Open to a Select Few? Matching Partners and Knowledge Content for Open Innovation Performance

Lars Bengtsson, Nicolette Lakemond, Valentina Lazzarotti, Raffaella Manzini, Luisa Pellegrini and Fredrik Tell

The purpose of the paper is to illuminate the costs and benefits of crossing firm boundaries in inbound open innovation (OI) by determining the relationships among partner types, knowledge content and performance. The empirical part of the study is based on a survey of OI collaborations answered by R&D managers in 415 Italian, Finnish and Swedish firms. The results show that the depth of collaboration with different partners (academic/consultants, value chain partners, competitors and firms in other industries) is positively related to innovation performance, whereas the number of different partners and size have negative effects. The main result is that the knowledge content of the collaboration moderates the performance outcomes and the negative impact of having too many different kinds of partners. This illustrates how successful firms use selective collaboration strategies characterized by linking explorative and exploitative knowledge content to specific partners, to leverage the benefits and limit the costs of knowledge boundary crossing processes.

Introduction

A number of arguments for opening up firms' innovation processes to collaboration with external partners have been provided (Chesbrough, 2003, 2007). Such claims build upon several antecedents in innovation research (see, e.g., West et al., 2014). One rationale is that technological advancement and globalization require external acquisition of specialized knowledge (Grant & Baden-Fuller, 2004). Open innovation (OI) is further considered an alternative for sharing increasing development costs with partners when technology becomes more complex and product life cycles shorten (Trott & Hartmann, 2009). In addition, it is expected that outbound OI, such as licensing out technology, may be a way to exploit innovations on a broader market and thus increase revenues (Teece, 1986).

Given the proclaimed benefits, it is not surprising that the research on how firms organize and apply open innovation has advanced in just a few years to one of the prime topics in innovation management and become an established research field that attracts numerous researchers. For instance, in an overview, Gassmann, Enkel and Chesbrough (2010) identified nine research streams and perspectives on OI, ranging from questions on globalization of research and roles of different actors to a more process-oriented perspective. The many suggestions for further research in the growing OI literature motivate a further investigation of the OI concept and its applications (Huizingh, 2011; West and Bogers, 2014; West et al., 2014).

One of the core questions concerns the relationship between open innovation and innovation performance (Cheng & Huizingh, 2014).

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Extant research does not provide a clear cut answer to this question. The attractiveness of open innovation is indeed emphasized in several studies (e.g., Rohrbeck, Hölzle & Gemünden, 2009; Van de Vrande et al., 2009; Remneland-Wikhamn et al., 2011), but other studies are waving caution flags about the implementation of OI. For instance, Laursen and Salter (2006) analysed which partners firms collaborate with (breadth) and the depth of the collaboration, and showed a curvilinear relationship between breadth and depth and innovation performance. This has been confirmed in more recent studies, which report that beyond a certain threshold, a greater share of external R&D activities reduces a firm's innovation performance (Berchicci, 2013; Garriga, von Krogh & Spaeth, 2013).

One reason for the inconclusive findings in the literature regarding the impact of OI on performance is that openness is not stringently defined. Several researchers have emphasized the need for further research on the concept of openness and not least how it is realized (Dahlander & Gann, 2010; West et al., 2014). Recent publications have persistently stressed the importance of investigating how different organizational and contextual factors moderate the relationship between openness and performance (e.g., Remneland-Wikhamn & Knights, 2012; Rass et al., 2013; Cheng & Huizingh, 2014). These studies also point to the costs related to the acquisition and integration of external knowledge when crossing firm boundaries (Knudsen & Mortensen, 2011; Berchicci, 2013).

Taking as the point of departure the view of innovation as a process by which diverse knowledge bases are recombined to create new and valuable outputs (Berggren et al., 2011; Felin & Zenger, 2014), this paper specifically examines the costs linked to knowledge content when crossing firm boundaries in inbound open innovation. Several studies have identified open innovation challenges related to knowledge crossing boundaries (Ollila & Elmquist, 2011; Parmentier & Gandia, 2013). However, little attention has been paid to the knowledge content of the collaboration in relation to the costs and benefits of crossing knowledge boundaries (Huizingh, 2011; Felin & Zenger 2014). Previous studies have shown the relationship between different partners and performance, but these studies (e.g., Brettel & Cleven, 2011) mainly lack analysis of what the partners contribute. By highlighting the knowledge content in open innovation processes, we focus on the actual innovation collaboration with external partners rather than the preceding search process in the subject of many OI studies (see Laursen & Salter, 2014).

To sum up, previous studies of OI seem to lack analysis of how collaboration relates to different kinds of performance, and specifically how this is influenced by the knowledge content. Consequently, the overall purpose of this study is to illuminate the costs and benefits of crossing firm boundaries in inbound OI collaborations, by analysing the relationship between partner types, knowledge content and performance. The more specific aim is to use an international survey, with observations from Sweden, Italy and Finland, to empirically determine how the knowledge content of OI collaborations moderates the contribution of openness to different partners to innovation performance. This has been specified in two research questions.

> **RQ1** How does openness to different partners (breadth and depth) in OI collaborations relate to innovation performance?

The study is limited to four types of partners: universities/consultants, value chain partners, competitors and firms in other industries; and two types of knowledge content brought into the collaboration by the partners: explorative content (new technology, product and processes) and exploitative content (supply chain management, project management and improvement). Innovation performance is analysed in terms of novelty and efficiency.

> **RQ2** How does the knowledge content of OI collaborations moderate the contribution of openness to different partners to innovation performance?

The study provides two main contributions to the OI literature. First, by focusing on the actual collaboration in the OI process, we add the analysis of how different partners contribute to innovation performance in both novelty and efficiency. Secondly, the examination into how knowledge content moderates partner openness in OI processes further explains when partner openness is beneficial for innovation. As partner types and knowledge content represent specific types of technological and organizational boundaries (Knoben & Oerlemans, 2006) that need to be bridged, the study offers insights into how different combinations of OI boundaries affect performance. The study illustrates how successful firms use strategies of selective collaboration on explorative and exploitative knowledge content with specific partners in order to optimize the benefits and limit the costs of knowledge boundary crossing processes.

The following section outlines the theoretical framework, including a conceptualization of openness and knowledge content, and presentation of the literature regarding the

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implications of open innovation for performance. It also presents the research framework.

Theoretical Framework and Hypotheses

Defining Open Innovation

When examining the outcomes of open innovation, the definition and understanding of open innovation and openness is crucial. Previous research uses a number of different approaches and definitions of openness (see overviews in, e.g., Dahlander & Gann, 2010; Huizingh, 2011). One important distinction has been made between inbound and outbound open innovation (Chesbrough, 2003). The former refers to the search for and incorporation of external knowledge and technologies into the innovation process of the focal firm. Outbound open innovation, on the other hand, refers to the externalization of internally developed ideas and innovation, for example licensing out patents, establishing spin-offs, etc. Later studies have also identified the conception of combined or coupled innovation processes (e.g., Enkel, Gassmann & Chesbrough, 2009).

The increasing role of knowledge integration in internationally dispersed firms (see, e.g., Berggren et al., 2011) is also reflected in the OI literature. In a recent study, Chesbrough and Bogers (2014, p. 24) define open innovation as 'a distributed innovation process based on purposively managed knowledge flows across organizational boundaries [. . .] These flows of knowledge may involve knowledge inflows to the focal organization, knowledge outflows from a focal organization or both.' This definition suits our study well, while emphasizing the management of knowledge flows and organizational boundaries.

Most studies seem to agree that openness should be regarded as a continuum between end points of open and closed innovation. However, the degree of openness could differ depending on one's perspective. Van de Vrande, Lemmens and Vanhaverbeke (2006) studied the organizational form of acquisition or commercialization in terms of the levels of integration and time horizon that define different degrees of openness. In the same vein, Pisano and Verganti (2008) discuss how different forms of governance and partners' participation define different levels of openness. The extent to which firms are involved in inbound, outbound and coupled innovation processes has also been used to define openness (e.g., Cheng & Huizingh, 2014). Additional ways to measure the degree of openness have been proposed in terms of partner breadth and partner depth (Laursen & Salter, 2006), innovation phases (Lazzarotti, Manzini & Pellegrini, 2011) or content of the collaboration (Huizingh, 2011).

Accordingly, we follow a stream of studies which considers the open innovation concept as linked to collaboration. In accordance with such studies, the degree of openness reflects how diversely (breadth) and intensively (depth) a firm uses external information to sustain innovation (Laursen & Salter, 2006). Particularly relevant for this study is also inbound innovation (Laursen & Salter, 2006; Dahlander & Gann, 2010; Gassmann, Enkel & Chesbrough, 2010), which refers to firms' use of external sources in innovation. Collaboration concerns the joint development of knowledge through relationships with external partners (Hagedoorn, 1993). Therefore, such collaboration implies that partners share their resources and knowledge, redefining the boundary between the firm and its surrounding environment (Laursen & Salter, 2006). We will focus on innovation collaboration (Laursen & Salter, 2014), not the search process, as innovation collaboration is more explicitly connected to the costs of the OI process.

Openness and Performance

The first research question concerns the relationship between openness in OI collaboration and innovation performance.

Two of the main arguments for opening up the innovation process are: (1) to expand the firm's knowledge base, to get access to advanced technology, new products and processes, and (2) to share innovation risks and costs for developing the new products and processes (Chesbrough, 2003, 2007; Calantone & Stanko, 2007; Huang, Chung & Lin, 2009). Empirical studies indicate that offensive and income-oriented improvements are more common than defensive cost reduction goals (see, e.g., Van de Vrande et al., 2009). How these goals are realized in practice is not well understood (Gassmann, Enkel & Chesbrough, 2010).

However, in recent years, a number of studies have tried to empirically validate the benefits of opening up the innovation processes to external partners (Leiponen & Helfat, 2010; Plewa et al., 2013; Wu, Lin & Chen, 2013). For example, Fernandes and Ferreira (2013) found a positive correlation between collaboration (between universities and knowledge-intensive business services) and innovation capacity. Brettel and Cleven (2011) showed that customers, suppliers, competitors and

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universities – but not independent experts – contribute to new product development (NPD) performance. However, the results are not uniform. Laursen and Salter (2006) found a curvilinear relationship between open innovation (in terms of partner breadth and depth) and performance (in terms of the proportion of the firm's turnover that pertains to products that are new or significantly improved). The outcomes imply that openness also entails costs related to the many relationships. Despite this insight, most studies have still focused on the benefits while analyses of the cost side of open innovation with some few exceptions (e.g., Keupp & Gassmann, 2009; Knudsen & Mortensen, 2011) remain quite rare and therefore have been requested (Dahlander & Gann, 2010).

These insights point to the need to differentiate the performance outcomes variables. There are some studies that distinguish among different types of outcomes as the result of collaborations with different partners. As an example, Belderbos, Carree and Lokshin (2004) found that co-operation with suppliers and competitors usually involve incremental innovations and increased productivity performance, and that co-operation with universities and competitors is essential for innovating and selling new products, whereas radical innovations are facilitated by co-operation with customers or universities. Along the same vein, Faems, van Looy and Debackere (2005) found that collaborations with customers and suppliers were positively associated with higher levels of turnover coming from improved products. Collaborations with universities and research centres are instead associated with higher turnover related to new products.

Garriga, von Krogh and Spaeth (2013) have also elaborated on how different search strategies affect different kinds of innovation. When replicating the findings of Laursen and Salter (2006) they conclude that: 'if firms engage in open innovation, the optimal search strategy for external knowledge may depend on the type of innovation pursued' (Garriga, von Krogh & Spaeth, 2013, p. 1140). In short, they found evidence that having many partners (breadth) is beneficial for incremental innovation, whereas depth is significant for radical innovation.

To measure innovation performance outcomes only on a scale ranging from incremental to radical, does not, however, capture the cost dimension of innovation. One example of a study that has included this is Alegre, Lapiedra and Chiva (2006) who use a distinction between efficacy and efficiency in their analysis of innovation outcomes. Efficacy captures how successful an innovation is, including newness of products and markets, while efficiency measures how much effort has been put into the innovation activities.

We acknowledge the value of making such a distinction by analysing innovation performance in two dimensions, which we call innovation novelty and innovation efficiency. Innovation novelty captures the degree of radicalness and covers the outcomes of the collaboration in terms of how new products, processes and markets are, while efficiency covers whether the OI collaboration has reduced development costs, risk and time-to-market (TTM).

To sum up, as we focus on the actual collaboration with partners, which compared to search activities most likely requires specific and costly efforts to manage, we propose a negative effect of having too many partners. Firms have limited resources to achieve necessary interaction during collaboration (Foss, Lyngsie & Zahra, 2013). Therefore, the more different partners they have, the less likely they are able to capture and absorb new and innovative ideas from these partners. As a consequence, the costs of co-ordinating the collaboration with too many partners may outweigh the benefits. This leads us to the following hypothesis concerning partner breadth (or diversity):When it comes to depth of OI collaboration, the studies above (e.g., Wu, Lin & Chen, 2013) suggest that deep partner collaboration is beneficial for performance, but that the outcome can differ depending on which partners are at play (e.g., Brettel & Cleven, 2011). Therefore, we stipulate the following:

H1 *The breadth of partners in OI collaboration (partner breadth) negatively influences innovation performance in terms of both novelty and efficiency.*

H2 *The depth of partner collaboration is positively related to innovation performance, but different partners have different impacts on novelty and efficiency respectively.*

Knowledge Content in Boundary-Crossing Innovation Processes

The second research question concerns how openness relates to innovation performance when taking the knowledge content into account. While what knowledge content partners can contribute in collaboration is reasonably a main driver for involving external partners in inbound OI, this topic is surprisingly neglected in the OI literature on openness and performance (Chesbrough & Bogers, 2014).

As an exception, Huizingh (2011) explored, in a conceptual paper, OI in terms of content

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(what), context (when) and process (how). The content dimension in Huizingh's work addressed three aspects of open innovation: the richness of the concept, the distinction between inbound and outbound open innovation and finally the effectiveness. He did not, however, specifically analyse the knowledge content or the desired capabilities of the partners that are in play in the open innovation processes. For this reason we instead turned to the concepts elaborated in the literature on innovative suppliers (e.g., Azadegan & Dooley, 2010), as all partners in inbound OI processes can be seen as contributors. From this literature it emerges that partners mainly contribute two main types of knowledge content that we use in our analysis: (1) explorative knowledge content in terms of access to cutting-edge technologies, new products and markets (see, e.g., Azadegan & Dooley, 2010), and/or (2) exploitative knowledge content in terms of technological and production capabilities (Oh & Rhee, 2010) and supply chain management capability (Wu et al., 2006).

The notions of explorative and exploitative knowledge content follow the distinction of March (1991), who stated that firms must manage the tension between 'improving the existing' (exploitation) and 'facing the not previously experienced' (exploration). Building upon this, it is worth stressing that our use of exploration and exploitation, in contrast to, for instance, Faems, van Looy and Debackere (2005), does not describe the type of innovation output but rather the process and the capabilities partners bring to the OI collaboration. More specifically, our notion of knowledge content tries to capture the actual learning behaviours in two dimensions, i.e. 'exploration of new possibilities' and 'exploitation of old certainties' as described by He and Wong (2004).

The main purpose of taking the knowledge content into account is that it brings further insights to the boundary-crossing challenges that appear for the firms that open up their innovation processes. When defining OI as knowledge flows across boundaries (Chesbrough & Bogers, 2014), openness can be understood in relation to proximity. The knowledge boundaries that are crossed when involving different partners and content are more or less distant from the focal firm. Previous studies have differentiated among several proximity dimensions that are relevant for inter-organizational collaboration: geographical proximity, organizational proximity and technological proximity (Boschma, 2005; Knoben & Oerlemans, 2006). By adding analysis of the knowledge content we set out to capture the types of technological proximity that characterizes the OI collaboration. Optimizing these boundaries is crucial for the success of OI processes.

Garriga, von Krogh and Spaeth (2013) suggest it is beneficial to have many partners when focusing on exploitative knowledge content, while partner breadth has no or a negative effect when dealing with explorative knowledge content. Even though their studies concentrate in particular on search strategies, we suggest this insight is useful also when studying the next phase, i.e. the collaboration with these partners.

From this background we propose that successful firms manage to optimize their boundary-crossing activities in two ways: they limit the boundary-crossing requirements by involving selected partners for specific knowledge content related to the desired outcomes, and they keep the firm open to any kind of partner. The combined strategy may help firms to better manage the trade-off of collaborating intensively with many partners. Since we expect negative effects of partner breadth (see motivation for H1), two paired hypotheses can therefore be suggested:When combining the motivation for H2 with a suggestion that the content of the collaboration affects the outcomes, the hypotheses on depth in partner collaboration become:

H3a *The breadth of partners in OI collaboration with regard to explorative knowledge content negatively influences novelty but has limited effect on efficiency.*

H3b *The breadth of partners in OI collaboration with regard to exploitative knowledge content negatively influences efficiency but has limited effect on novelty.*

H4a *The depth of partner collaboration on explorative knowledge content positively influences novelty but not efficiency.*

H4b *The depth of partner collaboration on exploitative knowledge content positively influences efficiency but not novelty.*

Research Framework

The research framework is illustrated in Figure 1. The control variables ('firm size' and 'industry character') are motivated in the Methodology section.

Survey Methodology and Constructs

Survey

To find answers to our research questions, we relied on a survey study developed in 2012 by a group of researchers from Finland, Italy and

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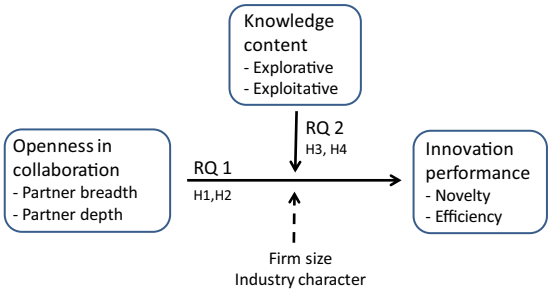

Figure 1. Research Framework

Sweden. To collect comparable data that could be pooled, the research groups used common guidelines and steps for survey design in accordance with Forza (2002).

The target population was three countries' manufacturing industry firms (codes 10–32 and 98 in NACE Rev. 2) with more than 10 employees. Although manufacturing is the most investigated industry in the OI literature, the empirical evidence on open innovation practices is still limited (Tidd, 2014). We excluded service firms because of their particularities, which would likely require partly unique open innovation practices. This would have required considering different variables and analysing the definitions of different constructs. The existence of so many studies in the manufacturing industry sector also allows for comparisons and theory testing.

Each research group selected a randomized stratified sample (strata defined by number of employees) of 1000 manufacturing firms. Probabilistic sampling was carried out in order to ensure representativeness of the sample (Babbie, 1990) and thus the generalizability of the results, at least as far as the three countries are concerned.

The measurement instrument was developed with specific guidelines for: (i) wording (the way questions are posed to collect specific information), (ii) respondent identification (identification of the appropriate respondents for the questionnaire) and (iii) rules of questionnaire design (following rules of courtesy, presentability and readability to help and motivate respondents to answer). Closed questions were used (except for those regarding the company's name, number of employees, and the previous fiscal year's turnover) to avoid double-barrelled questions (i.e., questions with different subparts with different possible answers). Regarding respondent identification, participating countries were urged to identify people who were knowledgeable about OI, in particular R&D managers or similar. The questionnaire was drafted in conformity with the design rules and supplemented with a clear, but concise introduction providing an explanation of the aims of the survey, instructions for filling it out and the guarantee of confidentiality.

The complete questionnaire covers questions on strategy, context (size, industry, etc.), openness, relational factors (collaboration modes) and performance. The focus in this paper lies on the constructs that concern the OI choices in terms of partners, knowledge content, and the effects of openness on performance and company characteristics (in particular size and industry character).

A pilot test of the questionnaire was conducted on two groups, colleagues and targeted respondents, to validate the quality of questionnaire. The target respondents from a number of firms answered a questionnaire translated into their native language to gather feedback on anything that might affect the answers. These two tests were conducted independently.

The data were collected by means of questionnaires distributed by email to R&D managers or similar persons knowledgeable about open innovation. The advantages of such a method include low cost, completion at the respondent's convenience, absence of time constraints, guarantee of anonymity and reduction of interviewer bias (Forza, 2002). Its shortcomings, on the other hand, are not least the lower response rate and lack of depth compared to other methods such as interviews with open-ended questions.

After three reminders we finally obtained in total 415 complete answers from firms that state they have collaborated with external partners in innovation (i.e., the development of new products, services or processes) during the past five years. Of the 415 answers used in the current analysis, 152 come from Italy, 176 from Sweden and 87 from Finland. This provides an overall response rate of about 13% (415/3000). Country-specific analysis of the non-response bias did not report any significant differences between respondents and non-respondents. The collected data can thus be regarded as representative for the manufacturing firms in the three countries.

Constructs

The core of the current analysis is the construct for measuring knowledge content and openness in terms of partner breadth and depth. All answers are measured by perceptive seven-point Likert scales, ranging from 1 = 'not at all' to 7 = 'to a very high extent', as well as 'do not know'.

The partner construct captures breadth and depth, i.e. which partners the firm collaborates with in open innovation and how intensive

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Table 1. Factor Analysis for Partner and Knowledge Content

	Academic/ consultant partners	Value chain partners	Explorative content	Exploitative content
Partners				
Universities, R&D centres	0.799			
Innovation intermediaries	0.633			
Government agencies	0.799			
Customers		0.758		
Suppliers		0.810		
Consumers		0.633		
(Competitors)				
(Companies in other industries)				
Knowledge content				
Advanced technologies			0.824	
Innovative products			0.829	
Innovative processes			0.764	
(Access to new markets)				
Reliable delivery				0.781
SCM responsibility				0.825
Project management capability				0.802
Improvement capability				0.716
Variance explained	29.1%	28.6%	37.2%	30.6%
Cronbach's alpha	0.628	0.613	0.779	0.822
N	415	415	415	415

(deep) the collaboration is with each partner. This approach is adapted from Laursen and Salter (2006), but we have used a more fine-grained 7-point scale to measure depth. We asked for the extent to which the firm has collaborated with eight specified stakeholders in innovation activities over the last five years. In order to further describe different OI approaches but also to capture the impact of partner breadth and depth on performance, the eight partners were reduced by the means of a factor analysis. An exploratory factory analysis resulted in two factors representing academic/public partners and value chain partners respectively (see Table 1). The last two items, measuring competitors and companies in other industries scored quite low and equally to these two factors and were thus discarded. The resulting constructs represent the depth of partner collaboration. Partner breadth was defined by the number of different types of partners that the firms have engaged in their open innovation processes (minimum = 1 and maximum = 8, median = 5, mean = 5.26 and standard deviation = 1.95).

The content construct specifies the knowledge that partners provide in the open innovation process. The chosen constructs are built on work on supplier innovativeness elaborated by Azadegan and Dooley (2010), Oh and Rhee (2010) and Wu et al. (2006). We defined eight items, covering access to new products, processes and markets and project and supply chain management (SCM) capabilities (see Table 1). In an exploratory factor analysis two regression factors were obtained. In line with He and Wong (2004), these correspond to either more explorative or more exploitative knowledge content. New technology, product and processes represent explorative knowledge content, whereas reliable deliveries, SCM, project management and improvement represent more exploitative knowledge content. The item measuring access to new markets was discarded due to equal loading on the two factors.

The performance effects of openness (see Table 2) were classified in terms of innovation novelty and efficiency, inspired by Alegre, Lapiedra and Chiva's (2006) distinction between efficacy and efficiency. The items used to operationalize innovation performance within these two groups followed the work by Lazzarotti, Manzini and Pellegrini (2011). The items corresponding to efficiency are lower development risks, costs and TTM, whereas

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Table 2. Factor Analysis for Performance and Industry Character

	Efficiency	Novelty	Innovative industry
Performance			
Decreased innovation risks	0.833		
Decreased development costs	0.881		
Decreased time-to-market (TTM)	0.838		
New or significantly improved products/services		0.816	
New or significantly improved processes		0.841	
New markets		0.751	
Industry character			
Products based on technological breakthroughs			0.740
Technology changes fast			0.751
Important to follow technology development			0.805
Technological complexity increases			0.826
High mix of scientific disciplines and technologies			0.819
Surveillance of many technologies important			0.837
Variance explained	72.4%	64.6%	63.6%
Cronbach's alpha	0.809	0.719	0.885
N	415	415	415

Table 3. Three Clusters based on Knowledge Content Focus in OI Collaboration

Cluster focus in OI collaboration	No of firms	Explorative factor		Exploitative factor	
		Mean	SD	Mean	SD
1. Explorative focus	138	1.00	0.655	0.473	0.656
2. Exploitative focus	114	–0.918	0.597	0.673	0.673
3. Other firms	163	–0.207	0.668	–0.934	0.628
Total	415	0	1	0	1

novelty is represented by new products, processes and markets.

To further describe how the different dimensions of openness relate to each other, we applied a cluster analysis. The clusters are derived from the two main types of knowledge content shown in the factor analysis, i.e. explorative and exploitative knowledge content. The description of the three clusters obtained in the K-means cluster analysis is shown in Table 3.

Finally, we use two control variables in the regression analysis: the firm size in terms of number of employees (the natural logarithmic value) and the industry character (Table 2) which reflects the perceived innovativeness of the industry (see, e.g., Gassmann, 2006; Huizingh, 2011). The number of employees in our sample varies between 10 and 56,000, with a mean value of 867 employees (standard deviation = 4239 and median = 50 employees).

The industry character construct refers to the technological turbulence (the first three items) and the technological complementarity (the last three items) that characterize the industry in which the firm operates. More exactly, technological turbulence refers to the rate of technology change and unpredictability, which rapidly makes a firm's existing technological knowledge obsolete (Hung & Chou, 2013). Such turbulence not only leads a firm to suffer the fate of competency traps because of responsiveness to current customers (Leonard-Barton, 1992; Zahra & George, 2002), but also disrupts its synergies among accumulated knowledge accompanied by

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Table 4. The Influence of Partner Breadth and Depth on Performance

	Novelty	Efficiency
Partner breadth	–0.252***	–0.219**
Universities/consultants	0.247***	0.279***
Value chain partners	0.114*	0.215***
Competitors	0.115*	0.045
Other industry firms	0.197***	0.111*
Firm size (ln)	–0.093*	–0.013
Innovative industry	0.351***	0.239***
Adj R^2	0.260	0.174
F	20.90***	12.95***
N	415	415

Note: significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

organizational inertia for the new product (Leonard-Barton, 1992). In turbulent environmental conditions, flexibly accommodating to environmental changes and relentlessly renewing knowledge bases is the best way to sustain competitive advantage (Katkalo, Pitelis & Teece, 2010). Therefore, in a turbulent technological environment, a firm tends to open its innovation process, because such an environment rapidly causes, on the one hand, its current technological knowledge and products to become rapidly obsolete (Eisenhardt & Martin, 2000; Grant & Baden-Fuller, 2004; Teece, 2007), and, on the other, its inability to cover all technological developments by means of internal R&D (Cesaroni, 2004). The measurements used (see Table 2) build on Lichtenthaler (2009) who measures technological turbulence by means of three items.

For the last three items of the construct (see Table 2) we build on Hagedoorn's (1993) operationalization of technological complementarity. Technological complementarity refers to the increased complexity and inter-sectoral nature of new technologies, as well as the cross-fertilization of scientific disciplines and fields of technology. Such an inter-relationship requires close collaboration between companies in order to create 'the necessary complementary technology inputs enabling these companies to capitalize on economies of scope through joint efforts' (Hagedoorn, 1993, p. 372). The central role of obtaining complementary knowledge assets in collaboration has also been stressed by others (Grant & Baden-Fuller, 2004; Parmigiani & Rivera-Santos, 2011).

We decided to focus on a five-year time-frame for collaboration to allow a particular activity (in this case, collaborative activities) to provide some effect (see Hardy, Phillips & Lawrence, 2003; Grimaldi & Grandi, 2005). Then we asked how well collaboration has performed against a set of objectives over the last three years. In this way, we could grasp potential influence on performance due to collaborative activities. The three-year time-frame diminishes the risk of potential distortion due to exceptional performance in one year.

Results

Openness and Performance

Table 4 reports the results of the regression analysis in which partner breadth and depth are the dependent variables and innovation novelty and efficiency the independent ones. It shows that the depth of partner collaboration performance significantly influences performance outcomes in OI processes, while breadth of partners has a negative impact. The novelty is mainly explained by intensive collaboration with universities/consultants and firms in other industries, whereas value chain partners are second in importance for efficiency. The results thus provide support for both the first and second hypotheses. Notable is also the strong explanatory value for firm size (negative) and firms being part of an industry where technology rapidly changes.

The Moderating Effect of Knowledge Content

The second research question concerns how the knowledge content moderates the performance impact of openness. Table 5 displays the regression analysis for the three clusters of knowledge content derived in the Methodology section (see Table 3).

The results in Table 5 show that the content of the collaboration has a clear impact on the kind of openness that explains performance.

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Table 5. The Influence of Partner Breadth and Depth on Performance for Firms with Different Knowledge Content in OI Collaboration

	Explorative content cluster		Exploitative content cluster		Other firms (Low on both)	
	Novelty	**Efficiency**	**Novelty**	**Efficiency**	**Novelty**	**Efficiency**
Partner breadth	–0.437**	–0.181	–0.076	–0.240^	–0.247	–0.164
Universities/consultants	0.328**	0.258*	0.071	0.102	0.217	0.281*
Value chain partners	0.114	0.170	0.151	0.252*	–0.005	0.150
Competitors	0.280**	0.048	0.010	0.074	0.159	0.044
Other industry firms	0.111	0.171	0.133	0.071	0.272**	0.077
Firm size (ln)	–0.105	–0.148	–0.180	0.018	0.006	0.089
Innovative industry	0.442**	0.270**	0.453**	0.288**	0.138	0.090
Adj R^2	0.326	0.194	0.265	0.095	0.090	0.490
F	9.92**	5.44**	6.56**	2.61*	3.21**	2.61*
N	138	138	114	114	163	163

Note: Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

For the cluster of firms that focuses on explorative knowledge content, the novelty is explained mainly by deep collaboration with universities/consultants and competitors, but strongly negatively connected to partner breadth. For the same group of firms, the efficiency is explained mainly by deep collaboration with universities/consultants, and to some extent value chain partner and firms in other industries. The negative impact from partner breadth is, however, not significant.

For the cluster focusing on collaboration on exploitative content, novelty is not explained by breadth or depth but rather an effect of being in an industry with that characteristic. The efficiency is a result of deep collaboration with value chain partners, whereas partner breadth contributes negatively. The models for the third cluster, as expected, explain performance less compared to the two other clusters.

This means that the results bring support to H3a and H3b. The content analysis reveals a limited effect of breadth on one of the performance indicators, but for the other indicator the negative effect is even stronger compared to what is valid for all firms. Hypotheses H4a and H4b are also supported. Deep partner collaboration focused on specific knowledge content has a positive but selective effect on innovation novelty and efficiency. Finally, we can notice that the industry character maintains its explanatory value also when separating into the content clusters. The negative impact from firm size is, however, only valid for one of the performance indicators, which are different for the clusters.

Discussion

One aim of this paper is to determine how the knowledge content of open innovation (OI) collaborations moderates the relationship between openness to different partners and innovation performance in terms of novelty and efficiency. The main idea is that such an analysis can advance our understanding of the costs and the benefits of crossing firm boundaries in inbound OI collaborations.

We started out by investigating how openness to different partners (breadth and depth) in OI collaborations relates to innovation novelty and efficiency. The results in Table 4 gave support to the H1 that partner breadth in OI collaboration has a negative impact on both novelty and efficiency. This result extends the findings of previous research (e.g., Laursen & Salter, 2006), as our results cover OI collaboration and not only the search phase. At the same time, the findings seem to contradict the study of Garriga, von Krogh and Spaeth (2013) who found positive correlations between partner breadth and incremental innovation. One explanation for the different results is that incremental innovation is not the same as efficiency. But beyond that, as broad OI collaborations from a knowledge integration perspective (Berggren et al., 2011; Chesbrough & Bogers, 2014) represent crossing of multiple boundaries, the efforts needed to bridge them are connected to severe transaction costs that might exceed the benefits. Similarly, the negative effect of partners' breadth on novelty could also be due to the fact that involving a

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wide variety of partners increases the level of complexity of the partnership and forces managers and researchers to put effort into organizational and managerial problems rather than innovation issues. These explanations are elaborated below when we analyse how a focus on certain knowledge content affects the relationship between openness and performance.

Our study furthermore confirms previous research stating that intensive and deep partner collaboration is beneficial for performance (e.g., Wu, Lin & Chen, 2013). The findings also disclosed that different partners have dissimilar impact on novelty and efficiency, which is mainly in line with the results of Brettel and Cleven (2011). But beyond their study, we are able to show that the performance effect of partner depth is valid for both dimensions of innovation performance, i.e. both novelty and efficiency.

The result seems quite reasonable; the more defensive motives for open innovation, such as costs, risk and time reduction (see, e.g., Calantone & Stanko, 2007; Huang, Chung & Lin, 2009; Van de Vrande et al., 2009) to a large extent rely on the later innovation phases. Previous studies have indicated that successful innovation processes presuppose not only efficient knowledge creation processes but also the ability to build up effective production and supply chains (Schiele, 2006; Rosell & Lakemond, 2012), an ability that becomes even more important as product life cycles shorten.

The topic of the partners' diverse outcomes leads us to our main purpose: investigating how the knowledge content of OI collaborations moderates the contribution of openness to different partners to performance. The results in Table 5 are quite clear: H3 and H4 were supported.

Building on the results in Table 5 it seems that the negative effect from partner breadth is only valid for one of the performance indicators when taking the knowledge content into account. More precisely, for the firms collaborating on explorative knowledge content, such as new technology, products and processes, the number of different partners is strongly negatively correlated to novelty. Inversely, for the exploitative content cluster, i.e. firms that collaborate on SCM, project management and improvements, breadth is negatively linked to efficiency. It thus seems more beneficial to concentrate the collaboration on targeted content to a few partners, which are universities/consultants and competitors for the explorative cluster and value chain partners for the exploitative cluster. Another interesting finding is that the negative effect of partner breadth is only significant for one of the two performance indicators: breadth in collaboration focused on explorative knowledge content has limited effect on efficiency. In contrast, partner breadth has limited effect on novelty when the collaboration concerns exploitative knowledge content.

These results add further understanding to previous OI studies that have revealed negative effects and costs of having too many partners (Laursen & Salter, 2006; Knudsen & Mortensen, 2011; Garriga, von Krogh & Spaeth, 2013). Our results suggest that this effect is not bound to all kinds of knowledge collaboration. The negative impact of partner breadth is valid mainly for the specific combinations of knowledge content and performance outcomes just described. Spelled out, this means that a focus on explorative knowledge content affects mainly novelty negatively, and a focus on exploitative knowledge content affects efficiency negatively when a company has many partners. For the inverse combination of knowledge content and performance, partner breadth does not have this negative impact, and the performance is instead governed by the depth of the collaboration. This leads us to the results of the fourth hypothesis.

Regarding H4, we found that the type of performance outcome of deep partner collaboration depends on the knowledge content of the OI collaboration. This finding adds to the results and literature discussed on H1. After separating firms in the different knowledge content clusters as in Table 5, the results become more consistent with the findings of Garriga, von Krogh and Spaeth (2013), who claimed that 'the optimal search strategy for external knowledge may depend on the type of innovation pursued'. In addition to their study, we have been able to show that not only the search strategy but also the content of the OI collaboration explain the type of performance outcome. When focusing on explorative OI collaboration on advanced technologies, products and processes, deep collaboration with a few selected partners provide novelty as performance. Moreover, when applying exploitative OI collaboration on SCM, project management and improvements, deep collaboration with selected partners in the value chain contributes to firms' efficiency in innovation processes.

This pattern does not seem to represent a trade-off problem. For both the explorative cluster and the exploitative cluster of firms, the partner depth has positive effects on the performance indicators, although not significantly. One explanation for firms focusing on explorative knowledge content is that these firms also have some focus on exploitation (see Table 3).

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A theoretical explanation for the results, specifically from the testing of H3 and H4, could be that successful firms are able to optimize and limit the boundary crossing in OI collaboration by two strategies. First, they manage to restrict boundary crossing by deeply involving a few selected partners in collaboration on knowledge content related to desired performance outcomes. While the knowledge content measured represents mainly the type of proximity that Knoben and Oerlemans (2006) call technological proximity, the strategy of selective content collaboration limits the technological boundaries that need to be bridged. Secondly, by linking knowledge contents and partner types, successful firms are at the same time able to keep the firm open to any kind of partners. This kind of selective OI strategy therefore enables firms to better manage the trade-off of having intensive collaboration with too many partners.

The analysis of the control variables shows that the context of innovation is very important for the innovation outcomes. Of the analysed control variables, size has a negative impact on ability to both obtain lower costs and develop new products and processes. Smaller firms thus tend to be more innovative than larger firms in OI collaboration. Further studies are needed to explain whether this is a general feature or due to the fact that smaller firms, in an open innovation context, are more specialized than large firms, and are therefore able to benefit more from OI in terms of innovativeness and novelty.

In contrast, the factor 'innovative industry' relates strongly to high innovation performance. This means that firms that compete in industries characterized by technology breakthroughs, fast technology changes, increasing technological complexity and a high mix of scientific disciplines and technologies are more innovative, by creating novel products, processes and markets, than other firms. This is in line with the several studies that emphasize the relevant role of industry characteristics on the companies' OI decisions and results (Hagedoorn, 1993; Jaworski & Kohli, 1993; Calantone & Stanko, 2007; Ozman, 2008; Fortuin & Omta, 2009).

This study is not without limitations. One important shortcoming is that the direct effect of openness on performance outcomes is likely moderated by the relationship strategy and methods applied by the collaborating firms (Dyer, 1997; Poppo & Zenger, 2002; Blomqvist, Hurmelinna & Seppanen, 2005). This analysis is, however, a subject for further research. Another limitation is that our survey study is conducted at the level of the firm. This means that the core constructs, i.e. partner breadth and depth, knowledge content and performance, represent the firms' collective OI activities. Further studies would benefit from taking a project-level perspective in order to validate the identified results.

Conclusions

This study illustrates the intimate linkages between partner types, knowledge content and innovation performance in open innovation (OI) collaboration. Two main conclusions can be drawn from this study. The first is that the pattern from studies on search strategies in OI is also valid when analysing OI collaboration. In line with earlier studies our results also indicate the problems of having too many different partners in OI collaboration processes. Going beyond previous research, we have also displayed how different partners contribute to different kinds of performance. More precisely, our findings show that deep collaboration with academia/consultants, competitors and firms in other industries contribute to innovation novelty in terms of new products, processes and markets, while intensive collaboration with value chain partners, but also universities/consultants, is most valuable for obtaining innovation efficiency in terms of lower costs, risks and time-to-market.

The second and major conclusion concerns the significance of the knowledge content of the OI collaboration. In the study we make a distinction between explorative knowledge content in terms of advanced technologies, innovative products and processes and exploitative knowledge content, including reliable delivery, SCM responsibility, project management and improvement capability. By including knowledge content in the analysis of OI collaboration, we have provided new insights into how successful firms manage to both exploit and limit their boundaries in a beneficial way.

The negative effects of having too many partners do not apply to all kinds of OI collaboration. There is instead quite a clear link between the specific knowledge content of OI collaboration and the performance outcomes. More specifically, our study shows that collaboration with many types of partners on explorative knowledge content affects mainly novelty negatively, while it has limited effect on efficiency. Conversely, when OI collaboration focuses on exploitative knowledge content, partner breadth has a negative effect mainly on efficiency but limited effect on novelty. The results further demonstrate that deep collaboration with a few selected partners that are linked to desired performance

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outcomes is most beneficial. The results therefore indicate that successful firms apply a selective OI strategy characterized by leveraging and limiting boundary crossing in OI collaboration.

One managerial implication from the study is that deep collaboration with a few kinds of partners is more beneficial for both novelty and efficiency in OI collaborative processes than having numerous kinds of partners. Firms are furthermore advised to form strategies based on conscious linkages between partner types and knowledge content to optimize breadth and depth in OI collaboration.

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Lars Bengtsson (lars.bengtsson@hig.se) is professor in Innovation Management at the University of Gävle, Sweden, associate professor at KTH in Stockholm and a member of KITE research group at Linköping University. He currently leads research focusing on innovation management, knowledge integration, manufacturing strategies and outsourcing in industrial firms.

Nicolette Lakemond is an associate professor at Linköping University in Sweden and a member of the KITE research group. Her research focus is on the organization of innovation in collaborative settings, more specifically purchasing and supplier involvement in product development, open innovation and knowledge integration.

Valentina Lazzarotti is an assistant professor at LIUC Università Cattaneo (Italy). She teaches Business Economics and Organization and Management Control Systems. She obtained her Master Degree in Business Administration from Bocconi University and PhD in Management Engineering from Politecnico di Milano. Her research interest concern R&D performance measurement and accounting for innovative activities.

Raffaella Manzini is full professor at LIUC – Università Cattaneo (Italy). She teaches 'Economics, Management and Organization' and 'Innovation and New Product Development' at LIUC. She is also lecturer of Innovation Management at ENI Corporate University. Since 2010 she is Director of LIUC IP Centre. Her research interests are R&D and innovation management, technology strategy, management and organization, innovation and intellectual property.

Luisa Pellegrini is an associate professor of Management Engineering at the University of Pisa where she teaches Finance and Business Economics and Organisation. She is actively involved in national and international research projects on continuous and open innovation.

Fredrik Tell is professor in Business Administration at Linköping University and director of the KITE Research Group. His research revolves around implications of innovation and knowledge integration for firm strategies, competitiveness and organization. Current research projects include: knowledge integration and innovation, internationalization of R&D activities to emerging economies, open innovation, IPR strategies, and project-based firms.

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