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Depth and breadth of external knowledge search and performance: The mediating role of absorptive capacity

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ABSTRACT

Nowadays it is commonly accepted that exploiting external knowledge sources is important for firms' innovation and performance. However, it is still not clear how this effect takes place and what internal capabilities are involved in the process. We propose to open the black box between external knowledge search strategies, and innovation and performance by proposing *absorptive capacity* (*AC*) as the mediating variable. A sample of 102 biotechnology firms from Spain is used to test the proposed theoretical model through structural equation modeling taking the partial least squares approach. Results suggest that AC acts as a full mediator in the relationship between the depth of external knowledge search and the innovation and business performance of the firm. Finally, some suggestions for managers and future lines of research are highlighted.

1. Introduction

A central part of the innovation process concerns the way firms go about organizing their search for new ideas that have commercial potential (Laursen & Salter, 2006). While a firm's innovation capability may depend on its existing knowledge base, firms also rely on external relationships and networks in order to access knowledge located outside their boundaries or to find sources for knowledge variety that facilitate the creation and combination of new technologies (Cockburn & Henderson, 1998; Martín-de Castro, Delgado-Verde, López-Saez, & Navas-López, 2011). This openness to external knowledge sources has been defined as 'open innovation' and involves the use of a wide range of external actors and sources to help firms obtain the knowledge they need for their innovation processes (Chesbrough, 2003).

While the influence of firms' openness on their performance represents an interesting research field, most of extant literature assumes a direct relationship between external knowledge search and performance (Foss, Laursen, & Pedersen, 2011). In a recent study, Laursen and Salter (2006) suggest *absorptive capacity* (*AC*) as a complementary factor to external knowledge search. Scholars in the literature on *AC* and organizational learning suggest that simple acquisition of external knowledge does not imply successful application (Lane, Koka, & Pathak, 2006); rather, firms need to possess the mechanisms that allow them to retain, reactivate and apply the new knowledge in their products and processes (Chen, Lin, & Chang, 2009; Lewin, Massini, & Peeters, 2011).

Although Laursen and Salter (2006) drew on Cohen and Levinthal's (1990) research and suggested *AC* as a complementary factor to external knowledge search *breadth* and *depth* in shaping innovation performance, they assessed *AC* as a one-dimensional concept and used R&D intensity as a proxy to measure it. However, the appropriateness and validity of R&D as a proxy of *AC* has been questioned, given that the empirical evidence is inconsistent and it does not capture *AC* as a dynamic capability (Lane et al., 2006; Zahra & George, 2002). Authors therefore recommend considering the multidimensional nature of *AC* when analyzing the concept instead of assuming it to be unidimensional (Lane et al., 2006: 857; Volberda, Foss, & Lyles, 2010). According to its process-based definition, *AC* represents a dynamic capability which confers firms with the ability to recognize, assimilate and apply externally held knowledge through three sequential processes, namely, exploratory, transformative and exploitative learning (Lane et al., 2006: 856).

Thus, the main contribution of this paper is to investigate the role of the multidimensional learning-based *AC* construct in the external "knowledge search — innovation/performance relation". This investigation implies identifying the organizational learning processes of *AC* in the context of firms' openness and how their complementarity provides a better understanding of interfirm discrepancies in benefitting from

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external knowledge. Previous researchers have argued that different ways of acquiring new knowledge may induce different modes of organizational learning (Chiang & Hung, 2010; March, 1991). Moreover these learning processes have been highlighted as the mechanisms that originate and make possible the development of a dynamic capability inside the firm (Eisenhardt & Martin, 2000; Helfat et al., 2007). Following this logic we address, theoretically and empirically, how intensively accessing knowledge from a limited number of external channels (open search *depth*) and from a broad range of external channels (open search *breadth*) is related to a higher level of *AC*, and how this capacity may explain performance differences between firms. Following previous studies, we considered innovation and firm performance as two different outcomes of *AC* (Tsai, 2001).

The structure of this paper is as follows. In Section 2, we provide a literature review and propose eight research hypotheses. In Section 3, methods are described. Section 4 presents the results obtained through structural equation modeling based on partial least squares (PLS), and finally the conclusions and implications are discussed in Section 5.

2. Literature review and hypothesis development

2.1. Effect of external knowledge search strategies on firms' innovation and performance

Since no company possesses all technological resources internally (Teece, 1986), firms need to develop external links to access knowledge located outside their boundaries or to find sources of variety that facilitate the creation and combination of new technologies and knowledge (Laursen & Salter, 2006).

Thus, the newer models of innovation suggest that innovators do not only work alone (Rampersad, Quester, & Troshani, 2010). Indeed, they interact with a range of institutions from inside and outside the innovation system (Belderbos, Carree, & Lokshin, 2004). Chesbrough (2003) defined these firms as open innovators as they integrate different external sources into their innovation processes and competitive strategy. In this respect, Laursen and Salter (2006:134) introduced two terms to define the openness of firms' external search processes. The first concept refers to external search *breadth*, which is defined as the number of external sources or search channels that firms rely upon to improve their knowledge base, whereas the second concept refers to external search *depth* and it is defined in terms of the extent to which firms draw deeply from the different external sources to increase performance.

Studies in this area highlight the importance of open behavior in searching for innovative opportunities and suggest that performance differences between organizations can be ascribed to this behavior (Bamford, Gomes-Casseres, & Forbes, 2003). Laursen and Salter (2006), for instance, using a large-scale sample of industrial firms from the U.K. innovation survey, found that searching widely and deeply across a variety of search channels can provide firms with new ideas and resources that help them to gain and exploit innovative opportunities. Chen, Chen, and Vanhaverbeke (2011) distinguished two modes for managing innovation: the science-technology-innovation mode (STI-mode, which is largely based on codified scientific knowledge), and the learning by doing, using and interacting mode (DUI-mode, which is more experience-based); these authors found that for both modes the intensity and number of collaborations were important factors for improving innovation performance. Amara and Landry (2005) suggested that firms introducing innovations with a greater degree of novelty were more likely to use a wider range of information sources to develop or improve their products. Furthermore they argued that sustained and intense interactions between firms and external sources of technical information increase the likelihood of this information being used to develop innovations with a higher degree of novelty. Nieto and Santamaría (2007) highlighted that collaborating with a diversity of external sources, rather than a single type of partner, favors innovation novelty. They argue that integration in a heterogeneous network promotes access to diverse sources of information, which allows firms to improve their innovation.

In sum, all the above studies suggest that firms that search more widely and deeply across a variety of search channels are more likely to obtain a higher level of innovative performance. Based on the above discussion, the following hypotheses are proposed:

H1a. The depth of external knowledge search will be positively related to innovation performance.

H1b. The breadth of external knowledge search will be positively related to innovation performance.

Although previous studies on the field of open innovation have mainly focused on the effect of knowledge search strategies on firms' innovation outcomes, few studies have analyzed the effect that this kind of strategy may have on firms' performance. Studies on the relational view suggest that organizations may be able to achieve superior performance by developing and maintaining successful relational exchange with external partners. In this view, communication represents one of the most important factors in developing successful knowledge interchange and, in consequence, superior performance (Bleeke & Ernst, 1993; Chen, Chang, Tseng, Chen, & Chang, 2013). For instance, when firms sustain effective communication with external actors such a clients, suppliers or collaborators, the level of trust in the network tends to grow, which leads to increased mutual cooperation, reduced propensity to leave and less opportunistic behavior (Chen et al., 2013; Morgan & Hunt, 1994; Paulraj, Lado, & Chen, 2008). That is, effective communication with external actors such as clients, suppliers or collaborators may give firms a better understanding of the benefits derived from mutual cooperation and enhance collaborators' willingness to make effective investment in relationship-specific assets, which in turn increase firm performance in sales and profitability.

As drawing knowledge from external sources through deep relations is positively connected with higher external communications and knowledge interchange, we argue that this strategy may also have a significant impact on the performance firms obtain. Searching deeply allows firms to create patterns of interaction and mutual understanding between collaborators, which have proven to be essential to create trust, to enhance communication and to obtain superior performance (Chen et al., 2013; Dyer & Nobeoka, 2000; Meek, Davis-Sramek, Baucus, & Germain, 2011). Based in the above, we propose the following hypothesis:

H2a. The depth of external knowledge search will be positively related to firms' performance.

Furthermore, broad search can also help firms to become aware of new market and technology developments, which suggest new applications and combinations for existing technologies and an enhancement of the firm's performance (Katila, 2002). For instance, Asakawa, Nakamura, and Sawada (2010) found that promoting collaboration with local universities, ventures and suppliers may provide laboratories with the complementary knowledge necessary to enhance the laboratory research performance. Lööf and Heshmati (2006) highlighted firms' collaboration with external knowledge sources as one of the mechanisms that allows organizations to enhance their knowledge capital, and suggested that an increment in the knowledge base was related to performance heterogeneity between firms. Searching broadly enriches the knowledge pool available to the firm by adding distinctive new variation to its knowledge base and providing new choices for solving problems (Katila & Ahuja, 2002; March, 1991). These new knowledge inputs may allow firms to shorten their development cycles, resolve problems sooner, and increase their productivity, all of which can be translated into superior economic rewards for firms (Sisodiya, Johnson, & Grégoire, 2013). Following this argument, the following hypothesis is proposed:

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H2b. The breadth of external knowledge search will be positively related to firms' performance.

2.2. Effect of external knowledge search strategies on firms' absorptive capacity

Open innovation scholars assume that organizations investing in broader and deeper searches are more capable of adapting to environment changes and increasing their commercial output (see e.g., Chen et al., 2011; Laursen & Salter, 2006: 134). However, it has been argued that sustaining a deep or a wide number of relations with external actors is not a sufficient condition for securing performance; it is therefore important to analyze organizational processes to understand how firms leverage external knowledge to foster innovation and increase performance (see e.g., Foss et al., 2011; Murovec & Prodan, 2009).

According to Helfat et al. (2007:4), dynamic capabilities allow firms to purposefully create, extend, or modify their resource base over time. Therefore, while external knowledge represents a critical component to improve performance (Cohen & Levinthal, 1990: 128), firms need to develop the ability to identify and assimilate the value present in external knowledge to be able to apply it in their products or processes (Lane et al., 2006; Zahra & George, 2002). In this regard *AC* has been highlighted as the essential dynamic capability that allows firms to utilize externally held knowledge through three sequential processes: (1) recognizing and understanding potentially valuable new knowledge outside the firm through exploratory learning; (2) combining existing knowledge with externally-acquired knowledge through transformative learning; and (3) using the assimilated knowledge to create new knowledge and commercial outputs through exploitative learning (Lane et al., 2006: 856). This process-based view by Lane provides a framework that integrates the contribution of some of the key papers in the field with the literature on organizational learning and returns the concept to the original dimensions proposed by Cohen and Levinthal (1990) (Sun & Anderson, 2010; Todorova & Durisin, 2007).

A central argument in Cohen and Levinthal's (1990) seminar paper is that absorptive capacity is primarily determined by prior related and accumulated knowledge. Therefore, firms may try to connect to their external environments in pursuing diverse knowledge across organizational boundaries and industry segments (Sun & Anderson, 2010). This path-dependent condition is also highlighted in the process-based definition of *AC* (Lane et al., 2006). In exploratory learning, the efficient acquisition of external knowledge requires similar cognitive structures, common skills and shared languages. Therefore, firms may try to develop deep connections with external actors to generate the truth necessary to transfer information from external sources and increase their exploratory learning (Hansen, 1999; Laursen & Salter, 2006). In addition, when the knowledge firms require for their processes is tacit, they may need to establish deep interaction with external actors to facilitate the transfer and combination of the knowledge with the already existing knowledge base (Chen et al., 2011).

Furthermore, interfirm differences in transformative learning depend on the level of knowledge accumulated in the exploration phase (Argote, McEvily, & Reagans, 2003; Garud & Nayyar, 1994). Moreover, firms may not develop high levels of exploitative learning to apply assimilated knowledge if they lack sufficient levels of the knowledge necessary to assimilate and maintain new external knowledge in the first place (Lane et al., 2006). Since the emphasis in exploitative learning is on incorporating the newly acquired and transformed knowledge into the operation and products (Sun & Anderson, 2010; Zahra & George, 2002), developing deep relations with an external actor may assist a firm in this process (Rowley, Behrens, & Krackhardt, 2000). For instance, Dyer and Nobeoka (2000) report that in the Toyota supplier network, core groups of five to seven suppliers sharing common operations and working closely together to generate knowledge and experience on how to make cost reduction improvements were more able to exploit their core innovation as a result of the sharing routines. Rowley et al. (2000) suggest that strong relations produce thick information exchanges, trust and joint problem solving, which allow firms to gain organizationally embedded know-how and assist them in their exploitation process. Rothaermel and Deeds (2004) find that exploitation is connected with fewer partners, less knowledge diversity, and stronger integration among the partners.

Therefore, as the three learning processes are complementary and firms' knowledge base is regarded as a common driver that may contribute to their development, we suggest that the external knowledge generated through sustaining deep relations with external actors may be connected to a higher overall *AC* in the firm. Based on the above, the following hypothesis is formulated.

H3a. The depth of external knowledge search will be positively related to absorptive capacity.

Concerning the *breadth* of external knowledge search, some studies have suggested a connection between searching broadly and the firm's level of *AC*. For instance, Cockburn and Henderson (1998) argued that in order to improve *AC*, pharmaceutical firms need to invest not only in basic research, but they should also be actively connected to the wider scientific community. Jones and Craven's (2001) case study of an SME in Birmingham found that the use of diversified sources, such as literature scan, customer contact, trade shows, competitor monitoring, customer input, supplier input, and reverse engineering for collecting external information and knowledge, contributes to organizational learning. George, Zahra, Wheatley, and Khan (2001) showed that various inter-organizational alliances in biotechnology firms, including horizontal, vertical, and alliances (purchasing or licensing agreement), provided these firms with access to multiple resources of new knowledge and enhanced their knowledge absorptive capacities. Murovec and Prodan (2009), using the responses to the Spanish and Czech Republic's third Community Survey, investigated whether collaboration with different types of actors (not only the actors located in the value chain of the product/service but also public or commercial knowledge institutions and consultants) influences organizational absorptive capacity, and found that broad collaborations were positively related to Spanish and Czech firms' capacity to absorb scientific knowledge.

According to the above studies, the *breadth* of external knowledge search exposes firms to multiple and varied sources of ideas that go beyond those the firm already has, thereby broadening their knowledge base and their capability to assimilate and acquire new knowledge. As *AC* constitutes a dynamic capability and learning processes represent the mechanisms that allow firms to generate this capacity at the organizational level (Lane et al., 2006; Sun & Anderson, 2010), we assume that firms sustaining broad relations with external agents may be in a better position to enhance their overall *AC*. The three learning processes underpinning a firm's *AC* are complementary and the firm's stock of knowledge constitutes the basis for knowledge flows among the three learning processes (Lane et al., 2006). Therefore, the new knowledge generated through the interaction with external sources may assist firms in enhancing their capability to assimilate, transform and apply the new knowledge by improving their learning processes (Fosfuri & Tribó, 2008). Based on the above, the following hypothesis is proposed:

H3b. The breadth of external knowledge search will be positively related to absorptive capacity.

2.3. Effect of absorptive capacity on firms' innovation and performance

Previous empirical studies have provided support for the notion that the higher a firm's *AC*, the greater its innovation and performance (e.g., Fabrizio, 2009; Murovec & Prodan, 2009). Following previous studies we consider innovation and firm performance as two different outcomes of *AC* (Tsai, 2001). These studies suggest that *AC* allows

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firms to easily understand and integrate various sources of knowledge, thus making knowledge sharing and application easier. For instance, García-Morales, Ruiz-Moreno, and Llorens-Montes (2007) suggested that firms with accumulated technological know-how and with a certain degree of technology *AC* were able to take advantage of the totality of technological opportunities present in the environment and increase their innovation. Murovec and Prodan (2009) highlighted that firms' capacity to absorb scientific and market knowledge had a positive effect on their process and product innovation output. Chen et al. (2009) suggested that greater levels of *AC* allow manufacturing firms to enhance both the quality and the commercial success of the new product introduced to the market, and the productivity of their processes. In addition, Daghfous (2004) found that *AC* enables firms to effectively acquire and utilize external as well as internal knowledge, which affects their innovation abilities. As a result, we suggest that higher levels of *AC* may lead organizations to obtain a superior innovation performance. Therefore, we hypothesize that:

H4a. Absorptive capacity will be positively related to innovation performance.

Furthermore, several studies suggest that promoting *AC* may also allow organizations to enhance their performance (Rhee, 2008; Tsai, 2001). According to Cohen and Levinthal (1990), absorptive capacity involves not only the ability to assimilate new external knowledge, but also the ability to apply such knowledge to commercial ends and, thus, create the opportunity for profits. Tsai (2001) suggested that units with higher *AC* have a better chance of successfully applying new knowledge to commercial ends, thereby increasing their business performance. Rhee (2008) found that the level of employees' *AC* was positively related to the performance of new ventures by enhancing the ability of these firms to deal with the risks inherent in internalization. Liu, Ke, Wei, and Hua (2013), based on the dynamic capability perspective, found *AC* to be an important source of superior firm performance.

We therefore posit that possessing a higher level of *AC* may allow firms to enhance their performance through improving their ability to acquire, transform and apply the knowledge present in external sources. Based on the above discussion, we hypothesize that:

H4b. Absorptive capacity will be positively related to firms' performance.

3. Methodology and measurement

3.1. Sample and data collection

We tested our hypotheses by focusing on a single industry: the Spanish biotechnology industry. By focusing on a single industry we avoid the common problem of inter-sector innovation studies, which are confounded by the differences in technological and economic diversity across sectors (Coombs, Narandren, & Richards, 1996). Moreover, the analysis of a single industry is useful in the assessment of performance, as new products will be more homogeneous with regard to their technology and their economic effects (Santarelli & Piergiovanni, 1996). Biotechnology firms also tend to be involved in various kinds of partnerships to make up for their lack of internal capabilities and resources (Arora & Gambardella, 1994; López-Sáez, Navas-López, Martín-de-Castro, & Cruz-González, 2010; Powell, Koput, & Smith-Doerr, 1996) and are characterized by a high degree of innovation and profitability (DeCarolis & Deeds, 1999). This industry therefore lends itself to our analysis.

Biotechnology is a young, science-based industry. The life cycle of most biotechnology products is at its inception (Alegre, Chiva, & Lapiedra, 2009). Biotechnology firms are characterized by high investment in R&D and are organized along similar lines to a university laboratory, which facilitates the creation of common technological communities between universities and biotechnology firms (Martin-de-Castro, López-Sáez, & Navas-López, 2008; Powell et al., 1996).

In 2011, R&D spending in the Spanish biotechnology industry stood at 537.88 million euros, that is 0.81 million euros on average per firm. Most of the investment (86.5%) comes from within Spain and is distributed as follows: 67.7% own resources, 22.1% public institutions, 8.8% other organizations, and 1.3% private non-profit institutions and universities (ASEBIO, 2012). Another important indicator of an intensive technology industry is the number of patents published (Powell et al., 1996). In 2011 430 patents were published, and 51% of the firms confirmed that they had carried out technology innovation during the previous two years (ASEBIO, 2012). The structure of firms in the biotechnology industry in Spain is characterized by a predominance of companies with fewer than 250 employees (only 3.18% of the firms have more than 250 employees).

Fieldwork was carried out from November 2011 to April 2012. To avoid concerns of common method bias the answers for the independent and dependent variables were collected from two different respondents. Following previous studies, we identified the head of R&D or similar as the first informant for the organizational learning processes (absorptive capacity). The second informant, assumed to have expert knowledge about the firm's openness in external knowledge search (*breadth* and *depth* measure) and its innovation and performance, was the CEO. The questionnaire items in this study were measured on an eight-point Likert scale, from strongly disagree to strongly agree.

In order to ensure that the questionnaire items were fully understandable in the context of the industry analyzed, a pre-test was carried out in four firms. These interviews reflected the insights from the literature and the informants were highly knowledgeable about the questions asked in this study. Therefore, the framework and questions that were derived from the literature analysis were used to conduct surveys in the firms.

To obtain a representative sample we contacted by mail all the firms (CNAE-2009 72.11. CNAE codes correspond to the Spanish Economic Activities Classification) included in the database of ASEBIO, the association of biotechnology firms in Spain, to ask them to participate in the study. A total of 110 firms out of the 617 identified agreed to participate; personal interviews were then arranged with each of them. We obtained a total of 104 completed questionnaires. However, since two of the firms in the sample were large firms we decided not to include them in the study to maintain a more homogeneous sample. According to previous studies, large firms tend to invest more in R&D activities, which can produce varied outcomes, ranging from new generation of products to novel innovations (Powell et al., 1996; Tsai, 2001). A total of 102 biotechnology firms, representing 17% of the target population (ASEBIO, 2012), were therefore analyzed. The firms included in the sample have on average 37 employees and invest a mean of 0.94 million euros in R&D. The firms' activity centers on the research, design, production and distribution of health products (such as the development of therapies and drugs for human diseases and diagnosis services), agriculture, food, clean energy and new materials. The revenue from sales generated by these firms in 2010 was an average of 21.01 million euros. We checked for non-response bias by comparing the industries represented in the sample with the population sample in terms of size and revenues from sales and found no significant differences between the two groups ($t = 0.49$, $p = 0.62$ for size and $t = 0.28$, $p = 0.78$ for revenues from sales). However, although the population and the sample largely corresponded on the above variables, we cannot rule out the existence of differences with respect to some of the questionnaire-based variables included in the study (Foss et al., 2011) (Table 1).

3.2. Definitions and measurements of the constructs

- *Absorptive capacity* (*AC*): Besides considering *AC* as complementary process to external *breadth* and *depth* in shaping performance,

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Table 1
Mean, standard deviations and correlations among study variables.

Variables		Mean	s.d	Min	Max.	1	2	3	4	5	6	7
1.	Breath	6.62	1.84	0.00	8.00	1.00						
2.	Depth	5.18	2.20	0.00	8.00	0.66**	1.00					
3.	Firm size	2.62	1.33	0.00	5.70	0.06	0.13	1.00				
4.	Env. dynamism	4.67	1.67	1.00	8.00	0.13	0.23*	0.12	1.00			
5.	Performance	5.38	1.60	1.00	8.00	0.06	0.23*	0.11	0.28**	1.00		
6.	Innovation	5.75	1.63	1.00	8.00	0.38**	0.39**	0.10	0.25*	0.48**	1.00	
7.	Absorptive capacity	6.44	0.80	3.78	8.00	0.18	0.33**	0.05	0.36**	0.28**	0.45**	1.00

Note: To calculate the correlation coefficients, we worked with the means of the items that make up each dimension.
* $p \leq 0.05$.
** $p \leq 0.01$.

Laursen and Salter (2006) defined *AC* as a one-dimensional concept and used R&D intensity as a proxy to measure it. However, assuming R&D as the key factor of a firm's *AC* has been questioned, given that the empirical evidence is inconsistent and it also ignores the dynamic nature of this concept (Cohen & Levinthal, 1990; Lane et al., 2006; Sun & Anderson, 2010). In this study we define absorptive capacity as firms' ability to acquire, assimilate and apply externally held knowledge through three sequential learning processes, namely, exploratory, transformative and exploitative learning (Lane et al., 2006). Therefore, drawing upon the process-based definition, we consider *AC* as a third-order construct that is constituted by different and complementary learning processes (Lane et al., 2006). Exploratory learning comprises two activities: recognizing and assimilating external knowledge. The resulting three-item scale for *recognize* ($\alpha = 0.78$) evaluates firms' ability to scan and search industry information from external sources (Arbussà & Coenders, 2007; Jansen, Van den Bosch, & Volberda, 2005; Szulanski, 1996). A three-item scale ($\alpha = 0.83$) measures assimilation and captures firms' activities aimed at absorbing knowledge from external sources (Arbussà & Coenders, 2007; Jansen et al., 2005; Szulanski, 1996). Transformative learning consists of two processes: maintaining and reactivating. *Maintain* ($\alpha = 0.76$) is measured with three items that assess firms' proficiency to retain, store and share knowledge internally (Marsh & Stock, 2006; Smith, Collins, & Clark, 2005). The *reactivate* scale ($\alpha = 0.80$) consists of three items that evaluate the extent to which firms can quickly react to opportunities present in the environment by internalizing existing knowledge through experience (Garud & Nayyar, 1994; Jansen et al., 2005; Marsh & Stock, 2006). Exploitative learning includes the processes of *transmuting* and *applying*. *Transmute* ($\alpha = 0.85$) is measured with three items and evaluates firms' ability to combine new and existing knowledge (Jansen et al., 2005; Smith et al., 2005). Finally, *apply* ($\alpha = 0.75$) consists of three items and refers to firms' proficiency in implementing technologies and adaptation in their new products (Jansen et al., 2005; Smith et al., 2005).

- *Breadth of openness*: *breadth* refers to the different types of partners with which innovating firms associate to sustain and increase performance (Chen et al., 2011). Following previous studies we included eight types of potential external partners: other organizations within the business group; competitor and other enterprises from the same industry; suppliers of equipment, materials, components or software; clients or customers; consultants; laboratories or R&D companies; universities or other higher education institutes and government or private non-profit research institutes (see Appendix B). This scale was operationalized as the number of types of external partners with whom the firm has a relationship. Each firm obtains a score of 0 when no partners are used and a score of 8 when the firm is collaborating with all potential collaboration partners.
- *Depth of openness*: *depth* is defined as the extent to which firms draw intensively from different search channels or sources of innovative ideas (Chen et al., 2011). Here we considered the same external knowledge sources as for *breadth* (see Appendix B). The answers were also based on an eight-point Likert scale, where 1 represented low importance and 8 high importance. The average of the eight scores represented the *depth* of external knowledge search. The limitation of this measure is that it does not allow us to distinguish the cases in which a firm has a very deep relationship with one or two specific external agents from firms whose relationships are not so deep but are sustained with more external partners. Therefore, we consider that firms placing a value on an external partner from zero to four do not have a deep relationship with the external partner, whereas firms valuing external partners with a score from five to eight represent deep relationships with the specific partner. We assign a score of zero to the former and one to the latter. Therefore, each firm obtains an average of 0 when no deep relationship is developed, and a value of 8 when the firm has a deep collaboration with all potential partners.
- *Innovation and performance* (see Appendix): based on previous studies, we consider *innovation* and *firm performance* as two different outcomes of the firm (Tsai, 2001). *Innovation performance* can be defined as the successful implementation of new ideas (Amabile, Conti, Coon, Lazenby, & Herron, 1996). This understanding includes novelty and usability as two indispensable conditions. Thus, innovation requires new ways to solve problems and achievement of commercial success (Alegre et al., 2009). In this study we assess *innovation performance* at an overall or program level and not at the project-specific level. The former captures more accurately the firm's view of the introduction of new commercial ideas to the market, given that individual project success is less important than overall program success in the long run (Song, Dyer, & Thieme, 2006). Therefore, to measure *innovation performance* ($\alpha = 0.91$) we use three items in which respondents rate their new product development program on an eight-point scale in relation to competitors (Dyer & Song, 1997; Song et al., 2006).
  On the other hand, *firm performance* captures the efficiency and effectiveness of the action adopted by the organization (Neely, Gregory, & Platts, 1995). This is one of the reasons why researchers take performance into account when investigating how organizational phenomena such as structure, strategies and planning contribute to firms' success (Ford & Schellenberg, 1982). In this study, we define performance in terms of goal attainment and measure it ($\alpha = 0.89$) with four items in which managers rate how well their firms are doing, relative to competitors, in overall performance, market share, profitability and attaining growth (Jaworski & Kohli, 1993; Reinartz, Krafft, & Hoyer, 2004).
- *Control variables*: we included two control variables that may provide possible alternative explanations for the result. *Firms' size* may affect the flexibility and willingness of firms to invest in the development of *AC* and may determine performance differences between firms; we therefore included the natural logarithm of the number of full-time employees in the organization to account for firm size (Jansen et al., 2005; Tsai, 2001). The second variable, *environmental dynamism*, can affect performance by influencing the resources available to firms. Under conditions of external uncertainty, managers may try to imitate the behavior of other organizations in their environment by adopting

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best-practices, comparable market positions or similar technologies (Heyden, van Doorn, Reimer, Van Den Bosch, & Volberda, 2013). Therefore, they adjust their systems and processes to be more open and focus on external information to enhance their ability to respond to external changes and increase performance (Jansen, Van Den Bosch, & Volberda, 2006). To measure environmental dynamism, we used a three item measure, rated on an eight-point Likert scale (Jansen et al., 2006; Jaworski & Kohli, 1993). Three items were used to measure it, rated on an eight-point Likert scale (Jansen et al., 2005; Jaworski & Kohli, 1993). The items are: "The technology in our markets is changing rapidly", "In our market customer preferences change relatively fast", and "New customers tend to have product-related needs that are different from those of existing customers".

4. Analysis and results

4.1. Assessing measurement variables

Reflective measurement models were used in our study. Except for absorptive capacity, which was measured as a third-order factor, all the variables were measured as first-order factors.

Four criteria are used to assess a reflective measurement model in PLS: factor loading, composite reliability, average variance extracted (AVE) and discriminant validity (Chin, 1998; Henseler, Ringle, & Sinkovics, 2009).

4.1.1. Factor loading

Table 2 shows the factor loadings of all constructs involved in the study. Carmines and Zeller (1979) recommend factor loadings equal to or above 0.707, which means that the shared variance between the construct and its indicators is greater than the variance of the error. Table 2 shows that the loadings for all items were above this minimum.

4.1.2. Composite reliability

This measure considers that indicators present different loadings and their value should be higher than 0.6. The value of this index for each of the constructs analyzed in the study is shown in Table 2. They all exceed the minimum required level.

4.1.3. Convergent validity

This criterion ensures that a set of indicators represents one and the same underlying construct (Fornell & Larcker, 1981). An AVE value of at least 0.5 means that a construct is able to explain more than half of the variance of its indicators on average. Table 2 shows that the AVE of all constructs was higher than 0.5.

4.1.4. Discriminant validity

This index indicates the extent to which a construct is different from other constructs. For discriminant validity to exist, the AVE must be higher than the squared correlation between the constructs. According to the values in Table 3, the above condition is met in all cases.

4.2. Assessing the structural model

We used SmartPLS software (Ringle, Wende, & Will, 2005) to test the proposed theoretical model following Preacher and Hayes' (2004) recommendations to analyze the mediation effect. The essential criteria to evaluate the structural model are the coefficient of determination (R^2) of the endogenous latent variables and the strength of the relationships between the constructs (Chin, 1998). Bootstrapping was used to generate standard errors and t-statistics. Following Chin's (2001) recommendations, the bootstrap estimates presented here are based on 500 bootstrap samples. The values and the significance levels of the path coefficients, together with the R^2 coefficients for each of the endogenous constructs are shown in Fig. 1 for the direct effect model (model 1) and in Fig. 2 for the mediated model (model 2).

The R^2 value of the dependent latent variable was used to determine the amount of variance explained by the model. According to Falk and Miller (1992), this index must be higher than 0.1, which ensures that at least 10% of the construct variability derives from the model. Lower R^2 values, in spite of being significant, provide very little information, so the hypothesis concerning this latent variable cannot be sustained.

Table 2
Measurement model results.

Factors	Factor loading	s.d	t-Value	α	CR	AVE
Absorptive capacity				0.818	0.889	0.731
Exploration	0.698***	0.105	6.673	0.569	0.670	0.508
Recognize	0.629**	0.226	2.787	0.778	0.865	0.682
REC01	0.900***	0.132	6.808			
REC02	0.735***	0.177	4.162			
REC03	0.833***	0.161	5.166			
Assimilate	0.972***	0.192	5.072	0.833	0.898	0.746
ASS01	0.842***	0.048	17.404			
ASS02	0.849***	0.047	18.192			
ASS03	0.900***	0.034	26.244			
Transformation	0.907***	0.012	34.386	0.488	0.683	0.519
Maintain	0.655***	0.139	4.718	0.756	0.849	0.652
MAI01	0.778***	0.177	4.396			
MAI02	0.775***	0.190	4.078			
MAI03	0.867***	0.142	6.094			
Reactivate	0.947***	0.035	28.010	0.802	0.882	0.716
REA01	0.717***	0.084	8.513			
REA02	0.881***	0.036	24.830			
REA03	0.927***	0.018	50.841			
Exploitation	0.941***	0.026	77.054	0.748	0.876	0.781
Transmute	0.906***	0.035	25.957	0.850	0.907	0.765
TRA01	0.906***	0.020	45.191			
TRA02	0.900***	0.033	27.402			
TRA03	0.815***	0.061	13.392			
Apply	0.877***	0.037	23.502	0.751	0.858	0.667
APP01	0.816***	0.071	11.528			
APP02	0.842***	0.045	18.553			
APP03	0.792***	0.086	9.248			
Innovation				0.908	0.942	0.845
INN01	0.911***	0.028	32.263			
INN02	0.950***	0.014	70.452			
INN03	0.896***	0.025	36.132			
Performance				0.888	0.923	0.752
PERF01	0.748***	0.063	11.894			
PERF02	0.889***	0.030	29.625			
PERF03	0.921***	0.021	42.994			
PERF04	0.902***	0.022	40.537			
Breadth	1.000	0.000	0.000		1.000	1.000
Depth	1.000	0.000	0.000		1.000	1.000
Size	1.000	0.000	0.000		1.000	1.000
Env. dynamism				0.791	0.898	0.816
ENV01	0.847***	0.080	10.567			
ENV02	0.957***	0.035	27.545			

Note: t-Values for n = 500 subsamples; CR, composite reliability; SE, standard error; AVE, average variance extracted.
** $p \leq 0.01$.
*** $p \leq 0.001$.

Table 3
Discriminant validity analysis.

Variables		1	2	3	4	5
1.	Breath	(1.00)				
2.	Depth	0.44	(1.00)			
3.	Performance	0.00	0.05	(0.75)		
4.	Innovation	0.14	0.15	0.23	(0.85)	
5.	Absorptive capacity	0.03	0.11	0.08	0.20	(0.73)

Note: Diagonal elements (in parenthesis) are the square root of the AVE; off-diagonal elements are the correlations among constructs in the inner model.

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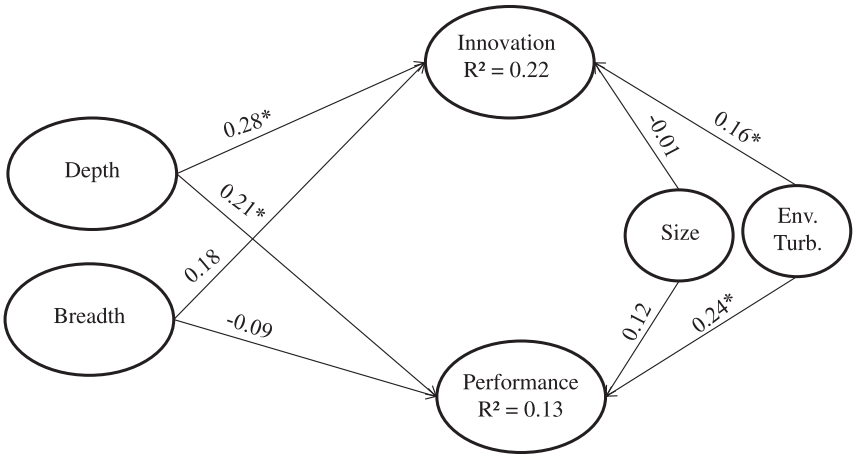

Fig. 1. Direct effect of openness of external knowledge search on innovation and performance. Note: †p ≤ 0.1, *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001.

In Fig. 2, the R^2 index of the innovation variable in the mediated model indicates that the theoretical model explains 34% of the variance of the construct, which can be considered as moderate. This index is also higher than that obtained in the direct effect model (see Fig. 1). When the exogenous latent variable is explained by a few exogenous latent variables, "moderate" R^2 is considered as acceptable (Chin, 1998; Henseler et al., 2009: 303); we can therefore conclude that our model has adequate predictive power for innovation. In addition, the R^2 value of the firm performance construct suggests that the mediated model explains 16% of this variable, which is also higher than the index obtained in the direct effect model (see Fig. 1). While this value may be considered low, it is higher than the required minimum of 0.1 (Falk & Miller, 1992: 80).

Another assessment of the structural model involves the model's capability to predict. The predominant measure of predictive relevance is the Stone–Geisser Q2 statistic (Geisser, 1975; Stone, 1974), which can be measured using blindfolding procedures. If this value for a certain endogenous latent variable is greater than zero, its explanatory variables provide predictive relevance (Henseler et al., 2009). As the values for the Stone–Geisser Q2 statistic presented in Table 4 are higher than zero we can conclude that our model has predictive relevance.

As can be seen in Table 5, model 2, the effects of *depth* and *breadth* of external knowledge search on innovation are both positive but not significant; H1a and H1b are therefore not supported. Similarly *depth* and *breadth* do not appear to enhance firms' performance and thus H2a and H2b are not supported.

Concerning the effect on *AC*, as expected, the connection of *depth* to *AC* is positive and significant, thus H3a is supported. However, the link between *breadth* and *AC* is negative and not significant; therefore H3b is not supported.

Finally, innovation and performance seems to be driven by *AC* as we found that *AC* presented a positive and significant effect on both outcomes; H4a and H4b are therefore supported.

4.3. Post-hoc analyses of the mediating effects of absorptive capacity

As we can see in the direct model in Fig. 1 the total effect of *depth* on innovation and firm performance is significant and different from zero, which indicates a direct relation (Preacher & Hayes, 2004, 2008). In the case of *breadth*, the results did not show the existence of an effect on innovation and firm performance. In the mediated model, the coefficients of the total effect of *depth* on innovation and firm performance

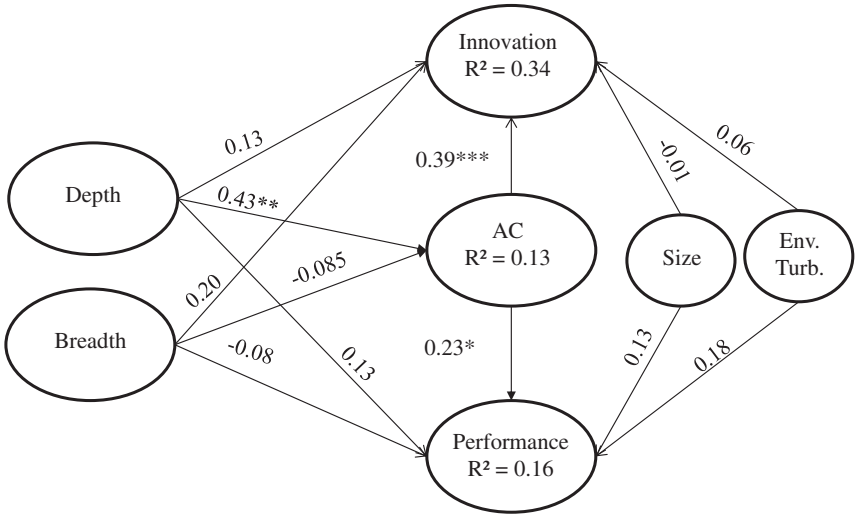

Fig. 2. Complete causal model. Note: †p ≤ 0.1, *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001.

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Table 4
Inner model assessment indicators.

Factor	R^2	Q^2
Innovation	0.34	0.29
Performance	0.16	0.12
Absorptive capacity	0.13	0.07

decrease after controlling for the level of *AC*. It is important to note that the relation between *depth* and innovation and firms' performance becomes not significant after controlling for *AC*, which suggests a full mediation of *AC*. The bootstrap outputs in Table 5 show that the indirect effect of *depth* through *AC* on innovation and firm performance is statistically significant and different from zero. Therefore, considering the two conditions established by Preacher and Hayes (2004: 719), *AC* fully mediates the effect of *depth* on innovation and performance. On the other hand, since the total effect of *breadth* on firm performance and innovation in model 1 was not statically different from zero, following Preacher and Hayes (2004), we cannot assume a mediating effect in that relation. Furthermore, the confidence intervals for each indirect effect of *breadth* on innovation and performance through *AC* include the 0, which confirms the no mediation effect (Preacher & Hayes, 2008: 886).

To further analyze the mediation effect in model 2, we assess the strength of the effect of *AC* using Cohen's (1988) f^2index. This effect size is calculated as the increase in R^2 relative to the proportion of variance of the endogenous latent variable that remains unexplained. Cohen (1988) indicated that f^2 values of 0.02, 0.15, and 0.35 represent small, medium and large effects, respectively. From the values reported in Table 6 we can conclude that *AC* has a medium predictive relevance on the variance of the innovation variable ($f^2 = 0.18$) and that the predictive power is smaller in the case of the firm performance variable ($f^2 = 0.04$). However, in both cases the strength of the effect of *AC* is higher than the effect of *depth* and *breadth* on innovation and performance.

5. Conclusion and implications

A prevalent theme in the strategic management and innovation literatures is that firms increasingly need to rely on external knowledge sources to gain and sustain competitive advantage (Foss et al., 2011). To deepen understanding about how firms draw knowledge from external sources, scholars have examined the role of external knowledge search strategies in shaping performance (e.g., Chen et al., 2011; Laursen & Salter, 2006). However these studies are silent about what internal processes allow firms to successfully assimilate, transform and apply the new knowledge in their processes and products. Rather, they assume a direct causal relationship between external knowledge search strategies and performance, and exclude other organizational processes that can positively influence the sourcing of knowledge from external agents and its subsequent exploitation for improving innovation and firms' performance.

Table 6
Effect size.

Effect	R^2 included	R^2 no included	f^2
Depth → Inn	0.34	0.33	0.02
Depth → Perf	0.16	0.15	0.01
Breadth → Inn	0.34	0.31	0.05
Breadth → Perf	0.16	0.15	0.01
AC → Inn	0.34	0.22	0.18
AC → Perf	0.16	0.13	0.04

Note: f^2 values of 0.02, 0.15 and 0.35 represent small, medium and large effects.

The present study enhances our understanding of the role of *absorptive capacity* (*AC*) in the context of firms' openness in external knowledge search. Research on AC highlights that this capacity matters for enhancing firms' product development programs (e.g., Fabrizio, 2009; Murovec & Prodan, 2009) and profitability (e.g., Liu et al., 2013; Rhee, 2008; Tsai, 2001). The theoretical model introduced in our study and our findings shows that this capacity is also important for allowing firms to assimilate valuable knowledge present in external sources and to successfully apply it to generate innovation and increase performance. Although Laursen and Salter (2006) considered *AC* as a complementary factor to external knowledge search *breadth* and *depth* in shaping innovation performance, they did not capture the multidimensional nature of *AC* and instead used R&D as a proxy to measure it. However, R&D intensity neglects essential parts of *AC* because it ignores the organizational processes that allow firms to successfully assimilate, transform and apply external knowledge (Lane et al., 2006; Todorova & Durisin, 2007). Simple acquisition of external knowledge does not imply successful application; rather, firms need to develop the processes necessary to explore, transform and exploit external knowledge (Lane et al., 2006). Therefore our study extends Laursen and Salter's (2006) approach by theoretically introducing the process-based view of *AC* and by empirically demonstrating that the *depth* of openness may improve innovation and firms' profitability when learning processes of *AC* are in place. As the three learning processes

Table 5
Analysis of the mediating effect.

	Model 1		Model 2							
	Total effect (c)	t-Value	Total effect (c)	t-Value	Direct effect (c′)	t-Value	Indirect effect (a. b)	t-Value	Percentile	
									Lower	Upper
Depth → Inn	0.28*	2.01	0.30**	2.40	0.13	1.13	0.17***	3.86	0.06	0.30
Depth → Perf	0.21*	1.87	0.23*	2.01	0.13	1.11	0.10**	2.94	0.01	0.25
Breadth → Inn	0.18	1.23	0.17	1.15	0.20	1.60	−0.03	−1.72	−0.13	0.06
Breadth -→ Perf	−0.09	0.70	−0.10	0.80	−0.08	0.66	−0.02	−1.96	−0.10	0.03
Env → Inn	0.16*	1.93	0.06	0.75	0.06	0.75	–	–	–	–
Env → Perf	0.24*	2.02	0.18	1.55	0.18	1.55	–	–	–	–
Size → Inn	−0.01	0.07	0.01	0.10	0.01	0.10	–	–	–	–
Size → Perf	0.12	1.38	0.13	1.47	0.13	1.47	–	–	–	–
AC → Inn	–	–	0.39***	4.53	0.39***	4.53	–	–	–	–
AC → Perf	–	–	0.23*	1.97	0.226*	1.97	–	–	–	–
Breadth → AC	–	–	−0.09	0.71	−0.09	0.71	–	–	–	–
Depth → AC	–	–	0.43***	3.62	0.43***	3.62	–	–	–	–

Note: t-Values for n = 500 subsamples.
* $p \leq 0.05$.
** $p \leq 0.01$.
*** $p \leq 0.001$.

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are complementary, the latter represents an indicator that a firm seeks to enhance its overall *AC* by simultaneously developing the three learning processes (Song et al., 2006).

The present study can also be seen as a contribution to the analyses of external absorptive capacity routines introduced by Lewin et al. (2011). According to these authors, *AC* routines can be aimed at identifying and recognizing value of externally generated knowledge, learning from and with external sources or transferring knowledge back to the organization (Lewin et al., 2011:90). The *depth* of openness allows firms to sustain a pattern of interaction with external agents over time, building up a shared understanding and common ways of working together (Laursen & Salter, 2006). This practice increases trust between firms to share even sensitive information and has been positively related to the outward-looking aspect of a firm (Chen et al., 2011; Foss et al., 2011). When a firm has in place a set of outward-looking organizational practices that allow it to detect and to interact with holders of pertinent knowledge, then the value of internal organizational practices will be enhanced because they can also be used to diffuse the external knowledge within the organization (Foss et al., 2011). Therefore, the positive relation we found between the *depth* of openness and *AC* suggests that firms' openness in external knowledge search may represent one of the external meta-routines that allow firms to increase their overall absorptive capacity.

On the other hand the effect of *breadth* on innovation and performance provides somewhat surprising results. Firstly, although previous studies have argued that broad collaboration may improve firms' innovation (see e.g., Chen et al., 2011; Laursen & Salter, 2006) and performance (see e.g., Asakawa et al., 2010; Lööf & Heshmati, 2006), our results did not support this argument (see e.g., Chen et al., 2011; Laursen & Salter, 2006). Furthermore, *AC* was not the mediator variable in these relations that we predicted. One reason for these results could be that broad relations might not be relevant for improving innovation performance in STI industries due to the characteristics of the knowledge they seek. STI industries base their innovation on codified scientific and technological knowledge (Chen et al., 2011). In order to successfully acquire and apply complex, scientific, external knowledge, firms need to sustain deep relations with external partners (Powell et al., 1996). Collaborating with a wide number of external agents may help firms in accessing external knowledge. However, to apply the new knowledge in their own context, stable patterns of collaboration need to develop between the two parties (Zollo, Reuer & Singh, 2002). The *breadth* of openness has been related to exploratory learning as it gives organizations flexibility to adapt to unpredictable changes and to expand the company's knowledge pool, whereas the *depth* of openness is more related to exploitative learning as it facilitates the transfer of in-*depth* and fine-grained knowledge that allows firms to induce well-defined solutions by matching new knowledge with market opportunities (Chiang & Hung, 2010). According to the data from a survey performed by ASEBIO, one of the main strategic priorities for biotechnology firms for 2012 was the introduction of products to the market, followed by the acquisition of new knowledge and technologies. The main reason why innovating firms cooperate is the lack of resources and capabilities to cope with emerging technologies (Chen et al., 2011). The fact that profits are primarily generated in exploitation processes (Zahra & George, 2002) and the danger of knowledge leakage tends to be greater when STI industries sustain a wide number of external collaboration (Chen et al., 2011) may explain why the *breadth* of openness was not relevant to improving firm innovation in the present study.

Furthermore, the non-relevance of *breadth* of openness to performance may be related to the economic conditions of the firms. Firms often go through a period of trial and error to learn how to gain knowledge from an external source. This process requires extensive effort and time to build up an understanding of the norms, habits and routines of different external knowledge channels (Laursen & Salter, 2006: 367). According to industry reports, most of the firms highlight two main barriers to their economic development, namely, the difficulties in obtaining credit, and the high cost of innovations. Large firms tend to have more resources with which to enhance performance than small firms (Tsai, 2001). Therefore, they may be able to expend more time and resources in learning how to obtain knowledge from external sources. As most of the firms in the industry are SMEs, the above reasons may explain why breath of openness was not relevant to improving the *AC* and obtaining a higher performance in these organizations.

5.1. Practical implications

From a practical perspective our study suggests that to pursue successful product development programs and obtain higher profitability, firms should be able to search for new ideas that have commercial potential. One way to meet this condition is by sustaining deep relations with external sources such as lead users, customers, suppliers or universities. However, managers should bear in mind that the mere fact of intensively drawing new ideas from external sources will not always guarantee improvements in firm performance. Despite the evidence that sustaining deep relations is a necessary condition to facilitate the identification and transfer of in-depth and detailed technologies and knowledge from external actors, we call for caution against the defense of this search strategy as the only necessary solution and argue that it is linked to the development of absorptive capacity.

The *depth* of openness facilitates access to both technological and market knowledge sources that may allow firms to renew their stock of knowledge. This stock of knowledge is a necessary condition to learn from external partners (Cohen & Levinthal, 1990). Thus, managers should use this strategy to generate the knowledge base necessary to facilitate the exploration, transformation and exploitation of the new commercial ideas identified in the environment. The above learning processes are complementary and emphasize the opportunities of gaining and sustaining a competitive advantage by developing *AC*. For a competitor, it would be a challenge to imitate the strategy used to gather information from the environment and three complementary learning processes. Managers therefore have opportunities to gain and sustain competitive advantage by developing strategies focused on the synergies between the external knowledge search and the generation of absorptive capacity.

5.2. Limitations

This study has some inherent limitations that may also suggest future research lines. First, the data were gathered at one point in time. A longitudinal study may provide further insight into the dynamics of the learning processes that take place inside the firm and how they allow organizations to generate competitive advantage from knowledge coming from external sources. Second, the target population was narrowly defined to include a fairly homogeneous set of firms, which may limit the generalization of research results. While the theory introduced here may hold in other empirical contexts, future studies could evaluate the generalizability of our findings by performing this study in other industries and other geographical contexts. In addition, although in the present study we collected the data from two different respondents, the responses for knowledge search strategies and firm performance were collected from the same person, which may suggest the possibility of common method bias. Although we performed Harman's single-factor test to assess the extent of common method variance and it showed a poor fit for this possibility, the potential of this bias in our results cannot entirely be excluded.

Furthermore, the model introduced in the study does not allow for the analysis of the importance of *AC* for the *breadth* and *depth* of external search within each individual channel and how it may contribute to improving firms' innovation and performance. Future research could assess this aspect by developing several fine-grained items for each of the knowledge sources. For example, including the average duration

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of the relationship could be a very interesting way to enrich the measure of *depth*.

Because we integrated *AC* in a third-order construct, the individual effect of each *AC* dimension is not addressed in our study, nor how each of the dimensions matters for the strategy (searching broadly and deeply) and the orientation of external knowledge search (collaborating with technological or market partners). According to Lane et al. (2006), it is necessary to explicitly separate *AC* into its original dimensions because each of them requires different, but complementary, processes within the organization. In addition, different types of partners have different technological skills and capabilities, so firms may tend to choose collaborations with specific partners depending on the kind of help and knowledge they need, and develop search strategies to facilitate incorporation of that knowledge into their processes (Chen et al., 2011). Future studies could assess how the orientation and the strategy that firms adopt contribute to the different learning processes underpinning *AC*, and how their complementarity allows the generation of competitive advantages. Finally, future research might assess how the turbulence of the environment can moderate the effect of external knowledge search strategies on the learning processes that generate a firm's *AC*. Previous studies have focused mainly on analyzing how turbulence affects the outputs of *AC*, such as innovation and business performance (Jansen et al., 2005). However, turbulence may also act as an external activation trigger that leads a firm to search widely or deeply in the environment (Zahra & George, 2002). Future studies could assess how other internal antecedents of the exploratory, transformative and exploitative leaning processes such as firm structure and human resource practices interact with the mechanism here identified in the development of a firm's *AC*. These studies may also incorporate multiple levels of analysis and examine other individual-level as well as organization-level variables (van den Bosch, Volberda, & de Boer, 1999).

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Appendix A. Absorptive capacity measurement scale

Please indicate your level of agreement with the following statements about your organization

Dimension	Item	Literature source
Recognize	X1: We frequently scan the environment for new technologies. X2: We thoroughly observe technological trends. X3: We observe in detail external sources of new technologies.	Arbussà and Coenders (2007), Jansen et al. (2005), Szulanski (1996)
Assimilate	X4: We periodically organize special meetings with external partners to acquire new technologies. X5: Employees regularly approach external institutions to acquire technological knowledge. X6: We often transfer technological knowledge to our firm in response to technology acquisition opportunities.	
Maintain	X7: We thoroughly maintain relevant knowledge over time. X8: Employees store technological knowledge for future reference. X9: We communicate relevant knowledge across the units of our firm.	Jansen et al. (2005), Marsh and Stock (2006), Smith et al. (2005)
Reactivate	X10: When recognizing a business opportunity, we can quickly rely on our existing technological knowledge. X11: We quickly analyze and interpret changing market demands for our technologies. X12: New opportunities to serve our customers with existing technologies are quickly understood.	Garud and Nayyar (1994), Jansen et al. (2005), Marsh and Stock (2006)
Transmute	X13: We are proficient in transforming technological knowledge into new products. X14: We regularly match new technologies with ideas for new products. X15: We quickly recognize the usefulness of new technological knowledge for existing knowledge.	Jansen et al. (2005), Smith et al. (2005), Todorova and Durisin (2007)
Apply	X16: We regularly apply technologies in new products. X17: We constantly consider how to better exploit technologies. X18: It is well known who can best exploit new technologies inside our firm.	Jansen et al. (2005), Smith et al. (2005), Szulanski (1996)

Appendix B. Sources of information for innovation measurement scale

Please indicate which of the following sources of information your organization has used to innovate. Please assess the level of importance of the sources used.

Item	Literature source
Other organizations within the business group Competitors and other enterprises from the same industry Suppliers of equipment, materials, components or software Clients or customers Consultants Laboratories or R&D companies Universities or other higher education institutes Government or private non-profit research institutes	Chen et al. (2011), Murovec and Prodan (2009)

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Appendix C. Innovation performance measurement scale

Please indicate your level of agreement with the following statements about your organization?	
Item	Literature source
The overall performance of our new product development program has met our objectives. From an overall profitability standpoint, our new product development program has been successful. Compared with our major competitors, our overall new product development program is far more successful.	Dyer and Song (1997), Song et al. (2006)

Appendix D. Firm performance measurement scale

Please state your firm performance compared to that of your competitors with regard to the following items	
Item	Literature source
Customer loyalty Sales growth Profitability Return on investment	Jaworski and Kohli (1993), Reinartz et al. (2004)

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