed as interpersonal constructs, it is increasingly standard practice to apply them at the inter-firm level as a way of making sense of the collective views of the individuals working within those firms (Gulati, 1995: 92; Molina Morales et al, 2011; Ring and Van de Ven, 1994, p. 94). This is the approach adopted here.

Why are reciprocity and trust central to the informal governance of inter-firm relationships? Consider the two linked steps in the innovation process, value creation and value appropriation. Value creation occurs by bringing together ideas and resources in novel ways (Hargadon and Sutton, 1997; Schumpeter, 1934). It requires participants to give and take freely, for example by sharing semi-formed ideas in the hope that they will spark off new possibilities with others. The creative process is quickly undermined if one party is unwilling to make certain resources available, or if they are guarded when contributing ideas. Value appropriation is the process of implementing a proven idea to generate commercial outcomes; in the context of a partnership it means dividing up those outcomes (e.g. in the form of ownership rights or cash flows) in an equitable manner, corresponding to a perception of "fair play" on both sides (Ring and Van de Ven, 1994). Such a perception will be undermined if one party treats the other badly or even has a reputation for failing to respect such norms.

In sum, for the relationship between a firm and its external partners to flourish there is a need for reciprocity between the two sides, to enable the free-flow of ideas that leads to value

creation, and mutual trust that the value appropriation process will be conducted equitably. However – and this is the nub of the argument – secrecy as a form of informal knowledge protection is built on very different values (deliberately withholding certain information) which do not fit well with the behavior required for innovation partnering. Partnering to access another firm's knowledge in tandem with being secretive about one's own knowledge base is likely to undermine the reciprocity and trust necessary for the relationship to flourish. Stated more formally:

Hypothesis 4: The use of secrecy (vis-à-vis external partners) by a focal in-sourcing firm mitigates the positive effects of openness to external knowledge on its innovation performance.

METHODS

Data

To test our ideas we used the responses to the fourth and fifth UK versions of the Community Innovation Survey (CIS). The CIS is conducted regularly across all European Union and European Economic Area countries and beyond. CIS4 and CIS5 cover innovation activities during 2002-2004 and 2004-2006 respectively, and were conducted by the Office for National Statistics (ONS). ONS is experienced in conducting surveys of this kind, which increases both the quantity and the quality of the response. Lessons learned from CIS1, CIS2, and CIS3 were implemented to improve the data collection process, for instance to tackle non-response. Robson and Ortmans (2006) and Robson and Haigh (2008) contain overviews of the methodology and basic descriptive findings of these versions. The response rates were 58% and 53% respectively. Our analyses were conducted in a cross-sectional manner by pooling observations from the two time periods (survey versions).[ii]

The firms in our sample are larger than the average firm in the UK and larger than the average firm that responded to the survey. There are a total of 12,152 firms in the sample. The largest industries include: manufacturing of food, clothing, wood, paper and publishing (1,292 firms); manufacturing of fuels, chemicals, plastics & metal (1,705); manufacturing of electrical & optical equipment (537); wholesale & retail trade and repair of vehicles & goods (767); hotels and restaurants (120); transport, storage and communications (1,063); financial intermediation (410); real estate, renting and business activities (2,765). The use of such a wide cross-section of firms substantially increases the generalizability of our findings.

The core questions in the CIS are based on the OECD's Oslo manual, which adds to the comparability of findings across industries and countries.[iii] The survey includes a page of definitions which respondents could refer to. A 'help' service was provided where respondents who struggled with questions could get some guidance. Respondents received a postal survey and two reminders, as well as a follow-up telephone call in some cases to maximize response rates. ONS sent the survey to the person responsible for filling out official government surveys. Respondents included many Managing Directors, Chief Financial Officers and heads of R&D. Many academic articles using versions of CIS databases have now been published (e.g. Battisti and Stoneman, 2010; Cassiman and Veugelers, 2002; Frenz and Ietto-Gillies, 2009; Laursen and Salter, 2006).

Measures

Dependent variable.

Innovation Performance: We use 'Introduction of New Products' as one measure of innovation performance. More precisely, the construct was operationalized as a dummy that took the value

of 1 if the firm introduced any product innovation during the three-year period 2002-2004 and zero otherwise.[iv] The advantage of this measure is that it captures commercialized products, is comparable across a wide range of industries, and has the largest number of responses in the survey, helping us avoid selection biases. In line with prior research (e.g., Laursen and Salter, 2006), however, we introduce a second dependent variable, 'Importance of New Products', which is the logarithm of the percentage of sales derived from three categories of products: New to the market, new to the firm and improved products. In other words, this measure captures all product sales that are not simply repeat sales of existing products. The advantage of this measure is that it provides a broader range of possible answers (anywhere between 0 and 100%). It has the drawback of offering us many fewer observations. If we can demonstrate consistency between the two measures, however, we believe this greatly increases confidence in the findings.

Independent variables:

Openness to external knowledge: This was operationalized in two different ways. First, we measured the use of partnerships ['External Partnering'] to access external knowledge. Here the survey asks "[d]id your enterprise co-operate on any of your innovation activities with other enterprises or institutes during the three-year period 2002-2004?" We included six types of organizations for such cooperation: suppliers; clients or customers; competitors or other businesses in the industry; consultants, commercial labs, or private R&D institutes; universities or other higher education institutions; government or public research institutes. The survey further specifies four possible locations, regional within UK, UK national, other Europe, all other countries. We calculated our external partnering variable by adding 1 for every organization-location combination that respondents indicated. The six types of partners were combined into a single scale, with a Cronbach Alpha of 0.89. Second, in order to capture less formal ways of

accessing external knowledge, we also used a measure of the number of external parties as innovation related information sources ('External Sourcing'). Respondents were asked "How important to your enterprise's innovation activities during the three-year period 2002-2004 were each of the following information sources?" We used nine types of sources: "suppliers of equipment / materials / services / software; clients / customers; competitors / other enterprises in your industry" universities or other higher education institutions; government or public research institutes; conferences, trade fairs, exhibitions; scientific journals and trade/technical publications; professional and industry associations; technical, industry or service standards. Respondents chose one of four answers, not used (coded 0), low importance (coded 1), medium importance (coded 2), and high importance (coded 3). The three sources were accumulated to form a single 'knowledge sourcing' variable with a range of 0 to 27 and a Cronbach Alpha of 0.90. In the models presented below we use both operationalizations of openness to external knowledge ("external partnering" and "external sourcing") to test our hypotheses.

Lack of financial resources. Here the survey asked how important certain factors were as constraints on innovation activities. It provides us with two related items to measure lack of financial resources, both measured on a scale from 0 (not experienced, i.e. not a problem) to 3 (highly important). One item measures 'cost of finance' and the other 'availability of financial resources for innovation'. The two items combine well, with a Cronbach alpha of 0.90, and we therefore created a single measure.

Lack of qualified personnel. The survey asks to what extent a lack of qualified personnel acted as a constraint on innovation. This was measured on a scale from 0 (not experienced) to 3 (highly important).

Secretive behavioral orientation. Firms were asked whether they used secrecy to protect their innovations using a scale from 0 (not used) to 3 (high degree of importance). To create the interaction variables, we mean centered the underlying main variables to avoid excessive correlations (Aiken and West, 1991).

Control variables. Prior research suggests that other factors could also be correlated with our dependent variables. We controlled for industry effects by including industry dummy variables. We controlled for 'firm size' by including the logarithm of a firm's number of employees in the year 2004 since larger firms have more resources available for innovation. A further dummy variable, 'new firm', tests whether the firm was established during the survey period. New firms may bring new products into the market. Previous research has shown that the firm's own R&D function, contributes strongly to innovation performance. Therefore we controlled for whether or not the firm invested in internal R&D ('internal R&D').[v] In a similar vein, we included four further dummy control variables for extramural R&D expenditure ('external R&D'), training specifically aimed at development or introduction of innovations ('training'), design for the development or implementation of new or improved goods, services and processes ('design'), and finally acquisition of machinery, equipment, and software for innovation purposes ('machinery'), in a belief that any of those may positively influence innovation performance. We also included in our models a variable to control for the monetary spending on external knowledge acquisition ('licensing') as well as for the use of patents as a method to formally protect knowledge ('patents'), which may be positively associated with innovation. Finally, we included a dummy variable for the survey version the firm answered ('survey version') given that we pooled observations from two CIS surveys.

RESULTS

We report in Table I the means, standard deviations and correlations among the variables. None of the observed correlations are excessively high.

INSERT TABLE I ABOUT HERE

As described above, we ran our models using two dependent variables: First the introduction of new products (Table II) and second the "Importance of New Products', which is the logarithm of the percentage of sales derived from new products (Table III). Given the discrete nature of these dependent variables, we used Stata's probit and tobit regression functions, respectively, with robust standard errors to counter the effects of heteroscedasticity (Wooldridge, 2002).[vi] We calculated variance inflation factors and concluded that multicollinearity was not an issue (a maximum VIF value of 4.17). The results are presented in Tables II and III, which displays the coefficients and standard errors. We also calculated the marginal effects, which were consistent (cf. Wiersema and Bowen, 2009).

Table II contains probit models and table III contains tobit models. The results are consistent between the two measures for the dependent variable. Models 1 and 9 contain the control variables only. The observed effects are broadly as expected. For instance, larger firms and firms making various forms of innovation investments, especially internal R&D and design, are significantly more likely to introduce new products and to have a larger percentage of sales stemming from innovative products. In Models 2 and 10 we then add the independent variables. We note that the external sourcing and external partnering variables are positive and significant throughout the regressions, which confirms Hypothesis 1.

We then proceed to add the interaction variables one by one (hierarchically) to avoid problems of multicollinearity. The interactions between secretive behavioral orientation and external sourcing (models 3 and 11) and secretive behavioral orientation and external partnering (Models 4 and 12) are both negative and significant, as predicted in Hypothesis 4. Likewise we find that the interactions between lack of financial resources and external sourcing (Models 5 and 13) and lack of financial resources and external partnering (Model 6 and 14) are negative and significant as per Hypothesis 2. We also find this effect for the interaction between lack of qualified people and external sourcing (Models 7 and 15), and for the interaction between lack of qualified people and external partnering (Models 8 and 16), supporting Hypothesis 3.

INSERT TABLE II ABOUT HERE

The true moderating effects in limited dependent variables models, however, cannot be observed directly from the regression coefficients (Ai and Norton, 2003; Bowen, 2012). Therefore we calculated the marginal effects of the interaction terms of our probit analyses using code provided by Bowen (2010, 2012). Specifically Bowen suggests that the total moderating effect is the sum of the structural and secondary moderating effects and that assessing this secondary moderating effect is essentially to determining whether a proposed moderating effect is significant. For our hypotheses the secondary moderating effect is only significant if the entire 95% confidence interval falls below 0. Using this method we were able to confirm that this is indeed the case for each of our models. In view of the large number of models and to save space we only report one sample graph below for model 11 (others are available upon request).

Overall, our graphs clearly showed that for all values a negative secondary moderating effect exists, and this is even more true for higher values of the dependent variable, which is consistent with our theory.

INSERT FIGURE 1 ABOUT HERE

Testing for Robustness

We performed several robustness tests. First, we ran models with alternative specifications for our independent variables. For instance, the results are robust to using a dummy variable for secretive behavioral orientation (instead of a continuous variable). Next, we ran models using a different operationalization of lack of financial resources (including only the availability of finance for innovation and excluding the cost of finance variable), and results were robust. Finally, we tested different operationalizations of one of our dependent variables (Importance of New Products) by examining each of the three underlying categories of the percentage of sales dependent variable and testing whether the effects would hold. Results were qualitatively the same in the vast majority of the cases. We do not include these additional 24 models here but they are available upon request. Thus, bearing in mind that we already present results for two different operationalizations of the dependent variable, the results are very robust.

A potential problem that arises with survey data is common method variance, i.e. "the variance that is attributable to the measurement method rather than to the constructs the measures represent" (Podsakoff et al., 2003, p. 879). Although we did not have direct influence over the

survey design, common method bias was addressed in various ways by using approaches suggested by Podsakoff et al. (2003). For example, the data we used for many independent variables are objective in nature, such as whether firms have partnering arrangements, which significantly reduces the possibility of bias in the results (Podsakoff and Organ, 1986). Moreover, one of the two measures for our dependent variable, percentage of sales derived from new and improved products, is objective in nature too. The Office for National Statistics (ONS) pre-designed the survey to minimize the occurrence of the common method bias problem (Podsakoff et al., 2003, p. 887-888). In the accompanying text, for instance, respondents were encouraged to consult with colleagues when answering questions. Furthermore, we attempted to address a possible concern that arises from our models that our independent variable may be endogenously determined (Bascle, 2008), but the survey did not provide viable instruments to tackle all the possibly endogenous variables. Using instruments from previous CIS versions was not an option either, given the limited number of responses to earlier surveys. Given that we were unable to pursue this route further, we acknowledge this as a limitation of the study.

DISCUSSION

The primary purpose of this paper was to provide new empirical evidence not only of the direct benefits of openness on a firm's innovation performance (measured in terms of innovation output as well as the percentage of revenues deriving from new products, cf. Laursen and Salter, 2006) but more importantly of some specific firm-level contingencies under which those benefits are more (or less) likely to transpire. Three broad sets of insights emerge from this study.

First, our results confirm the findings of previous studies showing a positive direct relationship between openness and innovation, be it in terms of the introduction of new products or the importance of the revenues coming from such new products (e.g. Ahuja, 2000; Gemser

and Lenders, 2011; Leiponen and Helfat, 2009; Rosenkopf and Nerkar, 2001; Rothaermel and Hess, 2007; Van Wijk et al., 2008). We believe this is an important empirical contribution to a field where there is a frequent call for more scholarly work to verify the effect of openness on innovation performance.

Second, we contribute to an emergent research stream about how a firm's resources available for research and development (R&D) are fundamental to enabling firms to benefit from external knowledge (Garriga et al., 2013). Specifically, we showed how financial and human resources play a critical role in allowing in-sourcing firms to benefit from external knowledge by introducing new products and increasing revenues from innovative products. Financial resources for R&D are increasingly important as R&D costs have been increasing considerably in the last decade (DiMasi et al., 2003, DiMasi, 2014). Our focus on the importance of qualified personnel (or lack thereof) to benefiting from open innovation also contributes to an increasingly important literature stream on the microfoundations of absorptive capacity (e.g. Lewin, Massini and Peeters, 2011, Volberda, Foss and Lyles, 2010). In sum, our study establishes important boundary conditions, highlighting organization-level constraints on the in-sourcing firm in terms of the financial and qualified human resources necessary to support innovation.

We also provide empirical evidence showing that the use of secrecy negatively moderates the effects of openness to external knowledge on innovation performance. Accessing external knowledge (formally or informally) involves knowledge exchange among the parties involved, enabling them to recombine knowledge (Kogut and Zander, 1992) and innovate. Knowledge exchange may be incompatible with the notion of secrecy, hence a tradeoff is required between the two because they represent competing mindsets.

Taken in tandem these results provide an empirical contribution to an increasingly important

literature stream (e.g. Grimpe and Kaiser, 2010; Helfat, 2006; Trott and Hartmann, 2009) that underlines not only the potential "gains" of open innovation (in our case the main effect of openness on external knowledge) but also its limitations (as represented by our moderators).

Finally, in addition to the above empirical contributions to a field where theory and empirical evidence needs to be constantly reconciled, we believe that this paper also sheds new light on the limits to openness by using the relational view as developed by Dyer and Singh (1998) to develop a set of contingencies that are likely to affect a firm's ability to profit from its openness to external knowledge. This relational view allowed us to unveil new aspects of how not only the firm's resources but also its strategic use of knowledge protection mechanisms (i.e. secrecy) may hinder the internalization of external knowledge. By focusing on the use of secrecy and its possible behavioral implications, we are offering a deeper and more granular conceptual understanding of new boundary conditions to an open innovation strategy. While a stream of research (Fosfuri, 2006; Gans et al., 2008; Jensen and Thursby, 2001; Ziedonis, 2004) has opted to investigate the relationship between legal knowledge protection and external knowledge sourcing, our study offers important new insights by shifting the focus from the legal to the strategic dimension (and the potential behavioral orientation it reveals) of the interaction between external knowledge sourcing and secrecy. In so doing it responds to the call by Murray and O'Mahony (2007, p. 1006) that organization scholars should have a place at a table that has been predominantly dominated by economic, legal and/or technological perspectives. Our findings are consistent with the argument that for firms to benefit from relational knowledge exchanges requires trust and reciprocity; in such circumstances if one of the parties is trying to keep secret what they know, the development of these behaviors will be hampered.

Implications for Management

Although normative implications should be offered with the necessary caution, we believe our study provides fresh insights for managers who are developing innovation strategies that involve access to external knowledge. Many organizations across the globe have created specialized mechanisms (e.g. external innovation areas, technology scouting units, corporate venture funds) to access knowledge across organizational boundaries, but without asking themselves whether they have the required resources and behavioral orientation to actually benefit from it. This study provides new empirical evidence that being open to external knowledge is associated with higher innovation performance; but at the same time organizations need both the financial and human resources, and the requisite behavioral orientation, to fully benefit from an open innovation strategy. Managers should therefore invest more time looking inward and preparing the organization to benefit from external knowledge, rather than exclusively allocating resources to outward-looking activities aimed at accessing external knowledge.

Limitations

Notwithstanding the robustness of our results across models and the absence of symptoms of bias, a number of limitations of this study should be borne in mind for future research. First, despite the fact that we used some objective data, we had a single respondent per firm. Future research would benefit from adopting different research designs where key variables could be obtained from different respondents. Second, we note that the measure of partnerships in CIS does not tell us exactly how many partners the firm works with, and it is indeed entirely possible that the same partner is counted more than once, in different locations. Furthermore the CIS measures for partners and sources differ in nature, although this could be seen as a drawback (limited comparability) as much as an advantage (our results are robust to many different

operationalizations). Future research may want to zoom in on specific sourcing and partnering relationships to provide a more fine-grained account of our hypotheses than we have been able to do here. Third, another measurement issue is that the variables for lack of financial resources and lack of qualified personnel are measured relative to the problems they cause when firms attempt to innovate. Although our hypotheses are not concerned with the direct effect of these measures on innovation, it would have been ideal to use an absolute measure of lack of financial resources and lack of qualified personnel alongside this measure to see how robust these findings are. Finally, as previously flagged, endogeneity is a possible limitation of our work as the test of hypotheses in a cross-sectional research design indicates association rather than causality. Our results should therefore be interpreted with caution, avoiding strong causal inferences. Indeed future research could investigate how the relationships investigated here play out using panel data and time lags.

CONCLUSION

In seeking to shed light on the boundary conditions of the positive association between openness to external knowledge and innovation outputs, this paper provides fresh empirical evidence of the specific tradeoffs firms face in open innovation, both in terms of resource constraints and strategic use of knowledge protection mechanisms, namely secrecy. We hope it will stimulate organizational scholars to examine some of the other tensions and tradeoffs inherent in open innovation, and embed our understanding of it in cognate bodies of literature in organizational theory, with a view to advancing theory in this domain.

NOTES

[i] Dyer and Singh (1998) also identify a fourth factor, namely "relationship-specific assets", that are valuable only in one specific relationship. These play a large part in their thinking as much of their research was done in the automobile sector where suppliers are often expected to build plants adjacent to the auto assembly plant they are selling to. In our setting, because we are dealing with a large mix of formal and informal relationships, this category does not seem as relevant.

[ii] As much as we would have liked to run a panel analysis, with only two time periods available the data would have produced a shallow and unbalanced panel.

[iii] We acknowledge that this implies the sample is heterogeneous in nature, which creates challenges. Notwithstanding, our theory should be applicable to a wide range of industries. We not only controlled for industry effects but also looked at a smaller focused sample of manufacturing firms, and the findings were qualitatively the same.

[iv] CIS5 contains the same measures as CIS4; it differs only in using a different three-year period (2004-2006). We describe the CIS4 measures here.

[v] The survey also contains a monetary amount for R&D expenditure and the next few expenditure items. Although this is a preferable operationalization of the variable, using it decreases the sample size significantly and unevenly across the survey versions. However, our results are robust when using the continuous R&D investment variable in this reduced sample.

[vi] Dropping the robust option from the probit analyses or using logit regressions did not qualitatively alter the findings. We also clustered the standard errors by firm and results were qualitatively the same.

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Table 1: Means, standard deviations and bivariate correlations. N = 7,426.

	Mean	SD	1	2	3	4	9	10	11	12	13	14
1 External sourcing	0.10	0.68										
2 External partnering	0.24	2.33	0.33									
3 Secretive orientation	0.92	1.12	0.52	0.28								
4 Lack of personnel	0.97	0.96	0.39	0.13	0.29							
5 Lack of resources	1.92	1.92	0.40	0.14	0.31	0.50						
6 Patents	0.53	1.00	0.40	0.26	0.55	0.19						
7 Licensing	0.00	0.00	0.10	0.05	0.06	0.07						
8 Survey version	4.17	0.38	0.18	0.12	0.17	0.04						
9 Firm size	4.33	1.57	0.22	0.17	0.23	0.05						
10 New firm	0.01	0.07	0.02	0.03	0.02	-0.01	-0.01					
11 Internal R&D	0.40	0.49	0.44	0.27	0.44	0.23	0.15	0.01				
12 External R&D	0.17	0.37	0.34	0.33	0.31	0.16	0.15	0.03	0.43			
13 Machinery	0.58	0.49	0.44	0.18	0.29	0.25	0.09	0.03	0.36	0.27		
14 Training	0.49	0.50	0.46	0.22	0.31	0.26	0.14	0.03	0.39	0.27	0.52	
15 Design	0.25	0.43	0.37	0.27	0.35	0.18	0.15	0.04	0.46	0.35	0.33	0.36

Table 2: Probit analysis predicting introduction of new products (models 1 to 8). Showing betas, standard errors and significance levels (***=0.001; **=0.01; *=0.05). N = 12,134.

	1	2	3	4	5	6	7	8
Patents	0.15(0.01)***	0.04(0.02)*	0.05(0.02)**	0.05(0.02)**	0.05(0.02)**	0.04(0.02)*	0.05(0.02)**	0.04(0.02)**
Licensing	79.28(37.14)*	66.85(36.74)	65.19(35.76)	65.33(36.79)	66.45(37.15)	69.43(36.86)	66.71(36.81)	67.34(36.72)
Survey version	-0.21(0.03)***	-0.18(0.03)***	-0.17(0.03)***	-0.17(0.03)***	-0.17(0.03)***	-0.17(0.03)***	-0.17(0.03)***	-0.17(0.03)***
Firm size	0.03(0.01)***	0.01(0.01)	0.01(0.01)	0.01(0.01)	0.01(0.01)	0.01(0.01)	0.01(0.01)	0.01(0.01)
New firm	0.13(0.10)	0.07(0.11)	0.08(0.11)	0.05(0.11)	0.09(0.11)	0.05(0.11)	0.08(0.11)	0.07(0.11)
Internal R&D	0.73(0.03)***	0.62(0.03)***	0.61(0.03)***	0.62(0.03)***	0.61(0.03)***	0.62(0.03)***	0.62(0.03)***	0.62(0.03)***
External R&D	0.18(0.04)***	0.09(0.04)*	0.1(0.04)*	0.09(0.04)*	0.09(0.04)*	0.09(0.04)*	0.09(0.04)*	0.09(0.04)*
Machinery	0.21(0.03)***	0.14(0.03)***	0.13(0.03)***	0.14(0.03)***	0.13(0.03)***	0.14(0.03)***	0.14(0.03)***	0.14(0.03)***
Training	0.39(0.03)***	0.29(0.03)***	0.29(0.03)***	0.29(0.03)***	0.29(0.03)***	0.29(0.03)***	0.29(0.03)***	0.29(0.03)***
Design	0.34(0.04)***	0.28(0.04)***	0.28(0.04)***	0.28(0.04)***	0.28(0.04)***	0.28(0.04)***	0.28(0.04)***	0.28(0.04)***
Secretive orientation		0.11(0.02)***	0.15(0.02)***	0.11(0.02)***	0.11(0.02)***	0.11(0.02)***	0.11(0.02)***	0.11(0.02)***
External sourcing		0.23(0.03)***	0.35(0.03)***	0.23(0.03)***	0.38(0.03)***	0.23(0.03)***	0.33(0.03)***	0.23(0.03)***
External partnering		0.06(0.01)***	0.07(0.01)***	0.10(0.01)***	0.06(0.01)***	0.09(0.01)***	0.06(0.01)***	0.07(0.01)***
Lack of personnel		0.03(0.02)	0.03(0.02)	0.03(0.02)	0.02(0.02)	0.03(0.02)	0.05(0.02)**	0.03(0.02)
Financial constraints		0.01(0.01)	0.01(0.01)	0.01(0.01)	0.03(0.01)**	0.01(0.01)	0.01(0.01)	0.01(0.01)
Secretive orientation X external sourcing			-0.13(0.02)***					
Secretive orientation X external partnering				-0.02(0.01)**				
Lack of resources X external sourcing					-0.08(0.01)***			

Lack of resources X external partnering						-0.01(0.00)**		
Lack of personnel X external sourcing							-0.10(0.02)***	
Lack of personnel X external partnering								-0.01(0.01)
Constant	-0.78(0.13)***	-0.80(0.14)***	-0.80(0.14)***	-0.80(0.14)***	-0.79(0.14)***	-0.80(0.14)***	-0.79(0.14)***	-0.80(0.14)***
Chi^2	3099.03	3141.71	3190.67	3252.7	3125.02	3167.13	3135.6	3163.76
Log likelihood	-5796.12	-5540.56	-5519.64	-5533.15	-5515.77	-5533.65	-5529.77	-5539.59
Pseudo R^2	.235	.257	.260	.258	.260	.258	.258	.257

Table 3: Tobit analysis predicting importance of new products (new to market, firm and improved products) (models 9 to 16). Showing betas, standard errors and significance levels (***=0.001; **=0.01; *=0.05). N = 7,426.

	9	10	11	12	13	14	15	16
Patents	0.35(0.04)***	0.09(0.04)	0.13(0.04)**	0.10(0.04)*	0.10(0.04)*	0.09(0.04)	0.10(0.04)*	0.08(0.04)
Licensing	203.92(86.83)*	165.03(84.81)	147.24(83.33)	153.72(84.51)	166.53(87.48)	170.99(84.99)*	168.41(85.74)*	166.5(84.45)*
Survey version	1.76(0.09)***	1.74(0.09)***	1.75(0.09)***	1.74(0.09)***	1.73(0.09)***	1.74(0.09)***	1.74(0.09)***	1.75(0.09)***
Firm size	-0.02(0.03)	-0.08(0.03)**	-0.08(0.03)**	-0.08(0.03)**	-0.08(0.03)**	-0.08(0.03)**	-0.08(0.03)**	-0.08(0.03)**
New firm	0.50(0.39)	0.43(0.39)	0.43(0.38)	0.45(0.39)	0.49(0.38)	0.43(0.39)	0.39(0.39)	0.41(0.39)
Internal R&D	1.93(0.10)***	1.63(0.11)***	1.54(0.10)***	1.61(0.11)***	1.59(0.10)***	1.62(0.10)***	1.59(0.10)***	1.63(0.11)***
External R&D	0.31(0.11)**	0.13(0.11)	0.17(0.11)	0.13(0.11)	0.13(0.11)	0.12(0.11)	0.14(0.11)	0.13(0.11)
Machinery	0.87(0.11)***	0.66(0.11)***	0.59(0.11)***	0.65(0.11)***	0.62(0.11)***	0.66(0.11)***	0.62(0.11)***	0.65(0.11)***
Training	0.85(0.10)***	0.61(0.11)***	0.60(0.10)***	0.60(0.11)***	0.59(0.10)	0.60(0.10)***	0.60(0.10)***	0.61(0.11)***
Design	0.71(0.10)***	0.55(0.10)***	0.56(0.10)***	0.55(0.10)***	0.57(0.10)***	0.56(0.10)***	0.56(0.10)***	0.55(0.10)***
Secretive orientation		0.36(0.05)***	0.54(0.05)***	0.39(0.05)***	0.36(0.05)***	0.36(0.05)***	0.36(0.05)***	0.36(0.05)***
External sourcing		0.62(0.08)***	1.14(0.10)***	0.60(0.08)***	1.18(0.11)***	0.61(0.08)***	1.01(0.10)***	0.61(0.08)***
External partnering		0.05(0.02)***	0.07(0.02)***	0.18(0.02)***	0.06(0.02)***	0.14(0.03)***	0.05(0.02)***	0.10(0.02)
Lack of personnel		0.03(0.05)	0.01(0.05)	0.02(0.05)	0.01(0.05)	0.02(0.05)	0.14(0.05)	0.05(0.05)
Financial constraints		0.04(0.03)	0.03(0.03)	0.04(0.03)	0.11(0.03)***	0.06(0.03)*	0.03(0.03)	0.04(0.03)
Secretive orientation X external sourcing			-0.49(0.06)***					
Secretive orientation X external partnering				-0.06(0.01)***				
Lack of resources X external sourcing					-0.26(0.03)***			

Lack of resources X external partnering						-0.03(0.01)***		
Lack of personnel X external sourcing							-0.39(0.06)***	
Lack of personnel X external partnering								-0.04(0.01)**
Constant	-10.77(0.41)***	-10.29(0.41)***	-10.22(0.41)***	-10.24(0.41)***	-10.20(0.41)***	-10.28(0.41)***	-10.25(0.41)***	-10.33(0.41)***
	0	0	0	0	0	0	0	0
Log likelihood	-9175.14	-8997.44	-8962.7	-8986.99	-8965.51	-8990.05	-8980.22	-8994.85
F-test	238.70	206.71	195.78	200.93	196.28	199.02	198.13	199.61
Pseudo R^2	0.1344	0.1454	0.1487	0.1464	0.1484	0.1461	0.1470	0.1457

Figure 1: Sample graph of secondary moderating effect for Tobit analysis of interaction between secretive behavioral orientation and knowledge sourcing following method proposed by Bowen (2010).