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Open innovation and firm performance: the role of organizational mechanisms

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Abstract

Purpose – The purpose of this paper is to examine the relationship between the use of open innovation (OI) practices and firm performance, and the role of organizational mechanisms (OMs) (formalization and decentralization) as moderator variables.
Design/methodology/approach – The authors build a theoretical framework to define a set of hypotheses that are then verified in an empirical study. These theoretical propositions are tested by using the data gathered from a survey addressed to 244 firms in Spanish low- and medium-technology industries.
Findings – With regard to inbound practices, the practices oriented to cooperate with partners in a R&D context have a positive influence. The results show that outbound practices, either by direct generation of revenues from licensing payments or, more indirectly, through the indirect marketing and technical benefits that can stem from revealing have a positive effect on firm performance. Coupled practices, which are related to participation in clusters and innovation networks, have the highest impact on firm performance. In the industrial context examined, decentralization exerts a positive effect which enhances the effect of outbound practices meanwhile formalization reduces their positive effect.
Practical implications – This study helps practitioners in low- and medium-technology firms to determine which OI practices are most beneficial to firm performance and how formalization and decentralization can influence the relationship between OI and firm performance.
Originality/value – This study helps determine the influence of OI practices in terms of inbound, outbound and coupled types through an analysis of low- and medium-technology firms. The OI literature is enriched by the types herein of the role of OMs, which includes an analysis of how formalization and decentralization moderate the influence of OI practices on firm performance.

Keywords Decentralization, Firm performance, Open innovation, Formalization, Low- and medium-technology firms

Paper type Research paper

1. Introduction

Ever since the publication of *Open Innovation, the New Imperative for Creating and Profiting from Technology* by Chesbrough (2003), the concept of open innovation (OI) has attracted enormous interest, both in practice and in academia. By focusing on various aspects of the OI process, many scholars have offered useful insights and have proposed various frameworks to support managerial decision making (Huizingh, 2011). A number of literature reviews are available which structure the contributions to the field and identify the trends and topics that should be further analyzed (see, e.g. Schroll and Mild, 2012; West and Bogers, 2014; Greco *et al.*, 2015; Randhawa *et al.*, 2016). The present paper focuses on two issues that have been described as relevant topics in the OI field: the need to understand how to benefit from

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OI, particularly in terms of its implications for overall firm performance and the role of context variables (Huizingh, 2011; Lichtenthaler, 2011; Schroll and Mild, 2012).

A basic characteristic of OI is that it allows ideas and knowledge in the innovation process to flow purposively across organizational boundaries in line with the organization's business model. While firms may get advantages from opening up their innovation process, they differ in their ability to capture value from OI and it does not always result in positive effects (Chen *et al.*, 2011). Thus, the analysis of how OI impacts a firm's performance is critical to offer a better understanding to firms that attempt to profit from innovation by opening their innovation processes. However, due to complexity and heterogeneity of OI, it is not easy to investigate this relationship (Ahn *et al.*, 2015; Caputo *et al.*, 2016), which is illustrated by the diversity of approaches to reflect openness and the mixed results obtained in the empirical studies on the relationship. In this research, we focus on the types of knowledge flows that characterize OI processes (Gassmann and Enkel, 2004). Managing purposively flows of knowledge across firm boundaries may involve leveraging external knowledge sources through internal processes (inbound OI), leveraging internal knowledge through external commercialization processes (outbound OI) or coupling both processes (coupled OI). While previous studies on OI effectiveness have primarily focused on inbound OI, research on outbound effects and coupled effects has received minor attention (Chesbrough and Bogers, 2014). Therefore, investigating the separated effects of inbound, outbound and coupled OI types on firm performance and examining the specific influence of different external sources constitutes a way of enhancing our understanding about how firms can benefit from OI.

Some contributions within the OI field have called for a contingency approach, stressing the need to consider the context factors in the performance effects of OI (e.g. Dahlander and Gann, 2010; Gassmann, 2006: Huizingh, 2011). In this vein, previous research has examined the moderating influence of different external and internal factors (e.g. Cheng and Huizingh, 2014; Cruz-González *et al.*, 2015; Sisodiya *et al.*, 2013). Surprisingly, in spite of the growing interest on internal factors, there has been little research on the role of organizational structure (Randhawa *et al.*, 2016), even though its relevance has been stressed as a contingency factor influencing the relationship between OI practices and performance (e.g. Elmquist *et al.*, 2009). Opening up the innovation process involves interacting on a continuous basis with a variety of external agents (Wallin and von Krogh, 2010). A firm's organizational structure represents the pattern of relationships, authority and communication of an organization. Hence, organizational challenges may emerge because of the higher complexity stemming from the new relationships and the requirements to manage them. In this context, coordination mechanisms may play a crucial role in boosting or decreasing OI effectiveness, as they can be helpful in facilitating the increased complexity of OI relationships.

Bearing in mind the above questions, in this study we contribute to the literature about the impact of firm's openness on its performance in three ways. First, we extend the analysis of OI strategies and rely on the distinction between inbound, outbound and coupled OI types to examine how they affect firm performance. Previous research has predominantly focused on inbound OI processes. Therefore, we provide a more complete representation of how the firms benefit from opening their innovation process by extending the research to outbound and coupled OI practices and examining how these three types of OI affect firm performance. A second contribution of the paper is related to the identification of different types of partners when examining the influence of external knowledge inflows. Some partners may have a more prominent role than other in invigorating the innovative performance of firms (Chen *et al.*, 2011). Our results show that R&D collaborations exert a positive influence whilst collaboration to get ideas from suppliers and customers do not significantly affect firm performance. A third contribution of this paper is the focus on the study of organizational mechanisms (OMs) as contingent variables that can affect the effectiveness of the three types of OI on firm's performance. Specifically, we examine the

role of formalization and decentralization. Our findings indicate that both OMs moderate the effect of outbound OI practices on firm results. Finally, also remarkable is that our study focuses on analyzing OI on low- and medium-technology firms, which have been considered sectors that deserve further attention in the OI literature (Vanhaverbeke *et al.*, 2014).

The remainder of this paper is structured as follows: the next section draws on the relevant literature and sets out the hypotheses of the study. Following that, the methodology of the study is presented, the data are described and metrics for each of the variables analyzed are given. We then present the findings and discuss them and, finally, in the last section, we offer our main conclusions regarding the implications for managers and propose the directions for future research.

2. Theory and hypotheses development

OI was recently redefined by Chesbrough and Bogers (2014), who stressed the distributed nature of the innovation process and the purposively management of knowledge flows across firm's boundaries by linking it to the three main types of OI, namely outside-in (inbound), inside-out (outbound) and the combined coupled type, as well as the associated mechanisms, including pecuniary and non-pecuniary flows. This conceptualization reflects the broad set of possibilities to reflect openness and the variety of facets that can be considered to examine and measure it. Accordingly, the relationship between OI and firm performance has been empirically studied by examining the effect of a wide range of facets related to openness and firm performance with different approaches and metrics.

Some works have examined the overall impact of OI on firm performance and confirmed the positive effect of aspects such as a firm's OI involvement (Chaston and Scott, 2012), OI proclivity (Hung and Chiang, 2010), the announcement of OI activities (Noh, 2015), OI capacities (Ahn *et al.*, 2013) or OI implementation (Cheng and Huizingh, 2014). Most studies have focused on the effect of inbound external knowledge and some suggested a direct positive influence of external knowledge sourcing on firm performance (Vrontis *et al.*, 2016; Wang *et al.*, 2015). Alike, they found that both a broad and intensive OI adoption and cooperation can contribute to performance (Ahn *et al.*, 2015). Nevertheless, some works did not find evidence of direct positive effects of the analyzed inbound OI aspects. More specifically, Cruz-González *et al.* (2015) examined the effect of external search breadth and depth and showed that none of the open search strategies had a significant positive impact on overall firm performance. In the same vein, Faems *et al.* (2010) showed that, although the technology alliance portfolio diversity has an indirect positive impact on financial performance via increased product innovation performance, a direct stronger cost-increasing effect was also observed.

A few scholars have examined separately the effect of outbound and inbound OI-related variables. Thus, Hung and Chou (2013) focused on external technology acquisition and exploitation and found that knowledge acquisition positively affects firm performance, whereas external technology exploitation does not. Also, the pecuniary flows that OI transactions generate were examined and inbound was found to be a more relevant behavior than outbound in terms of its impact on the business of companies (Michelino *et al.*, 2015). Similarly, Caputo *et al.* (2016) investigated separately inbound and outbound OI adoption by following a pecuniary perspective and found that sales growth exhibits a positive trend with openness, although operating profit and asset turnover decrease with OI adoption, which leads them to suggest that a higher resort to external sources hinders the efficiency of firms because of time spent in managing external relationships.

The differentiated effect of coupled OI in addition to inbound and outbound OI has been examined at a lesser extent. Although Cheng and Huizingh (2014) relied on an entire range of outside-in activities, inside-out activities and coupled activities, they measured them aggregately. Mazzola *et al.* (2016) examined the concurrent effect of inbound, outbound and coupled OI on both

economic-financial and innovation performance in the biopharmaceutical industry and found that their effect depended not so much on aggregate levels but on the specific type of practice.

Despite the value of all these works in drawing a general picture of the effects of OI on firm performance, the diversity of approaches to reflect openness and the mixed results obtained make it difficult to draw general remarks on the relationship. Additionally, the fact that previous research has mainly investigated the inbound side of OI, with a less focus on the outbound and coupled processes of OI suggests that an approach focusing on a broad variety of practices that are implemented by firms when adopting the three types of OI can contribute to provide a deeper understanding on the relationship between OI and firm performance. Hence, in the following sections we develop a set of hypotheses on the effect of the three types of OI on firm's performance by focusing on the practices firms may adopt when opening their innovation process. Next, since internal context variables can be determinant in OI success, we examine the role of OMs in facilitating their influence.

2.1 The influence of inbound practices on firm performance

The outside-in type of OI involves companies sourcing or acquiring external knowledge to complement their internal base in order to innovate (Dahlander and Gann, 2010). Since firms cannot possess all types of knowledge to create the innovations they want, searching across a variety of sources can provide ideas and resources that help them gain and exploit innovative opportunities (Laursen and Salter, 2006).

External knowledge sources may include suppliers, customers, competitors, consultants, research institutes and universities or governments. Thus, firms can source knowledge from customers and suppliers to increase their understanding of the market and to get insights from materials, equipment and techniques (Cheng and Huizingh, 2014; Theyel, 2013). In addition, they may resort to universities and other research institutes for new directions to explore as these institutions may facilitate access to new and complex knowledge (Perkmann and Walsh, 2007). Firms can also acquire inventions and inputs to the innovation process through license-in and less formal relationships (Dahlander and Gann, 2010). Although it may imply an effort to identify the most appropriate technology and negotiate the terms and conditions with counterparts, in-licensing can be an excellent strategy (vs beginning an internal project) to invent around the technology, as it constitutes a means of accelerating new product development and commercialization if a technology has already been developed externally to a certain stage (Tao and Magnotta, 2006).

As far as a broader knowledge base can provide firms with more choices for upgrading their problem-solving capacity, the new external knowledge will allow for more effective improvements of product features, develop new offerings and shorten the time to market for new products, factors that should translate to superior economic rewards for the firm (Hung and Chou, 2013; Sisodiya *et al.*, 2013). Also, the fact that there is a deliberate strategy of combining external knowledge with internal resources can boost the efficient use of firm resources, what suggests that firms can improve their financial performance (Sisodiya *et al.*, 2013). Bearing in mind the above arguments, we posit that:

H1. Inbound practices exert a positive influence on firm performance.

2.2 The influence of outbound practices on firm performance

When firms implement outbound practices, they no longer restrict themselves to the markets they serve directly and externalize their knowledge (Enkel *et al.*, 2009). They do this either by licensing intellectual property (IP) or by co-exploiting this knowledge with other companies outside their own industry or market to obtain monetary or non-monetary benefits (Cassiman and Valentini, 2016; Hung and Chou, 2013).

Out-licensing allows commercialization of unused assets and exploitation of the existing technological knowledge outside a firm's boundary when the company lacks sufficient market

knowledge or other complementary resources to exploit its technologies internally (Chesbrough and Garman, 2009). Nevertheless, despite outward licensing generates revenues in the form of licensing payments, firms should be aware that current profits might decrease when licensees use their technology to compete in the same market (van de Vrande *et al.*, 2009). In addition to out-licensing, firms can place some of their assets or projects outside their walls by partnering with venture capital investors and spinning off nonstrategic initiatives to other firms, instead of developing and bringing former internal projects to market on their own: by taking a smaller role in the project, they reduce their costs and risks, while simultaneously preserving technological opportunities for future growth (Chesbrough and Garman, 2009). Hence, managers that decide to license out their IP or divest knowledge assets can get a profit from it, at least in the short term (Lichtenthaler, 2009). Additionally, the fact that the firm sells its underused ideas and refocus on developing its core capabilities can contribute to outperform its competitors who choose to do otherwise (Hung and Chou, 2013). Firms can also reveal internal resources without immediate financial rewards, seeking indirect benefits to the focal firm (Dahlander and Gann, 2010). By revealing, firms adopt strategies to selectively disclose some of their technologies to the public in order to get collaboration (Henkel, 2006). Likewise, in the literature on standards, being open and focusing less on ownership increase the opportunities to gain interest from other parties, which enhance collective development and greater advancements (Dahlander and Gann, 2010).

As a whole, outbound OI can have monetary and strategic advantages for firms exploiting their technological knowledge outside their boundaries or co-developing it with another organization (Hung and Chou, 2013). Thus, the possibilities arising from channeling knowledge to the market and participating in other segments may generate different streams of benefit that contribute to create greater overall revenue (Enkel *et al.*, 2009; Gassmann and Enkel, 2004). As a result, we expect outbound OI to improve a firm's performance:

H2. Outbound practices exert a positive influence on firm performance.

2.3 The influence of coupled practices on firm performance

Companies that establish coupled processes combine the outside-in process (to gain external knowledge) with the inside-out process (to bring ideas to market) (Gassmann and Enkel, 2004). While coupled OI can, in principle, involve any combination of the respective mechanisms for inbound and outbound OI, companies may implement specific mechanisms, all involving complementary partners (Chesbrough and Bogers, 2014).

Coupled practices can lead to improved performance because firms can combine knowledge inflows and outflows to efficiently accelerate internal innovation (Cheng and Huizingh, 2014). Cooperation in strategic networks and regional innovation clusters are two examples of OI practices combining inflows and outflows of knowledge that can effectively enhance a firm's innovation capabilities and performance. Network arrangements can assist firms in capturing complementary knowledge and capabilities, enhancing potential variety and availability of external knowledge, and creating value through the whole value chain from the early stages of technology development toward the commercialization of innovation outputs (Chesbrough and Rosenbloom, 2002). Indeed, collaborative networks with different partners can substantially enhance innovation by increasing the amount and variety of knowledge to be shared, thereby enabling the alliance partners to fill out their initial resource and skill endowments (Nieto and Santamaria, 2007). Also, regional clusters can provide firms positive enhancements in terms of firms' innovativeness as close geographical proximity tends to increase inter-firm explicit and tacit knowledge flows (Huang and Rice, 2013). It is fostered by a highly supportive setting, sustained by a higher degree of expected mutual benefit and limited transactional and other costs.

In this sense, firms operating in regional clusters will reduce their costs and benefit from increased trust and reciprocity created within the geographic space (Huang and Rice, 2013). Thus, benefits of coupling are related to improvements in firms' strategic position or costs minimization (Cassiman and Valentini, 2016; Cheng and Huizingh, 2014; Gassmann and Enkel, 2004). Based on the above, we propose the following hypothesis:

H3. Coupled practices exert a positive influence on firm performance.

2.4 The moderation effect of OMs

As it has been pointed out by Huizingh (2011), it is unlikely that a management concept has positive effects in any situation, implying that the effectiveness of OI must be context dependent. Previous contributions adopting a contingent view when examining the influence of OI types on firm performance have considered both the effects of external and internal variables. Table I shows some studies that adopted this view and followed a moderating approach. In it, we can observe that external factors studied included technological and market turbulence; technological dynamism; transaction rate in technology markets and competitive intensity (Cruz-Gonzalez *et al.*, 2015; Hung and Chou, 2013; Lichtenthaler, 2009; Popa *et al.*, 2017). Internal factors that have been analyzed are internal R&D, strategic orientation, relational capability and resource slack. In this regard, Hung and Chou (2013) found that internal R&D investment generates complementary effects of both external technology acquisition and exploitation on firm performance. Also, the explicitness of strategic orientation enhances the effectiveness of OI, being the effect especially strong with an entrepreneurial orientation (Cheng and Huizingh, 2014). Sisodiya *et al.* (2013) confirm that inbound OI efficacy for generating performance gains increases on the presence of relational capability. They also consider the effect of flexibility in the form of financial resource slack. Their results show that when firms possess strong relational capabilities and adopt an OI approach, they achieve higher financial performance if they have a low or a high level of flexibility.

To our knowledge, the moderating role of organizational structure variables on the relationship between OI and firm performance has not been examined, in spite of the fact that some of the managerial challenges when organizing and implementing OI are related with how firms design their organizations to purposively manage knowledge flows across organizational boundaries (Wallin and von Krogh, 2010). Organizing OI can be considered a matter of selecting the appropriate OMs that facilitate exploration, integration and exploitation of knowledge outside and within firm boundaries. When exploring, firms look

References	OI analysis	Moderator variable
Cheng and Huizingh (2014)	Inbound, outbound and coupled	Strategic orientation
Hung and Chou (2013)	Inbound and outbound	Internal R&D; technological turbulence; market turbulence
Cruz-Gonzalez *et al.* (2015)	Inbound	Technological environmental dynamism
Sisodiya *et al.* (2013)	Inbound	Relational capability Network spill overs Flexibility – resource slack
Popa *et al.* (2017)	Inbound and Outbound	Environmental dynamism and environmental competitiveness
Lichtenthaler (2009)	Outbound	Technological turbulence Transaction rate in technology markets Competitive intensity

Table I. Studies with a moderating approach when analyzing the influence of OI on firm's performance

outside their boundaries for new knowledge which has to be transferred inside and applied to produce new products. That requires an intermediate stage, which implies the integration of different types of specialized knowledge held by the individuals who look for new combinations to be exploited. This posits specific challenges related to encouraging and controlling employees when dealing with external agents, and also to enhancing the proper direction of knowledge flows (Foss *et al.*, 2011). Hence, the organizational structure may exert an influence on the effectiveness of OI.

In this paper, we focus on two elements of the organizational structure: formalization and decentralization. We selected these elements because, although there is no consensus about which elements should be included when describing an organizational structure, most of the proposals that examine it embrace formalization and centralization as two distinctive dimensions of it. Also, the few studies that deal with organizational design within the OI field include formalization- and/or decentralization-related variables (e.g. Bucic and Ngo, 2012; Foss *et al.*, 2011; Foss *et al.*, 2013; Ihl *et al.*, 2012). Accordingly, this paper focuses on the role of the organizational structure as a specific factor of a firm's internal context and suggests that the more flexible it is, by means of a lower degree of formalization and a higher decentralization, the more effective inbound, outbound and coupled OI will be in influencing firm performance. The next subsections describe our reasoning with the corresponding hypotheses.

2.4.1 Formalization. Formalization has been defined as the degree to which a codified body of rules, procedures or prescribed behavior is developed to handle decisions and work processing (Pierce and Delbecq, 1977). The studies of formalization in innovation contexts provide both positive and negative arguments about its effects (Damanpour, 1991). These mixed arguments remain in the scarce OI literature that has studied this OM, stating opposing effects (e.g. Bucic and Ngo, 2012; Ihl *et al.*, 2012). Some studies have posited that a positive effect of formalization on the influence of OI practices on performance may be justified by enhancing clarity, transparency, objectivity, efficiency and speed. All that because through formalization, processes related with the search, transfer and application of knowledge are organized and systematized (Ihl *et al.*, 2012). Hence, by means of formalization, firms may define accurately what kind of knowledge they need access externally and what procedures they get it through (Giannopoulou *et al.*, 2011). Also formalization may help to specify how to manage the new external knowledge, where and who to share it with. Altogether, formalization allows that the access to new external knowledge and its integration can be done in a more efficient way. Similar arguments can be used to suggest a positive influence of formalization with regard to knowledge outflows. For instance, when the external technology commercialization process is considered a regular practice, rather than an ad-hoc activity, the establishment of systematic technology exploration processes may help to develop the capabilities for identification of the partner's technological and market-related knowledge and to discover novel opportunities (Giannopoulou *et al.*, 2011; Lichtenthaler, 2009). Hence, to the extent that external knowledge exploitation processes are developed through formalized processes and structures, the identification of the relatedness and differences in collaborator's competences will facilitate the recognition and evaluation of possible partners. Also, the fact that these processes are formalized will help develop competences related with knowledge exploitation, what will enhance the effect of outbound practices on firm performance.

On the other hand, formalization can be conceptualized as a moderating variable that decreases the effect of OI on performance. In general terms, it is mainly explained by the mechanistic effect of formalized systems through rules, policies and routines, affecting employees' work and interactions, hampering the integration across functions and hindering creativity, collaborative learning, spontaneity and flexibility (Bucic and Ngo, 2012;

Naqshbandi and Kaur, 2011), all the opposite of what is needed for innovation. More specifically, when considering the effect of OI practices, formalization can reduce the scope of the external search. To the extent that formalization defines the exploration process, the search for new sources of knowledge will be restricted (Ihl *et al.*, 2012), what suggests that the identified and acquired inbound knowledge flows are not necessarily the ones that best fit firm's innovation process, which might render in lower performance. Although formalization allows the communication of explicit knowledge at a low cost, integration of tacit knowledge constitutes a challenge. In this sense, non-formalized organizational routines provide mechanisms for coordination that are not dependent upon the need for explicit communication. The advantage of non-formalized routines over formalization is in economizing on communication and a greater flexibility to vary responses to a broad range of circumstances (Grant, 1996), which would help firm's effectiveness in managing external knowledge inflows. With regard to the effect of formalization on effectiveness of managing knowledge outflows, similar reasoning can be applied. The key in outbound processes is to capture value from external exploitation of internal knowledge, especially when it is not the core activity in the firm. It implies having mechanisms to understand the technology markets and identify the most suitable options to channel out the internal knowledge, even though the firm is not familiar with them. The exploitation of knowledge outside the company is related to the company's capability to transfer its knowledge to the outside environment. The selection of partners that are willing and able to multiply the new technology is also an important element of inside-out processes (Gassmann and Enkel, 2004). A low formalization level may give higher possibilities to search beyond the known markets to find the target markets for the new products and applications and the best partners for them. Hence, having a broader knowledge of the technological markets and being able to anticipate the value of technologies and select the most appropriate partners can help enhance the opportunities to better exploit the knowledge externally (Gassmann and Enkel, 2004).

Despite the fact that arguments can be used to state opposite effects, the literature on how formalization affects the characteristics of organizational structures and innovation gives a sense that innovation is more favored by informal rather than formalized organizational structures (Naqshbandi and Kaur, 2011). We postulate that formalization influences negatively the relationship between OI and firm performance, which leads us to posit the following hypothesis:

H4. A high degree of formalization in organizational structure exerts a negative influence on the relationship between OI practices and a firm's performance.

2.4.2 Decentralization. The degree of decentralization reflects the locus of decision-making power and refers to whether decisional authority is relatively concentrated or dispersed in the organization (Pfeffer, 1981). Both the innovation literature in general and the OI literature in particular offer a number of explanations that support that a higher degree of decentralization can increase the effectiveness of OI practices.

The exploration and integration of new knowledge coming from outside will be higher in as much as this process is carried out by employees that are able to select the relevant sources and information that fit with firm needs (Foss *et al.*, 2011). Decentralization allows that these specialists act as gatekeepers, since they continuously interact with external agents or have the specific knowledge to identify the resources that best complement the firm knowledge base. At the same time, the greater delegation of decisional responsibilities may facilitate the access to a wider set of knowledge sources (Bucic and Ngo, 2012; Foss *et al.*, 2011) because the number of sources to be explored expands to all those employees which activities are related with external knowledge sources. Decentralization also saves the costs of transmitting, receiving and processing information, insofar as

decisional powers are placed on those who possess the knowledge to make the decisions. The integration of external knowledge may be easier in less centralized structures, as many tasks in the innovation process require solving problems by the involvement of specialists in different domains of knowledge, which may be made by means of innovation teams (Wallin and von Krogh, 2010). Therefore, the effectiveness of inbound OI can be enhanced as much as decentralization permits a better identification of external knowledge sources and a faster decision making that accelerates the innovation process and takes advantages of shorting the time to market.

The effects of external knowledge exploitation can also be enhanced by decentralizing due to the delegation of decisions on those that have better knowledge of external agents. It enables that activities related with outbound exploitation are executed in a more effective way. The identification of the external options will be more accurate since individuals are aware of the potential targets to search for the new applications and have the pertinent specific information to assess the new opportunities. Also, negotiation and maintaining costs will decrease due to the greater knowledge of the partners the firm is going to cooperate with. Altogether, it suggests that decentralization will favor the positive effect of outbound OI on firm's performance:

H5. A high degree of decentralization in the organizational structure exerts a positive influence on the relationship between OI practices and firm performance.

As a final remark, Figure 1 shows the research model that integrates the five research hypotheses that we test in the following sections.

3. Methods

3.1 Sampling and data collection

The hypotheses were tested by using data from a survey addressed to innovating Spanish firms with more than 50 employees in medium-low- and low-technology industries from the OECD (2011) classification of manufacturing industries based on technological intensity. We used the threshold of 50 employees because smaller companies find it more difficult to draw on a high number of external sources of knowledge, especially for those activities that require greater formalization and financial investment (Cruz-González *et al.*, 2015; van de Vrande *et al.*, 2009).

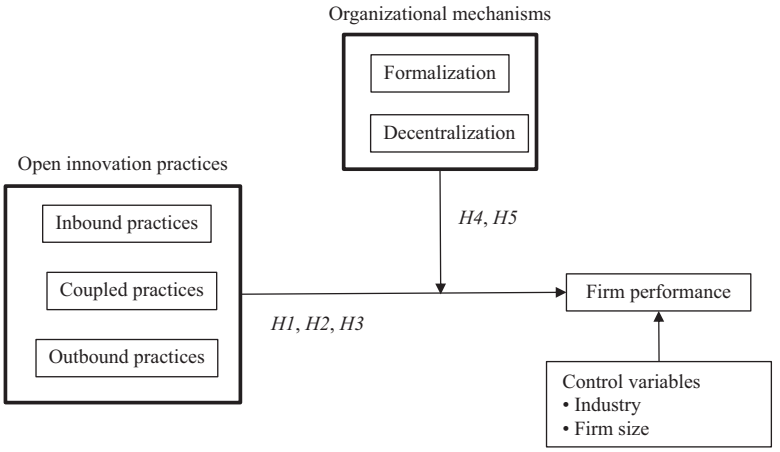

Figure 1.
Research model of the study

To select the industries, a first criterion was considering medium-low- and low-technology industries with a higher proportion of innovating companies. Accordingly, we relied on the results of the 2012 Spanish Innovation in Companies Survey carried out by the Spanish National Statistics Institute to identify those industries with the highest percentage of innovating companies in both medium-low and low-technology categories. A second criterion taken into account was the existence of industry and trade associations that could collaborate in the process of identifying innovating firms in their respective industries. Finally, a third condition was that the chosen industry offers a sufficient population of innovating firms to render a satisfactory number of firms in the final sample. We applied these criteria to select the following industrial sectors: food, textile, paper and cardboard, rubber and plastics, other machinery and equipment and furniture. According to the Spanish National Statistics Institute, over 30 percent of the medium-low-technology industries (rubber and plastics and other machinery and equipment) are innovating and about 20 percent of the low-technology industries (food, textile, paper and cardboard and furniture) are innovating. In general terms, these percentages doubled when we narrowed the sample to firms with more than 50 employees.

The final sample consisted of 244 innovating firms. This sample size was chosen to obtain a confidence level of 95 percent and a ±5 percent sampling error. The sample composition was obtained through a sampling process that was stratified in terms of sectors and size. Table II shows the composition of the population and the final sample.

The survey was conducted by using computer-assisted telephone interviews executed by a polling company between October and December 2014. The survey requested information on different issues related to the innovation activities of firms, their performance, and some internal variables. To avoid common-method bias, two respondents in each firm, the general manager and the innovation manager, were interviewed based on two different structured questionnaires. Following the same approach as used in prior studies that collected data on firm performance (see, e.g. Cruz-González *et al.*, 2015), OI practices (see, e.g. Cheng and Huizingh, 2014; Van de Vrande *et al.*, 2009) and formalization (see, e.g. Jansen *et al.*, 2005), we identified the general manager of the company as the first informant on these variables. The second informant was the innovation manager (or equivalent position), who provided us with data on decentralization and some control variables. When considering innovation activities, this type of informant has been used in the previous studies as a source of information for collecting data on decentralization (see, e.g. García-Granero *et al.*, 2014).

Information about companies was drawn from the Dun & Bradstreet database on Spanish firms. To assure that the survey was answered by innovating firms, the questionnaire addressed to the general manager began with a screening question. Thus, following the guidelines of the Oslo Manual (OECD/Eurostat, 2005), the respondents were first asked if their company had developed at least one innovation in the previous three years. In this way, we guaranteed that all firms considered in this study were innovative.

	50–249 employees		> 249 employees		Total	
Sector	Population	Sample	Population	Sample	Population	Sample
Food	195	72	145	25	340	97
Textile	42	19	23	2	65	21
Paper and cardboard	34	14	29	4	63	18
Rubber and plastics	153	37	41	7	194	44
Other machinery and equipment	120	40	127	10	247	50
Furniture	41	11	30	3	71	14
Total	586	193	395	51	982	244

Table II. Population and sample composition

3.2 Measurement of variables

Control variables. Our analysis included several variables to control for other factors that may influence the results. Specifically, we controlled for company size, which we measured in terms of the number of fulltime employees. Company size is a common control variable in studies on the innovation activities of companies (Cruz-Gonzalez *et al.*, 2015; Chen *et al.*, 2011; Cheng and Huizingh, 2014). This information was provided by the general manager and was verified against data obtained from the Dun & Bradstreet database. We also controlled for industry effects because different industries may display distinct needs with respect to innovation and have different outcomes of innovation (Chen *et al.*, 2016). To represent the specific industries in the analysis, five dummy variables were created for the following sectors: food, textile, paper and cardboard, rubber and plastics and other machinery and equipment.

Dependent variable. Firm performance was measured by applying a scale formed by four items based on perceptual indicators which was adapted from Slater and Narver (1994). Information was gathered from general managers, who rated on a seven-point scale their firm's performance compared with that of its main competitors in terms of profitability, growth, market share and overall performance. Reliability of the scale was confirmed through Cronbach's α value ($\alpha = 0.844$). The average score on the four items was used in the subsequent analysis.

Independent variables. OI practices. We extensively reviewed the literature to identify the practices that represent the different OI activities in which the firms take part. Table III lists the practices we selected for the study with their definition and the references that support them.

The respondents were asked to rate on a seven-point scale the degree of importance of each of the practices in their firm's innovation process over the previous three years (1 = not important at all; 7 = very important).

As stated by Huizingh (2011), OI measurement scales should reflect the multidimensional nature of OI activities and allow the dimensions to not be (fully) correlated. Bearing in mind these considerations, the variables were factor-analyzed to identify the existence of

Abbreviated name	Description	References
Customer involvement	Participation in activities aimed to get ideas from both real and potential customers	Gassmann and Enkel (2004), Parida *et al.* (2012), van de Vrande *et al.* (2009), Theyel (2013)
Supplier involvement	Participation in activities aimed to get ideas from both real and potential suppliers	
R&D outsourcing	Buying R&D services from research centers to seek innovations from external sources	De Araújo *et al.* (2014)
IP purchasing	Inward licensing of IP	Tao and Magnotta (2006), van de Vrande *et al.* (2009)
Cooperation with universities	Sponsoring research by universities and research centers to develop research projects	Perkmann and Walsh (2007)
Joint R&D	Research partnerships with other firms or R&D consortia	Tether and Tajar (2008)
IP selling	Selling of patents or know-how or licensing agreement or IP out-licensing	De Araújo *et al.* (2014)
Revealing	Revealing internal knowledge without immediate financial rewards, seeking indirect benefits	Dahlander and Gann (2010)
Corporate venturing	Venture capital funds or external corporate venturing	Vanhaverbeke *et al.* (2008)
Innovation networks	Participation in innovation networks	Lee *et al.* (2010), Huang and Rice (2013)
Innovation clusters	Active participation in regional innovation clusters	Bullinger *et al.* (2004)

Table III.
Open innovation practices

underlying dimensions in the data and a principal component analysis with varimax rotation was also done. In a previous step, we followed the guidelines to fulfill the assumptions required by the factor analysis and applied the Kaiser-Meyer-Olkin (KMO) test to verify the sampling adequacy and Bartlett's sphericity test to verify the correlation matrix. The results were satisfactory, with a KMO value of 0.786 and Bartlett's test being significant at the level of 0.000.

In the exploratory factor analysis, an item can be removed if: it has a factor loading lower than 0.5, the item has similar loadings on two factors or it does not load in a group to which it belonged (Hair *et al.*, 2010). Bearing in mind these aspects, throughout this process, we removed one item (corporate venturing) that loaded with a very similar weight on two different factors and another item (IP purchasing) was removed because it did not load in the group to which it belonged. The principal component analysis allowed us to identify four factors that accounted for 74.52 percent of the total variance. This solution featured strong individual loadings on each factor, thus enabling conceptual interpretation (Table IV). The first factor, which we labeled "Inbound R&D-related practices", was formed by three items: cooperation with universities, joint R&D and R&D outsourcing. We labeled the second factor "Inbound industry value-chain practices," because it consisted of the items related to participation in activities aimed to involve suppliers and customers. The third factor was labeled "Coupled practices" and was formed by items related to participation in regional innovation clusters and participation in innovation networks. The fourth factor was labeled "Outbound practices" and includes practices associated with IP selling and revealing. Reliability was assessed and Cronbach's α value for inbound R&D-related practices was 0.71, and a strong correlation existed between items forming each of the remaining factors ($\rho = 0.704$ for inbound industry value-chain practices, $\rho = 0.366$ for coupled practices, $\rho = 0.400$ for outbound practices). Factor scores were calculated for use in the subsequent analyses.

Organizational mechanisms. To represent the level of formalization, we used the scale proposed by Naziya Kasim *et al.* (2012) and asked the respondents to indicate on a seven-point Likert scale their level of agreement with the statements (1 = completely disagree, 7 = completely agree). Information on this aspect was provided by the general manager. Information on the degree of decentralization was obtained from innovation managers, and we used an instrument adapted from Miller and Dröge (1986). In this case, the respondents were asked to rate on a four-point scale the extent of decentralization in decision making related with the aspects being listed, with 1 = highest centralization (firm's top management) and

	Factor loadings			
	Factor 1. Inbound R&D-related practices	Factor 2. Inbound industry value-chain practices	Factor 3. Coupled practices	Factor 4. Outbound practices
Cooperation with universities	0.838			
Joint R&D	0.714			
R&D outsourcing	0.669			
Supplier involvement		0.902		
Customer involvement		0.876		
Innovation clusters			0.832	
Innovation networks			0.803	
IP selling				0.825
Revealing				0.712
% of variance explained	41.278	13.975	10.331	8.936

Notes: Measure of sample adequacy Kaiser-Meyer-Olkin: 0.786; Bartlett's sphericity test: 662.836; significance: 0.000

Table IV.
Results of exploratory factor analysis for OI practices

4 = highest decentralization (lowest managerial level in the firm). The measurement items for these variables are provided in the Appendix. Reliability analyses yield high Cronbach's α values ($\alpha = 0.922$ for formalization and $\alpha = 0.972$ for decentralization). The averages of the scores on the items forming each scale were used for subsequent analyses.

4. Findings

Hypotheses were tested through moderated hierarchical multiple linear regression analysis. To assess potential problems arising from multicollinearity, we checked bivariate correlations and calculated variance inflation factors (VIFs). Table V lists the correlation values; they are well below the recommended threshold suggested by Hair *et al.* (2010). Also, the VIFs for all variables are below 4.8, which indicate no multicollinearity issues (Table V).

Table VI presents the regression results. A first model was estimated in which firm performance was introduced as a dependent variable, and the independent variables were the control variables representative of size and sector and those representing the OI practices related to inbound R&D and industry value-chain practices, coupled and outbound activities (Model 1). Next, we estimated a second model (Model 2) in which we added the variables representing the two analyzed OMs. In a third stage, we estimated a model with the aim of examining how OMs moderated each type of OI practice. We did this by incorporating the interaction terms representative of formalization and decentralization and each type of OI practices into the regression equation. Model 3 in Table VI shows the results for this complete model with the main and moderating effects.

The results from Model 1 show that the overall regression equation is statistically significant ($F = 4.633$, $p < 0.001$), and the set of independent variables incorporated into the model explain 13.5 percent of the variance in performance. With regard to control variables, we note that company size has a significant positive effect on company performance ($\beta = 0.174$, $p < 0.05$). Furthermore, the dummy variables show that no industry significantly influences firm performance. With regard to OI, the results confirm the influence of OI practices on firm results. The first hypothesis suggests the positive effect of inbound practices. Our analysis gives mixed results: of the two variables used to represent inbound OI practices, only the one related to R&D activities presents a positive and statistically significant coefficient ($\beta = 0.126$, $p < 0.1$). The coefficient associated to inbound industry practices, although positive, is not statistically significant ($\beta = 0.051$, $p > 0.1$). Outbound practices are found to have a positive effect on company performance ($\beta = 0.194$, $p < 0.05$), which supports our second hypothesis. For *H3*, the results provide evidence of the positive influence of coupled practices on firm performance ($\beta = 0.257$, $p < 0.001$). Model 2 shows the results that stem from including the main effects related to coordination mechanisms variables. A significant positive effect of formalization on firm performance ($\beta = 0.119$, $p < 0.1$) is observed, along with an insignificant effect of decentralization ($\beta = 0.088$, $p > 0.1$).

	1	2	3	4	5	6	7	8
(1) Size	1	0.154*	0.014	0.121	0.062	−0.157*	0.124	−0.136*
(2) Firm performance	0.154*	1	0.134*	0.072	0.272**	0.188**	0.155*	0.139*
(3) Inbound R&D-related practices	0.014	0.134*	1	0.000	0.000	0.000	0.101	0.024
(4) Inbound industry value-chain practices	0.121	0.072	0.000	1	0.000	0.000	0.007	0.045
(5) Coupled practices	0.062	0.272**	0.000	0.000	1	0.000	0.235**	0.126
(6) Outbound practices	−0.157*	0.188**	0.000	0.000	0.000	1	−0.092	0.061
(7) Formalization	0.124	0.155*	0.101	0.007	0.235**	−0.092	1	0.064
(8) Decentralization	−0.136*	0.139*	0.024	0.045	0.126	0.061	0.064	1

Notes: *,**Correlations are significant at the 0.05 and 0.01 levels, respectively

Table V.
Correlations between variables in the analysis

	Model 1			Model 2			Model 3	
	β	t	VIF	β	t	VIF	β	t
Size	0.174**	2.772	1.056	0.174**	2.754	1.086	0.143**	2.215
Food	0.075	0.566	4.757	0.088	0.661	4.777	0.091	0.651
Textile	0.092	1.019	2.198	0.087	0.963	2.204	0.093	0.996
Paper and cardboard	0.055	0.613	2.190	0.045	0.494	2.209	0.072	0.782
Rubber and plastics	−0.007	−0.062	3.310	−0.022	−0.196	3.321	−0.021	−0.182
Other machinery and equipment	0.126	1.086	3.609	0.114	0.988	3.621	0.123	1.010
Inbound R&D-related practices	0.126*	2.052	1.013	0.108*	1.757	1.032	−0.692	−1.500
Inbound industry value-chain practices	0.051	0.823	1.022	0.047	0.759	1.025	0.255	0.658
Coupled practices	0.257***	4.161	1.024	0.220**	3.472	1.094	0.221	0.528
Outbound practices	0.194**	3.047	1.088	0.198**	3.123	1.100	0.824**	2.178
Formalization				0.119*	1.845	1.126	0.107	1.576
Decentralization				0.088	1.379	1.107	0.116*	1.796
Inbound R&D-related practices × formalization							0.616	1.430
Inbound industry-related practices × formalization							−0.270	−0.740
Coupled practices × formalization							0.098	0.248
Outbound practices × formalization							−0.972**	−2.690
Inbound R&D-related practices × decentralization							0.198	1.541
Inbound industry-related practices × decentralization							0.093	0.603
Coupled practices × decentralization							−0.094	−0.633
Outbound practices × decentralization							0.354**	2.344
R^2	0.173			0.193			0.250	
Adjusted R^2	0.135			0.149			0.179	
Change in R^2				0.021*			0.056**	
F	4.633***			4.394***			3.528***	

Notes: *$p < 0.1$; **$p < 0.05$; ***$p < 0.001$

Table VI. Results of hierarchical regression analysis: effects of OI practices and organizational mechanisms on firm's performance (standardized coefficients β)

H4 and *H5* were tested by using a moderated regression model that examined how formalization and decentralization affected the effectiveness of OI practices. The results show a significant increase of the explained dependent variable for Model 3, which means the OMs exert a moderating effect. Nevertheless, our findings only provide partial support for the hypothesized relationships because the moderating effects were only significant for outbound OI practices. Specifically, Model 3 reveals that formalization has a negative moderating effect ($\beta = -0.972$, $p < 0.05$) and that decentralization has a positive moderating effect ($\beta = 0.354$, $p < 0.05$) on the relationship between outbound practices and company performance. In both cases, the interaction terms are significant in their respective predicted directions.

5. Discussion

Our results show that the adoption of an OI strategy has a positive effect on company performance in line with the existing works on different aspects of OI and a firm's performance (e.g. Cheng and Huizingh, 2014; Hung and Chou, 2013). In addition to the consensus on the benefits of openness, the specific examination on the effectiveness of the three types of OI enriches our understanding of the phenomenon.

Particularly, for inbound innovation, our results confirm its positive influence on firm performance. These findings coincide with results obtained by previous research in OI literature (e.g. Hung and Chou, 2013; Michelino *et al.*, 2015; Sisodiya *et al.*, 2013; Wang *et al.*, 2015).

Nevertheless, our approach examines the influence of inbound OI activities by differentiating between R&D-related practices and industry-related practices. This distinction assumes that collaborations with suppliers and customers aimed at getting ideas for the innovation process play a different role than collaborations involving R&D, which is also stated in Chen *et al.* (2011). Inbound industry-related practices are not significant in explaining superior performance. This may be justified by the fact that these practices, which are associated with active interaction with customers and suppliers, constitute usual activities for innovating firms. In other words, they can be regarded as activities done by any company that innovates. Additionally, although important in most firms' strategies, the fact that customer and supplier involvement is usually associated with the first stages of the innovation process suggests that, in many cases, they may not reach the requirements to go ahead in the subsequent stages of the innovation process and do not allow for innovation and financial performance to occur. It can be thought that, on one side, they are aimed at getting ideas, which may not be so focused to solve specific innovation problems; on the other side, even though they identify or suggest specific questions, this knowledge still will have to pass through a number of filters to be implemented. Indeed, this point may also help to explain our results with regard to the positive effect of inbound practices related to R&D activities. For instance, science-based partners such as universities and research institutions develop and disseminate cutting-edge scientific knowledge and provide firms with a better understanding of the underlying mechanisms behind the fundamental and basic knowledge. Therefore, such institutions are helpful in providing solutions to concrete technological problems that firms may be facing in their innovation process, which, once solved and new knowledge is incorporated into the innovation process, lead to a higher performance. Similar reasoning applies for the case of joint R&D and R&D outsourcing, since innovating firms adopting these practices are purposively seeking complementarities to their internal efforts, which suggests a more focused effort that pays off. In this sense, a contribution of this paper is the identification of the distinct impact of R&D-related inbound practices.

Consistent with the previous research (e.g. Lichtenthaler, 2009), outbound innovation practices also have a positive effect on firm performance. Certainly, although Chesbrough and Crowther (2006) saw that many of the outbound-oriented concepts were not being extensively used in OI "early-adopter" companies operating outside the high-technology industries, our study provides evidence that these outbound activities, when occurring, have a positive effect on firm performance. Hence, our results show that they can contribute to the effectiveness of a firm's OI strategy, either by direct generation of revenues from licensing payments or, more indirectly, through the indirect marketing and technical benefits that can stem from revealing. Therefore, it confirms that external exploitation can be an option for the firm to exploit fully its internal technologies when it lacks enough market or other complementary resources to do it on its own (Chesbrough and Garman, 2009).

This research also found a strong relationship between coupled innovation practices and firm performance. We focused on two specific coupled practices, which are participation in clusters and in innovation networks. According to Huang and Rice (2013), benefits in regional clusters are related with the provision of an environment within which the direct costs associated with open strategies (such as contractual, knowledge search costs and indirect costs particularly in terms of knowledge transmission costs), the uncertainty in collaborative relationships and the conflicts between inbound and outbound knowledge flows, can be minimized. In the same vein, the results in the study by Lee *et al.* (2010) showed that participating in networks benefited firms in terms of trust creation, information networking, procedural learning and know-how transfer, which contributed greatly to the network's success. Our research complements the findings in these two studies by stressing the relevance of coupled practices in a context of analysis that also includes inbound and outbound OI types. That is it, participating in clusters and

networking should be considered an important and effective option as a part of their OI strategy by firms in industries where there is not a high intensity in internal R&D efforts. It can be explained by the fact that they represent an encouraging scenery, which helps at complementing firm's internal resources and enables knowledge transfers thanks to the linkages and flows of tacit knowledge between cluster-based firms and institutions. Therefore, a contribution of this research is showing that coupled practices can play a notable role in OI strategies in a firm's performance.

We also studied how OMs influence the relationship between OI strategy and firm performance and, in doing so, we examined the effect of formalization and decentralization. We could not confirm that the effect of inbound and coupled practices is enhanced by having a lower degree of formalization or by supporting decentralization at a greater extent. With regard to inbound OI, neither the effect of ideas from value chain partners nor cooperating in R&D activities is facilitated by decreasing formalization of procedures and rules or implementing a higher decentralization. A first explanation for our results might rely on the notion that customer and supplier involvement in getting ideas for the innovation process can be considered, *per se*, activities that, in general terms, are developed as a consequence of contacts and interactions between firms on a daily basis. In most cases, these practices have an informal component and, as so, there is no point in further loosening rules and procedures or delegating authority in order to boost their potential effect on performance. Nevertheless, the fact that these relationships with customer and suppliers did not have a direct effect on performance on their own, suggests that getting the most of customers and suppliers involvement by acting on the organizational structure in this context requires actions different from those examined here, which would deserve further research.

Similar reasoning could be applied for the non-significant moderating effects of formalization and decentralization on R&D-related inbound OI and performance. However, the differential aspect now is that R&D-related cooperation activities exert a positive influence on firm performance on their own. In this case, to suggest a justification for these findings, we rely on Foss *et al.*'s (2013) explanation, who did not find support for evidence for a moderating relationship between delegation, the use of external knowledge sources and opportunity exploitation. According to these authors, this fact may indicate that delegation is not helpful in all types of incoming knowledge. For example, they suggest that absorbing complex external knowledge may require coordinated efforts among several departments and functions in a firm and would be compromised by the strong delegation. We extend this reasoning both to decentralization and formalization issues and suggest that, in a LMT context, with firms lacking strong internal research capabilities, R&D-related cooperation may be conceived as a high-complex activity that entails difficulty for them and this fact discourages the firms from trying to implement higher levels of decentralization and lower formalization. Hence, in line with the suggestion by Foss *et al.* (2013), decentralization and formalization may have both negative and positive moderating effects that may cancel each other out.

With regard to coupled practices, they are associated in most cases to informal relationships, which, by their own nature, already have a low formalization and are possible thanks to the personal ties of employees who enjoy the power to make their own decisions on this regard. Hence, this might explain the fact that higher levels of decentralization or lower levels of formalization would not contribute significantly to enhance the effectiveness of coupled practices.

Our results in relation with OMs show that decentralization enhances firm performance when the effect of the three types of practices is considered, which is in line with previous research (Bucic and Ngo, 2012; Ihl *et al.*, 2012). The fact that we identify a positive direct influence indicates an overall beneficial effect on firm performance as a consequence of

dispersion of the authority of decision-making power. Additionally, a moderating effect of outbound practices on firm performance is showed, with a positive effect for decentralization and a negative effect for formalization. Such significant moderation suggests that, in general, a more flexible structure enhances the effectiveness of outbound practices. A possible explanation of these results is that, in these contexts, better conditions for outbound OI initiatives are found because they encourage employees' attitudes toward knowledge exploitation (Lichtenthaler *et al.*, 2011) and they do not discourage risky decisions (Bucic and Ngo, 2012; Naqshbandi and Kaur, 2011). At the same time, a better identification of market opportunities facilitates the development of knowledge transfer and the selection of appropriate partners by different people of the firm (Gassmann and Enkel, 2004).

6. Conclusions, implications and limitations

6.1 Conclusions

This study is framed by the OI contingency literature and discusses the effect of different types of OI practices and OMs on firm performance in LMT firms. On the basis of this research, the following conclusions are drawn.

With regard to inbound practices, the practices oriented to cooperate with partners in a R&D context have a positive influence, whereas practices related to getting ideas from suppliers and customers do not significantly affect firm performance. Also notable is that outbound practices and coupled activities are showing a positive effect. Coupled practices, which are related to participation in clusters and innovation networks, have the highest impact on firm performance within this industrial context.

The findings indicate that formalization and decentralization have to be considered as contextual factors that influence the effect of OI practices on firm results. In the industrial context examined, decentralization exerts a positive effect which enhance the effect of outbound practices meanwhile formalization reduces their positive effect.

Also remarkable is our contribution with regard to the empirical setting, since our study focuses on low- and medium-technology firms, which have been considered sectors that deserve further attention in the OI literature (Vanhaverbeke *et al.*, 2014). Our results show that adopting OI may be an effective way to favor firm results in low- and medium- technology industries through the implementation of inbound, outbound and coupled practices.

6.2 Managerial implications

Several implications for managers result from this study, especially for those involved in LMT firms. First, our study provides clear evidence about the fact that OI can be a way to obtain an advantage from innovation in LMT firms. Second, managers should take into account that the three types of OI practices, inbound, outbound and coupled, can contribute to enhance a firm's competitiveness. With regard to inbound practices, since adopting value-chain related practices does not influence performance, managers should reinforce inbound practices related to generate new knowledge and solve technological problems by either collaborating with universities and research centers, by participating in joint research with other firms or by contracting this activity out to specialized organizations. For instance, they could take advantage of public funds to carry out projects with scientific partners. The effect of outbound activities is an indicator of the potential that OI practices related to selling IP or revealing can have in LMT firms. Nevertheless, managers have to consider that outbound practices also involve cultural, political and organizational challenges, which may limit the extent and success of a firm's outbound OI approach (Chesbrough and Garman, 2009), being necessary a proficient internal management to avoid the potential risks and to capture the benefits (Lichtenthaler, 2015). Coupled practices also influence significantly firm performance.

In this way, participating in clusters and networking can be an important element in firms' OI strategies. For a better achievement, managers may look for the support of innovation intermediaries (consultants, industrial associations) in fostering networking initiatives and also participating in and being sensitive to public programs aiming to develop regional clusters.

Third, managers should be aware that the use of the adequate OMs can foster the effectiveness of OI practices. This is especially noticeable in the case of outbound practices, where a greater decentralization and a lower formalization clearly facilitate advantages that stem from external innovation exploitation and may help counterbalance the above-mentioned challenges related to outbound OI. If managers implement outbound open practices, they should also be committed to introducing OMs that can help in enhancing flexibility in structure and processes.

In conclusion, this research illustrates that adopting OI practices has a positive influence on firm performance, which supports the efforts of managers that attempt to broaden their firm's innovation processes in low- and medium-technology industries. Therefore, our findings suggest that managers aiming to achieve superior performance should try not only to explore external knowledge sources but also to implement OI practices that focus on externally exploiting their innovation results and combining external knowledge inflows and outflows.

6.3 Limitations and future directions

This study has several limitations that constitute avenues for further research. A first limitation is that its scope was limited to innovating Spanish firms. Firms in other political and social settings may face different conditions that might modify the relations uncovered in this paper. Thus, the generalization of these results should be carried out with this caution. A second limitation stems from the fact that even though our results suggest a complementarity of the direct effects of the three types of OI (in all three cases they were positive and significant), we did not explore their specific complementarities. Cassiman and Valentini (2016) suggest that a fundamental element of novelty of the OI framework is the complementarity between inflows and outflows of knowledge, that is, the idea that the marginal return from engaging in one type of knowledge flow increases as the intensity of the other increases. As we study the individual effect of each OI type (inbound, outbound and coupled) on performance, it could be relevant to analyze the complementarities of implementing the three types of practices by further examining interactions among them. Finally, this study constitutes a first step toward developing an insight into the internal factors of firms that condition OI effectiveness. The fact that we only examined formalization and decentralization as OMs gives us a partial representation of the effect of organizational structure. Further research should more deeply analyze the contingent effect of organizational conditions by including additional variables representative of informal communication and socialization.

Additionally, further extensions could enrich our results by carrying out qualitative studies based on interviews and/or case studies, since they would let us gather valuable contextual information about the factors influencing OI and firm performance, which is difficult to get in a quantitative empirical work. Finally, future research could also benefit from extending the study in order to get a more detailed knowledge of OI in specific settings and industries. For instance, even though there have been developed some works about the specific implementation of OI in SMEs (e.g. Popa *et al.*, 2017; Van de Vrande *et al.*, 2009), the study carried out by Vanhaverbeke (2017) emphasizes the existence of differences on motivations and management from large firms. In this sense, it could be relevant to extrapolate our analysis to this type of firms.

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Appendix

1. Formalization

Indicate your level of agreement with the following statements concerning organizational aspects in your firm (1 = completely disagree; 7 = completely agree):

(1) Formal policies and procedures guide most decisions.

(2) Important communication between units members are documented by memo.

(3) Formal job descriptions are maintained for each position.

(4) Reporting relationships are formally defined.

(5) Lines of authority are specified in a formal organization chart.

(6) Rewards and incentives are administered by objective and systematic criteria.

(7) Capital expenditure are planned well in advance.

(8) Plans tend to be formal and written.

(9) Formal operating budgets guide day to day decisions.

2. Decentralization of decision making

Indicate the degree of decentralization of autonomy to make decisions related to the following (1 = maximum centralization (top management of the company); 4 = maximum decentralization (lower management levels in the company)):

(1) Developing new products or services.

(2) Making major changes in marketing activities.
(3) Prioritizing projects within the department.
(4) Cooperating with other units in the firm.
(5) Collaborating with external firms or organizations.
(6) Deciding which new projects to pursue in the department.
(7) Making quality control decisions.
(8) Making significant changes in product and services.
(9) Making major changes in the department's routines.
(10) Discontinuing a major product or service.

3. Firm performance

In relation to your major competitors, what is the performance of your business in the following indicators (1 = far below my competitors; 4 = similar to my competitors; 7 = far above my competitors)?

(1) Global performance.
(2) Market share.
(3) Growth.
(4) Profitability.

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