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ORGANIZING FOR INBOUND OPEN INNOVATION: HOW EXTERNAL CONSULTANTS AND A DEDICATED R&D UNIT INFLUENCE PRODUCT INNOVATION PERFORMANCE

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Abstract

Firms increasingly acquire technological knowledge from external sources to improve their innovation performance. This strategic approach is known as inbound open innovation. The existing empirical evidence regarding the impact of inbound open innovation on performance, however, is ambiguous. The equivocal results are due to moderating factors that influence a firm's ability to acquire technological knowledge from external sources and to transform it into innovation outputs. This article focuses on a relevant yet overlooked category of moderating factors: organization of R&D. It explores two organizational mechanisms, one informal and external-oriented (involvement of external consultants in R&D activities), and one formalized and internal-oriented (existence of a dedicated R&D unit), in the acquisition of technological knowledge through R&D outsourcing, a particular contractual form for inbound open innovation.

Drawing on a capabilities perspective and using a longitudinal dataset of 841 Spanish manufacturing firms observed over the period 1999-2007, this article provides a fine-grained analysis of the moderation effects of the two organizational mechanisms. The involvement of external consultants in R&D activities strengthens the impact of inbound open innovation on innovation performance, by increasing marginal benefits of acquiring external technological knowledge through R&D outsourcing. Moreover, it reduces the level of inbound open innovation to which the highest innovation performance corresponds. Instead, the existence of a dedicated R&D unit makes the firm less sensitive to changes in the level of inbound open innovation, by reducing marginal benefits of acquiring external technological knowledge through R&D outsourcing, and increases the level of inbound open innovation to which the highest innovation performance corresponds.

The results regarding the role of informal and formalized R&D organizational mechanisms contribute to research on open innovation and absorptive capacity, and also inform managers as to what organizational mechanism is recommended to acquire external technological knowledge, depending on the objectives that the firm pursues.

Practitioner Points:

- The study provides guidance on how to improve the benefits of inbound open innovation using two different mechanisms: external R&D consultants or a dedicated R&D unit.
- Using external consultants allows firms to achieve larger innovation outputs, even with only small increases of R&D outsourcing, and is therefore beneficial for firms that want to increase innovation performance by increasing inbound open innovation.
- Establishing a dedicated R&D unit allows firms to achieve higher levels of R&D outsourcing before negative consequences occur, and is therefore beneficial for firms

with significant R&D outsourcing that wish to better manage an extensive flow of external technological knowledge.

INTRODUCTION

This article examines whether and how the organization of Research and Development (R&D) influences the relationship between the acquisition of technological knowledge from external sources and innovation performance. The practice of acquiring technological knowledge from external sources, in addition to generating it internally, is known as inbound open innovation (IOI) (Chesbrough and Crowther, 2006; Spithhoven *et al.*, 2010). The growing importance of IOI is evident both in theory and in practice. Recent statistics show that over one third of innovative firms cooperate with external partners to access their technological knowledge (Eurostat, 2011). The ongoing division of labor in technological innovation, the diffusion of innovation intermediaries, and the strengthening of intellectual property regimes will likely support this trend in the future. Academics have also recognized the importance of IOI, as evidenced by the appearance of special issues of academic journals devoted to the subject, including *R&D Management* (Gassmann *et al.*, 2010) and *Research Policy* (West *et al.*, 2014), as well as recent review articles (West and Bogers, 2013).

The extant empirical evidence of the effects of IOI is equivocal. Scholarly works find positive (Brown and Eisenhardt, 1997; Ettlie and Pavlou, 2006), negative (Kessler *et al.*, 2000; Jones *et al.*, 2000), and not significant (Zahra, 1996) influences of externally acquired technological knowledge on innovation performance. The ambiguous results may derive from the coexistence of benefits from IOI, e.g., access to know-how from distant fields, higher flexibility, reduced time to market, risk and cost sharing, as well as of drawbacks, e.g., lower knowledge appropriability, loss of control over core competencies and high transaction costs (Kessler *et al.*, 2000; Cassiman and Veugelers, 2006). The inverted U-shaped relationship found in more recent studies (Grimpe and Kaiser, 2010; Laursen and Salter, 2006) suggests that the positive contribution of IOI on performance has diminishing returns and, after a certain level of investment in external technological knowledge, becomes negative.

The equivocal findings in the literature suggest the need to identify contingencies that shape the IOI-performance relationship (Katz and Allen, 1982; Rothaermel and Alexandre, 2009; Chatterji, 1996). Clearly, there are moderating factors that influence the ability of a firm to acquire, assimilate and transform technological knowledge developed elsewhere into innovative outputs, i.e., its absorptive capacity (Cohen and Levinthal, 1990; Zahra and George, 2002). Prior examinations of such factors mainly focused on internal R&D

investments (Cassiman and Veugelers, 2006; Jones *et al.*, 2000; Rothaermel and Deeds, 2006), the diversity of partners from which knowledge is sourced (Grimpe and Kaiser, 2010; Katila and Ahuja, 2002), the experience with IOI (Anand and Khanna, 2000), and the socialization tactics used to disseminate and integrate knowledge (Lewin *et al.*, 2011). Interestingly, evidence is ambiguous also on the moderating effect of these firm-level factors (Laursen and Salter, 2006; Chen *et al.*, 2009; Hoang and Rothaermel, 2010).

Following recent calls for further research on the IOI–performance relationship and on the factors that influence the firm's ability of managing inbound open innovation (e.g., West and Bogers, 2013; Lichtenthaler and Lichtenthaler, 2009), this article focuses on an important domain which has not been adequately discussed in existing research, namely, the organization of R&D. The importance of a proper organization of R&D activities has been long recognized, although conceptualized primarily in a closed innovation setting (Chiesa, 2001). This stream of research has focused on intra-organizational factors, such as formalized and informal organizational structures (Teece, 1996), human resource management practices (Laursen and Foss, 2003), control and communication mechanisms (Nobel and Birkinshaw, 1998). As firms increasingly adopt IOI, it is critical that they design an organization for R&D that adequately supports the interaction with the external context (Siggelkow and Levinthal, 2005; Arora *et al.*, 2014). Prior open innovation research has shown that the direction and efficacy of knowledge transfer processes significantly depend on the organizational mechanisms adopted by firms to configure information processing structures and social networks (Colombo *et al.*, 2011). Hansen and Nohria (2004) and Chiaroni *et al.* (2011) highlight the importance of intervening at the organizational level to ensure successful acquisition and exploitation of externally acquired technological knowledge. However, empirical tests of the influence of organizational factors on the IOI-performance relationship are lacking.

This article argues that two mechanisms for R&D organization, the involvement of external consultants in R&D activities and the existence of a dedicated R&D unit, influence a firm's ability to turn external technological knowledge into product innovation. Consultants include external actors such as experts, technology brokers, innovation agencies, technical and scientific service providers, which support firms in their R&D activities on an ad hoc, temporary basis and without being formally recognized within their organizational structure (Bessant and Rush, 1995; Tether and Tajar, 2008). The existence of a dedicated R&D unit, through the allocation of full-time employees and resources to R&D activities, represents instead a formalized mechanism with lasting impacts on a firm's organization (Chiesa, 2001).

This study focuses on these two organizational mechanisms because research on the critical success factors in R&D and new product development (Ernst, 2002; Brown and Eisenhardt, 1995) suggests that formalizing R&D activities and creating social and personal ties to establish rich communication networks represent two key antecedents to superior product innovation. The impact of these factors on innovation performance has, however, been analyzed in a closed innovation paradigm, according to which firms generate and exploit technological knowledge primarily within their boundaries. To date, there is no empirical evidence of whether and how these two organizational mechanisms may benefit firms that practice IOI. By considering informal and external-oriented (consultants) and formalized and internal-oriented (dedicated R&D unit) organizational mechanisms, this study offers a multifaceted (though naturally incomplete) view of R&D organization.

Moreover, this article focuses on R&D outsourcing as a contractual form for the acquisition of external technological knowledge. Although very common in practice (Howells *et al.*, 2008), R&D outsourcing, defined as "buying R&D services from other organizations, such as universities, public research organizations, commercial engineers or suppliers" (van de Vrande *et al.*, 2009, pp. 428), has received limited attention in innovation research, compared to other forms of IOI, e.g., mergers and acquisitions, joint ventures and in-licensing (Chiesa and Manzini, 1998; Kotlar *et al.*, 2013). Differently from equity-based IOI transactions, which are characterized by low reversibility, long time horizon and a strong control over the acquisition process, R&D outsourcing is a more reversible non-equity form that typically entails lower control and commitment by the parties involved. The study by Grimpe and Kaiser (2010) explicitly examines factors that influence the relationship between technological knowledge acquired through R&D outsourcing and innovation performance. Note, however, that the factors considered in Grimpe and Kaiser (2010) (the intensity of internal R&D and the breadth of formal R&D collaborations) differ from those included in this article.

The conceptual framework developed in this study is empirically tested using a dataset including 841 Spanish firms from 20 manufacturing industries over the period 1999-2007. The findings extend the theoretical understanding of IOI bringing new evidence to the lively but controversial debate on this phenomenon. In particular, adopting a capability-based view of IOI, this article develops and tests theoretical arguments about the role of R&D organizational mechanisms in building the capabilities of managing IOI. In an open innovation context, the transfer of technological knowledge and complex relationships with R&D contractors expose managers to additional challenges as compared to those working in closed systems. This article also complements extant research on IOI focusing on a contractual form, R&D outsourcing, which so far has been under-researched. Finally, this study provides interesting implications for managers searching for organizational mechanisms to help their firms benefit from technological knowledge acquired from external sources.

The article is structured as follows. The next section develops theory and hypotheses. The third and fourth sections describe the sample, the variables and the model used for the empirical analysis, whereas the fifth section presents the findings of the study. Finally, results are discussed and conclusions are outlined.

CONCEPTUAL FRAMEWORK AND RESEARCH HYPOTHESES

Technological innovation can be conceptualized as a process that transforms a set of inputs (technological and market knowledge) into outputs (new products). Consistent with the growing diffusion of the open innovation paradigm, one increasingly important input to this process is external technological knowledge, which can be acquired from contractors through R&D outsourcing agreements. Based on prior research, it is proposed that the relationship between this particular input and product innovation performance has an inverted U-shape. Several studies have documented a positive contribution of external technological knowledge to the quality (Haour, 1992; Gavetti and Levinthal, 2000), flexibility (Tapon and Thong, 1999; Kessler *et al.*, 2000), speed (Leone and Reichstein, 2012) and cost of the technological innovation process (Grimpe and Kaiser, 2010). As the reliance on IOI increases, however, it shows diminishing returns on performance, because it enhances the likelihood that the firm acquires technological knowledge that produces lower yields (Deeds and Hill, 1996). Past a tipping point, any investment in IOI has negative performance effects. Over-acquiring external technological knowledge results into the loss of control over critical technological competences, a very dispersed knowledge base and the proliferation of ex-ante and ex-post transaction costs (Wang *et al.*, 2009; Becker and Zirpoli, 2003).

This study adopts a capability-based view of open innovation processes (Lichtenthaler and Lichtenthaler, 2009). According to this perspective, the productivity of the transformation of external technology knowledge into innovation outputs depends on a set of capabilities that allow firms to identify and screen external sources of technological knowledge, analyze and interpret this knowledge, adapt and integrate it with existing internal knowledge, and incorporate the resulting combination into new products. Influential articles in innovation research discuss these capabilities for managing IOI in relation to the concept of absorptive capacity (Zahra and George, 20 Lewin *et al.*, 2011).

The next section argues that two R&D organizational mechanisms, the involvement of external consultants in R&D activities and the existence of a dedicated R&D unit, influence the development of these capabilities and thus moderate the relationship between external technological knowledge acquired through R&D outsourcing and product innovation performance.

The moderating role of external consultants

The moderation exerted by the involvement of external consultants in R&D activities on the IOI-performance relationship is posited to be positive because this organizational mechanism allows the focal firm to develop a set of capabilities that are needed to productively acquire technological knowledge from R&D contractors and to transform it into new products (Bessant and Rush, 1995).

As the innovation process opens up, the interorganizational transfer of technology becomes a key task. This task is inherently social (Podolny and Stuart, 1995), as most open innovation deals are initiated through personal contacts and are established within socially embedded networks of direct and secondary relationships (Bidault and Fischer 1994). The importance of relationships stems from the imperfect nature of markets for technology (Bianchi *et al.*, 2014). External consultants are primary sources of relationships and they build and maintain thick and extended social networks as they fill structural holes (Allen, 1977; Burt, 1992). According to Gans and Stern (2003), the brokering role played by external consultants can increase the operational effectiveness of markets for technology, as they are able to reach a wider and more sophisticated population of potential partners. These professionals leverage their contacts, often colleagues working in the same field in other organizations, to keep themselves abreast of technological developments, to be more exposed to emerging opportunities and to technology suppliers, to identify value-adding knowledge to be absorbed (Allen, 1977). Richer networks and personal relationships result in more proficient acquisition of technological knowledge. As a result, the involvement of external consultants allows the focal firm to develop a first critical capability for IOI, namely, the capability to scout and identify potentially valuable providers of R&D outsourcing services.

Personal relationships and the social embeddedness in the markets for technology granted by external consultants are especially relevant when the good to be transferred, technological knowledge, is difficult to appropriate, has ill-defined property rights and whose quality is hard to assess in advance. In a context of weak appropriability, trust and credibility of external consultants, who have repeated interactions in the markets for technology, facilitate the closing of R&D outsourcing agreements by mitigating information asymmetries and transactional uncertainty (Arrow, 1996). This invites firms to open up and increase the likelihood that a mutually convenient agreement is reached between the contractor and the focal firm. External consultants also facilitate negotiations by balancing the power of the counterparts (Bessant and Rush, 1995; Robinson and Stuart, 2007). Personal relationships and the resulting trust thus permit the spotting of better IOI opportunities, and also facilitate seizing these opportunities by allowing high potential external technological knowledge into the innovation process. Consequently, the involvement of external consultants allows the focal firm to develop other critical capabilities for IOI, such as creating a trustworthy relationship with the external contractor and effectively negotiating the terms of the R&D outsourcing agreement.

Relationships with external consultants are also critical in the assimilation of externally acquired technological knowledge. Many R&D collaborations fail due to problems emerging during the implementation and management of the deal. In particular, shirking and other opportunistic behaviors typically arise when the technological knowledge is transferred from the contractor to the focal firm. The personal ties, reputation and informal approach provided by external consultants mitigate these problems and ensure that the transferred knowledge is not limited to the codified and contractually agreed parts but also includes the tacit knowledge that resides in invidual minds. Bell and Zaheer (2007) show that social relationships between staff from different organizations are superior conduits for knowledge flow between geographically separate and culturally different entities. Therefore, the involvement of external consultants allows the focal firm to develop the capability to amplify the transfer during the collaboration with the R&D contractor, including both tacit and codified aspects.

In the light of the influence that the involvement of external consultants in R&D activities has on critical capabilities for managing IOI (summarized in the upper part of Table 1), the following hypothesis is presented:

H1: The relationship between external technological knowledge acquired through R&D outsourcing and product innovation performance is positively moderated by the involvement of external consultants.

[Table 1]

The moderating role of a dedicated R&D unit

The existence of a dedicated R&D unit is posited to positively moderate the IOI-performance relationship. This effect derives from the influence played by this organizational mechanism on certain capabilities needed to productively acquire technological knowledge from R&D contractors and to transform it into new products, which are discussed below.

Establishing a dedicated R&D unit is a formalized decision that deeply impacts a firm's existent structures and routines. The higher openness of innovation processes calls the R&D function to assume a new role. Rather than being the repository of a firm's core technological competencies where internal innovation opportunities are generated and pursued, the R&D unit takes on critical brokering functions to effectively leverage external sources of technology (Chiesa and Frattini, 2008). Playing a brokering role implies that the professionals in the R&D unit have to perform or at least coordinate previously distant tasks, such as due diligence, partner screening, negotiation and relationship management. The continuity of action resulting from assigning employees to a dedicated unit fosters learning effects based on prior experience. The unit thus becomes a collector for the know-how on IOI available in the company (Zollo and Winter, 2002). In an examination of innovation alliances, Kale *et al.* (2002) show that establishing a dedicated function to capture, integrate, and disseminate experience-based alliance know-how is a significant driver of success, above and beyond the positive effect of experience. Therefore, it can be argued that the existence of a dedicated R&D unit enhances the firm's capability to leverage learning effects about how external technological knowledge should be acquired and transformed into new products.

Stronger IOI capabilities rest not only upon experiential learning, but also on the creation of routines that articulate and codify the procedural knowledge gained from prior experience with R&D outsourcing. The development of these routines, which are at the basis of deliberate learning, and their diffusion within the organization are favored by the establishment of a dedicated R&D unit (Kale and Singh, 2007), which contributes to a more formalized management of IOI management. Routines help reduce the amount of managerial attention needed to perform R&D outsourcing, and can make more efficient use of the available attention (Ocasio, 1997). Consequently, firms can rely more on R&D outsourcing without suffering from its negative effects. Therefore, the existence of a dedicated R&D unit allows the focal firm to develop a critical capability for IOI, namely the capability to establish formalized routines for the acquisition of external technological knowledge.

A dedicated unit that pools R&D resources allows the firm to develop a thorough understanding of its technological needs and of the future desired trajectories. This helps making correct decisions about the R&D tasks to be outsourced and the external contributor with which to collaborate. Better assessment of the current knowledge endowment of the firm and of its knowledge gaps, and the constant monitoring of their evolution, reduce the risks that critical technical competencies weaken as the reliance over external technology increases. Therefore, the existence of a dedicated R&D unit contributes to the development of the capability to understand and anticipate the technological needs of the focal firm.

Once the external technological knowledge is absorbed, the dedicated R&D unit serves as an internal hub for synthesizing, reconfiguring and aligning the knowledge pertaining to different technical domains and originating from external and internal sources (Faraj and Sproull, 2000; Kale and Singh, 2007). By leveraging complementarities between heterogeneous knowledge bases and generating novel combinations, a dedicated R&D unit improves the firm's capability to combine and integrate external technology with its internal knowledge basis. A dedicated R&D unit also helps the focal firm establish a more defined governance structure for the R&D outsourcing agreement, where authority and responsibility over activities and results are clearly assigned and communicated. A collaboration organized this way is more likely to be allocated the necessary resources, to be protected from organizational interference and to avoid being hostage to political conflicts.

Finally, a dedicated unit allows a more accurate and timely monitoring of the contractors' behavior, of the respect of milestones, of budgets and of quality targets. This should reduce the magnitude of ex-post transaction costs that severely characterize technology transfer deals, where the contractor may act opportunistically and reduce the effort and the quality of the information supplied. Through a dedicated R&D unit, the focal firm can thus develop the capability to monitor the behavior of the contractor during the technology transfer process.

In the light of the influence that the existence of a dedicated R&D unit has on critical capabilities for managing IOI (summarized in the lower part of Table 1), the following hypothesis is presented:

H2: The relationship between external technological knowledge acquired through R&D outsourcing and product innovation performance is positively moderated by the existence of a dedicated R&D unit.

SAMPLE AND MEASURES

The article draws on longitudinal data from the Spanish Business Strategy Survey (SBSS), an annual survey of a representative sample of Spanish manufacturing firms conducted by the Spanish Ministry of Industry, Tourism and Commerce. Firms in the survey represent 20 industrial sectors according to the NACE-Rev.1 classification (National Classification of Economic Activities, revised in 1993). Overall, the sample ranges from 1999 to 2007, including 1,856 firms. Because some firms stopped providing information during the sample period for several reasons and because only firms whose data were available for at least three consecutive years are included, the article is based on an unbalanced panel of 841 firms, consisting of 6,161 firm-year observations. Table 2 provides an overview of the entire sample.

[Table 2]

Dependent variable

A firm's product innovation performance (NP_{it}) is measured using the number of new products developed and commercialized by firm *i* in year *t*. In the dataset, new products are recognized as such only if they are completely different from previous product lines or if they have undergone substantial modifications from existing products. Therefore the number of new products measures both the firm's ability to introduce new products in the market and its ability to upgrade current ones, which are critical indicators of innovative performance (Schoonhoven *et al.*, 1990). Other studies use closely related measures of innovative performance such as patents, invention counts and sales growth (Ahuja and Katila, 2001; Scherer, 1983). By using this measure, this study departs from Grimpe and Kaiser (2010) who use the share of sales due to products new to the market. Firms in this sample introduced, on average, 4.25 new products annually.

Independent variable

The level of external technological knowledge acquired through R&D outsourcing ($R\&D\_Outsourcing_{it}$) is measured using the average ratio of expenditures for R&D outsourcing in Euros over total sales, spent by firm *i* in the last three years *t*, *t-1* and *t-2*. This operationalization allows controlling for endogeneity concerns. The ratio, instead of the absolute expenditures, is used in order to remove size effects. In addition, as for some sample firms sales are close to zero, this produces an extremely skewed and leptokurtic distribution of the R&D outsourcing ratio. Because the presence of outliers could severely bias the results, this variable is winsorized (e.g., Dixon and Yuen, 1974) with a 1% cut-off for each tail. Specifically, the value corresponding to the 99th percentile of its distribution is calculated, and assigned to all observations falling beyond it. This approach, which is established in innovation research (Nguyen *et al.*, 2010, Baum *et al.*, 2013), reduces the impact of outliers and allows the use of a larger number of observations than it would be possible if outliers were deleted. The average sample firm invests, on average, 0.204% of its sales in R&D outsourcing. Out of 841 firms, 516 had positive R&D outsourcing expenditures. The ratio among R&D outsourcing expenditures over sales range for these firms from 0.0001% to 3.435%, with an average ratio equals to 0.454% (0.118% in median).

Moderating variables

To investigate the moderation played by the R&D organization, two items that capture whether a firm uses the following organizational mechanisms in R&D are considered: (i) involvement of external consultants in R&D activities ($R\&D\_Consultants_{it}$); (ii) existence of a dedicated R&D unit ($R\&D\_Unit_{it}$)[i]. These items, measured every year, are dummy variables that take value 1 if the firm *i* used the specific mechanism in at least one of the last three years. The moderating factors over three years are estimated in order to control for the endogeneity of these factors. Moreover, it should be considered that the effect on innovation performance may not occur for some time[ii]. During the years covered in the sample, 532 firms involved external consultants in R&D, whereas a dedicated R&D unit existed in 487 firms. 381 firms use both organizational mechanisms, representing a subset of the firms previously considered.

Control variables

Following seminal studies on absorptive capacity (Cohen and Levinthal, 1990; Rothaermel and Alexander, 2009), internal R&D ($R\&D\_Internal_{it}$) is included as a control variable. The same procedure is used to estimate the R&D outsourcing variable and internal R&D is measured as the average ratio between internal R&D expenditures in Euros and total sales estimated over the last three years, and winsorized at 1% level. *Existing products$_{it}$* measures in logarithms (logs) the whole range of products commercialized by firm *i* in year *t*. This control gives the opportunity to partial out differences across firms in terms of the weight that product innovation has on the overall firm's product business. In order to control for the cumulated knowledge basis of the firm, the variable *Patents stock$_{it}$* is included, which accounts for the size of a firm's patent portfolio in logs, including both national and international patents granted to firm *i* in year *t*. A dummy variable $Patents_{it}$ is also included, indicating whether firms have patents or not, because many sample firms do not have any patent. To control whether firms faces international competition, a dummy variable $Export_{it}$ is used, indicating if firms export products or not. Furthermore, the relevance of export is taken into account by including the share of sales from exports ($Export\ intensity_{it}$). A dummy variable ($Subsidized_{it}$) indicates whether the firm received a public subsidy. The number of employees in logs is used to measure firm size ($Employees_{it}$). This variable is preferred over sales or other measures of size because it is more stable across time and less sensible to macroeconomic shocks. Age_{it} is measured with the number of years since foundation in logs. The average sample firm is 28 years old and has 362 employees. Finally, possible macroeconomic and business cycle shocks common to all industrial sectors are controled, using time dummies for all the years in the sample.

Table 3 provides the descriptive statistics and bivariate correlation matrix for the variables included in the analysis.

[Table 3]

MODEL SPECIFICATION

To test the IOI-performance relationship, the following model is estimated as the baseline (please see the Appendix for a more detailed description of model specification, and Tables 4 and 5 for the empirical results):

$$y_{it} = \beta_0 + \beta_1 R\&D\_Outsourcing_{it} + \beta_2 R\&D\_Outsourcing_{it}{}^2 + \sum_j \beta_j x_{it}^j + \varphi Z_t + \varepsilon_{it} \quad [1]$$

where y_{it} is the logarithm of NP_{it}, the number of new products developed and commercialized by firm *i* in year *t*, $R\&D\_Outsourcing_{it}$ measures the level of IOI through R&D outsourcing, and x_{it}^j are the control variables, as defined in Sections 3.1, 3.2, 3.4., Z_t contains period fixed effects and ε_{it} is an error term. β_1 is expected to be positive and significant and β_2 to be negative and significant, indicating an inverted U-shaped relationship between IOI through R&D outsourcing and product innovation performance. The baseline model (Equation 1) is modified as follows. First, a model is derived that only includes the direct effect of the two R&D organizational mechanisms on product innovation performance:

$$y_{it} = \beta_0 + \beta_1 R\&D\_Outsourcing_{it} + \beta_2 R\&D\_Outsourcing_{it}{}^2 + \beta_3 M_{it} + \sum_j \beta_j x_{it}^j + \varphi Z_t + \varepsilon_{it} \quad [2]$$

where M_{it} indicates the proxies for the use of R&D organizational mechanisms ($R\&D\_Consultants_{it}$ and $R\&D\_Unit_{it}$), as described in Section 3.3. More in detail, two different models are estimated in which the direct effect of each R&D organizational mechanism under analysis is inserted separately (see Model A1 and Model B1 in Tables 4 and 5). The direct effect engendered by each moderating variable is described by the coefficient β_3: if positive and significant, it would indicate an increase of product innovation performance related to the use of the specific mechanism.

To test the hypotheses on the moderation caused by the R&D organizational mechanisms (H1 and H2), two different operationalizations found in prior innovation research are used. The first, named *Moderation Effect 1*, refers to the effect that the moderating variable has on the *elasticity* of the inverted U-shaped IOI-performance curve. According to this operationalization and the hypotheses, the adoption of a specific organizational mechanism (involvement of external consultants or existence of a dedicated R&D unit) positively moderates the inverted U-shaped IOI-performance relationship because the marginal benefits of increasing the level of R&D outsourcing on product innovation performance are stronger when the firm adopts the specific organizational mechanism. This operationalization of moderation has been used by Rothaermel and Alexander (2009) who show that the slope (elasticity) of the inverted U-shaped relationship between technology sourcing mix and firm financial performance becomes steeper when the firm possesses higher levels of absorptive capacity.

The second operationalization, named *Moderation Effect 2*, refers to the effect that the moderating variable has on the horizontal positioning of the *tipping point* of the inverted U-shaped IOI-performance curve. According to this operationalization and the hypotheses, the IOI-performance relationship is positively moderated by the adoption of a specific organizational mechanism (involvement of external consultants or existence of a dedicated R&D unit) in such a way that the tipping point after which increasing R&D outsourcing has negative effects on product innovation performance is reached at higher levels of R&D

outsourcing when the firm adopts the specific organizational mechanism. This operationalization of moderation has been used by Grimpe and Kaiser (2010) who find that the tipping point of the IOI-performance curve moves towards higher levels of R&D outsourcing as the firm's internal R&D and breadth of R&D collaborations increase. Figures 1a and 1b illustrate the two distinct moderating effects and show that four types of curves can result from the moderation played by each organizational mechanism on the baseline, depending on the sign of each moderation effect (positive or negative). In the hypotheses H1 and H2, both a positive *Moderation Effect 1* and a positive *Moderation Effect 2* are hypothesized to exist.

[Figure 1]

The distinction between *Moderation Effect 1* and *Moderation Effect 2* is relevant, because the two effects have different implications from a managerial point of view. A positive *Moderation Effect 1* signals that an increase in the level of R&D outsourcing leads to a stronger improvement of product innovation performance when the firm uses a specific organizational mechanism. Instead, a positive *Moderation Effect 2* indicates that, by using a specific organizational mechanism, the firm starts experiencing the negative effects of IOI on product innovation performance at higher levels of R&D outsourcing. These two operationalizations of moderation have not been tested jointly in innovation research so far, and thus represent a further contribution of this article.

To assess moderation, the following model is estimated, in which the interaction terms of the moderating variables with both the linear and the squared terms of $R\&D\_outsourcing_{it}$ are included:

$$y_{it} = \beta_0 + \beta_1 R\&D\_Outsourcing_{it} + \beta_2 R\&D\_Outsourcing_{it}{}^2 + \beta_3 M_{it} + \beta_4 M_{it} * R\&D\_Outsourcing_{it} + \beta_5 M_{it} * R\&D\_Outsourcing_{it}{}^2 + \sum_j \beta_j x_{it}^j + \varphi Z_t + \varepsilon_{it} \quad [3]$$

Two different models are estimated in which the effect of $R\&D\_Consultants_{it}$ and $R\&D\_Unit_{it}$, and their interactions with the linear and the squared terms of $R\&D\_Outsourcing_{it}$, are inserted separately (see Model A2 and Model B2 in Tables 4 and 5). *Moderation Effect 1* exists if the elasticity of the IOI-performance relationship is modified by the presence of the specific moderating factor M_{it}. Thus, both the linear and the squared terms of $R\&D\_Outsourcing_{it}$ must be evaluated in presence of the moderating factor M_{it}. Because the sign and the significance of the coefficients β_4 and β_5 only indicate how and whether each moderating variable influences the IOI-performance relationship, a test is conducted on a combination of parameters in Equation [3] that allow estimation of both the linear and the squared terms of R&D outsourcing in the presence of the moderating factor M_{it}, as follows:

$$\begin{cases} Linear\ term\ of\ R\&D\_Outsourcing_{it} = \beta_1 + \beta_4 \\ Squared\ term\ of\ R\&D\_Outsourcing_{it} = \beta_2 + \beta_5 \end{cases} \quad [4]$$

In order to evaluate *Moderation Effect 2* the level of R&D outsourcing at which the curve reaches its maximum is estimated as follows:

$$-(\beta_1 + \beta_4)/2(\beta_2 + \beta_5) \quad [5]$$

RESULTS

The results of the estimation models predicting product innovation performance are shown in Table 4, which reports the following models: the baseline model, which includes all the control variables as well as the independent variable $R\&D\_Outsourcing_{it}$; Model A1, which considers only the direct effect of $R\&D\_Consultants_{it}$; Model A2, which includes also its moderating effect to test H1; Model B1, which considers only the direct effect of $R\&D\_Unit_{it}$; Model B2, which includes also its moderating effect to test H2.

[Table 4]

Considering the baseline model, an inverted U-shaped relationship exists between external technological knowledge acquired through R&D outsourcing and product innovation performance. The linear term of $R\&D\_Outsourcing_{it}$, β_1, is positive and significant, while the squared coefficient, β_2, is negative and significant. This result holds in all models (except for Model A2, where the coefficients have the predicted sign but lose significance). In the baseline model the tipping point from which additional R&D outsourcing has a negative effect on product innovation performance is estimated, by performing the following test: $-\frac{\beta_1}{2\beta_2}$. The test indicates that the tipping pont is reached at a level of R&D outsourcing equal to 2.061%

of firm sales. The positive and significant β_3 coefficients in Models A1 and A2 indicate that firms that involve external consultants in R&D activities achieve higher product innovation performance. The same coefficients in Models B1 and B2 show the same results for firms that establish a dedicated R&D unit.

Hypothesis H1 predicts that the involvement of external consultants in R&D activities positively moderates the IOI-performance relationship. Model A2 includes both the linear and squared interaction terms between $R\&D\_Consultants_{it}$ and $R\&D\_Outsourcing_{it}$, whose coefficients are found significant, indicating that the involvement of external consultants modifies the IOI-performance curve. Specifically, the linear interaction term is positive and significant and the squared term of interaction is negative and significant. To assess the shape of the moderated curve, the coefficients of the linear and squared terms of R&D outsourcing when external consultants are involved are estimated, according to Equation [4]. These coefficients, reported in Table 5 (Model A2, lower part "With R&D organizational mechanisms"), are found to be significant, thus suggesting that the IOI-performance relationship is still U-shaped in the presence of external consultants and that the involvement of external consultants has a positive *Moderation Effect 1*, i.e., it increases the elasticity of the IOI-performance curve by strengthening the marginal effects of increasing the level of R&D outsourcing on product innovation performance. To correctly evaluate *Moderation Effect 2*, the results of Equation [5] are considered, where the tipping point of this moderated curve is estimated (Model A2). It is found that the tipping point for firms that involve external consultants is reached at a lower level of R&D outsourcing equal to 1.934% of firm's sales, while the one estimated in the baseline model is equal to 2.061% of firm sales. This suggests a negative *Moderation Effect 2.* Therefore, hypothesis H1 is supported if the moderation of the involvement of external consultants is operationalized as *Moderation Effect 1*, while the same hypothesis is rejected if the moderation is operationalized as *Moderation Effect 2*.

Hypothesis H2 predicts that the existence of a dedicated R&D unit positively moderates the IOI-performance relationship. Model B2 includes both the linear and squared interaction terms between $R\&D\_Unit_{it}$ and $R\&D\_Outsourcing_{it}$. The results in this model indicate that the existence of a dedicated R&D unit modifies the IOI-performance curve. This is true because, even though the squared term of interaction is not significant, the linear term of interaction is found negative and significant. The shape of the moderated curve can be assessed by estimating Equation [4]. As reported in Table 5 (Model B2, lower part "With R&D organizational mechanisms"), the coefficients of the linear and squared terms of R&D

outsourcing when a dedicated R&D unit exists, are significant and with the expected signs, suggesting that the IOI-performance relationship has still an inverted U-shape in the presence of a dedicated R&D unit. The lower value (in absolute terms) of the coefficients indicates that the existence of a dedicated R&D unit has a negative *Moderation Effect 1*, i.e., it reduces the elasticity of the IOI-performance curve by attenuating the marginal effects of increasing the level of R&D outsourcing on product innovation performance. To correctly evaluate *Moderation Effect 2*, the results of Equation [5] to estimate the tipping point of this moderated curve are examined (Model B2). It is found that the tipping point for firms with a dedicated R&D unit is reached at a higher level of R&D outsourcing equal to 2.158% of firm's sales, compared to the tipping point in the baseline model equal to 2.061% of firm sales. This result suggests a positive *Moderation Effect 2*. Therefore, hypothesis H2 is supported if the moderation of the existence of a dedicated R&D unit is operationalized as *Moderation Effect 2*, while the same hypothesis is rejected if the moderation is operationalized as *Moderating Effect 1*.

[Table 5]

Figures 2a and 2b illustrate the shapes and the tipping points of the IOI-performance curve estimated in the baseline model and of the curves moderated, respectively, by the involvement of external consultants and by the existence of a dedicated R&D unit (only the coefficients for R&D outsourcing are plotted; the other coefficients are set at the value of zero).

[Figure 2]

Finally, as a complement to the theoretical framework proposed in Section 2, a test is conducted for the existence of synergistic effects from the simultaneous use of external consultants and of a dedicated R&D unit. The example of leading firms with long experience in open innovation, such as Procter & Gamble (Huston and Sakkab, 2006), Fiat (Di Minin *et al.*, 2013) and DSM (Kirschbaum, 2005), point to the existence of benefits from combining informal and formalized organizational mechanisms. Thus, this study's empirical models contiain a dummy variable that takes value 1 if the firm *i* both involves external consultants in R&D ($R\&D\_Consultants_{it}$) and establishes a dedicated unit for R&D ($R\&D\_Unit_{it}$), in at least one of the last three years. The estimates of the models A3 and B3, built in the same fashion as for each single moderating variable, are reported in the last columns of Tables 4 and 5. The linear and the squared terms of interaction are both not significant. These results suggest that the combined presence of external consultants and a dedicated R&D unit does not significantly influence the effects of R&D outsourcing on product innovation performance, leaving the shape and the tipping point of the curve unaltered. The coefficients of the linear and squared terms of R&D outsourcing when both external consultants and a dedicated R&D unit exist, estimated by Equation [4] and reported in Table 5 (Model B3, lower part "With R&D organizational mechanisms"), are significant, indicating that the IOI-performance curve is still U-shaped. Overall, the results of the empirical analysis suggest that by combining the use of external consultants with the presence of a dedicated R&D unit, their moderation effects on the IOI-performance relationship may cancel out.

DISCUSSION AND CONCLUSIONS

IOI is a major component of the innovation approach of most innovative firms. To deepen the understanding of this important phenomenon, this article investigates the influence of two R&D organizational mechanisms on the relationship between external technological knowledge acquired through R&D outsourcing and product innovation performance. Besides showing that this relationship has an inverted U-shape, the empirical study identifies multiple moderating effects stemming from the involvement of external consultants in R&D activities and from the existence of a dedicated R&D unit. The results concerning *Moderation Effect 1* indicate that the involvement of external consultants strengthens the marginal benefits of R&D outsourcing on product innovation performance (in the ascending part of the curve), whereas the existence of a dedicated R&D unit attenuates these benefits. The results concerning *Moderation Effect 2* show that the involvement of external consultants reduces the optimal level of R&D outsourcing to which the highest product innovation performance corresponds, whereas the existence of a dedicated unit increases the optimal level (see Table 6). Below is an interpretation of these findings and, in particular, of the contrasting results from the two different operationalizations of the moderation.

[Table 6]

The involvement of external consultants in R&D activities can be interpreted as an organizational mechanism that makes the firm more sensitive to the impact of changes in the level of R&D outsourcing on product innovation performance. This mechanism increases the elasticity of the inverted U-shaped curve while reducing the value of R&D outsourcing that corresponds to the highest number of new products developed and commercialized. The involvement of external consultants may increase the proficiency of the focal firm in scouting and identifying potentially valuable contractors. By leveraging the thick extended social networks of the external consultants, firms can access the most suitable partners whose R&D services contribute to higher product innovation performance. The personal ties and credibility afforded by external consultants contribute to more collaborative and trust-based outsourcing agreements where the different languages and knowledge domains existing within and across the counterparts are harmonized. In this environment, the knowlege transfer process is augmented, meaning that by involving external consultants the firm can make the most out of the acquired technological knowledge and achieve the highest innovation performance at lower levels of R&D outsourcing.

The establishment of a dedicated R&D unit can be interpreted instead as an organizational mechanism that reduces the sensitivity of the firm's innovation performance to changes in the level of R&D outsourcing. This mechanism attenuates the marginal benefits from R&D outsourcing while increasing the level of R&D outsourcing after which its effects on product innovation become negative. This latter effect may occur because, by establishing a dedicated R&D unit, the firm may better address the typical drawbacks of extensive IOI such as lower knowledge appropriability and loss of control over core competencies. The existence of a dedicated R&D unit supports the creation of formalized routines that govern the process of acquiring technological knowledge from external sources. While this level of formalization may introduce some rigidity and may result in a lower marginal contribution to innovation performance of each R&D outsourcing agreement, the existence of a dedicated R&D unit allows firms to do more inbound open innovation without suffering from its negative effects, e.g., as a result of more effective monitoring of the partner behavior and reduced knowledge spillovers.

The different moderating role played by the two organizational mechanisms might suggest that they have contrasting effects on the critical capabilities for managing IOI and also explain why their combined use has no significant effect on the IOI–performance relationship. This result is not in line with existing anecdotal evidence that highlights the advantages of an assorted approach to the organization of open innovation processes (Di Minin *et al.*, 2013; Kirschbaum, 2005). Procter & Gamble's Connect & Develop system, for instance, is successfully supported by both informal decentralized mechanisms, like the technology entrepreneurs network, and centralized formalized ones, like the External

Business Development Group (Huston and Sakkab, 2006). While these synergistic effects may occur only at companies at the forefront of open innovation practice, the diverse firms investigated in this large scale empirical study may experience inefficiencies due to the increased complexity and investments required by combining the two R&D organizational mechanisms.

Implications for research

This article has implications for research on open innovation, R&D management, absorptive capacity and related capabilities. Regarding open innovation, this study offers a thorough analysis and critical re-examination of IOI and of its impact on firm's performance, thus contributing to the current debate on this topic (Laursen and Salter, 2006; West and Bogers, 2013). The findings for R&D outsourcing, which among the different forms for IOI has received less attention among scholars, are consistent with those reported in Deeds and Hill (1996) and Rothaermel and Deeds (2006), that show an inverted U-shaped relationship between IOI and innovation performance. As these studies focus on strategic alliances in the context of entrepreneurial biotech firms, it appears that the abovementioned curvilinear relationship is generalizable, regardless of the contractual form used to acquire external technological knowledge and of the characteristics of the innovative firm. Moreover, this study supports the need to adopt a contingency perspective when studying the phenomenon of IOI. The proficiency with which a firm acquires and transforms external technological knowledge depends on a set of organizational mechanisms. The focus on R&D organization contributes to research on open innovation, where few articles have systematically investigated which organizational levers affect the performance of open innovation processes and how (Bianchi *et al.*, 2011).

The article also contributes to research on the organisation of R&D activities (Chiesa, 2001). Research on the critical success factors for R&D and new product development highlights the importance of formalizing R&D activities and of creating social and personal ties to establish rich communication networks. This article indicates that these two R&D organizational mechanisms, which have been traditionally studied in a context of closed innovation, continue playing a key role under the more recent, and arguably more complex, open innovation paradigm. This role varies depending on the specific nature of the organizational mechanism, as discussed in this article.

Finally, this article extends prior capabilities research, in particular the stream focusing on absorptive capacity. Absorptive capacity has been typically conceptualized and measured with aggregate variables like internal R&D expenditures or patent stocks (Rothaermel and Alexandre, 2009). The rationale was that a stock of prior internal technological knowledge increases the proficiency with which firms absorb and exploit external knowledge. The analysis shows that this focus on resources as antecedents of absorptive capacity is not sufficient. Instead, absorptive capacity strongly depends on the adoption of appropriate R&D organizational mechanisms that influence the capabilities needed to transform external technological knowledge into new products (Zahra and George, 2002). This article conceptually identifies these capabilities and suggests that they may be differently influenced by distinct organizational mechanisms. The results for formalized versus informal mechanisms inform the growing body of capability-based studies in several managerial settings, e.g., new product development and alliance management, about the need to account for the heterogeneity of R&D organization and for its differential role in capability development.

Implications for managers

This study provides important managerial implications. First, it highlights the positive impact that IOI has on a firm's product innovation performance. Firms that ground their competitive advantage on product innovation can acquire external technological knowledge to increase the number of new products that they develop and commercialize. Nevertheless, the study advises managers against the risk of over-acquiring external technological knowledge. The results show that an optimal level of expenditures for R&D outsourcing exists. After this point, acquiring technology knowledge from external sources has detrimental effects on innovation performance. In this sample of Spanish manufacturing firms, the optimal ratio of R&D outsourcing expenditures to sales is approximately 2%. Of course, this level varies depending on a large number of influencing variables.

This study also provides managers with suggestions as to how they can improve the benefits of IOI on innovation performance. The involvement of external consultants and the establishment of a dedicated R&D unit can serve this purpose, although they have different effects. The involvement of external consultants increases the sensitivity of the firm's innovation performance to changes to the level of R&D outsourcing. It thus allows achieving larger innovation outputs even with small increases of R&D outsourcing. However, this mechanism reduces the level of R&D outsourcing after which its negative consequences become manifest. Therefore, involving external consultants seems to be more appropriate for those firms that have relatively low levels of R&D outsourcing expenditures and want to increase their product innovation performance on an ad hoc basis, by increasing the level of IOI.

On the other hand, the existence of a dedicated R&D unit attenuates the sensitivity of of the firm's innovation performance to changes to the level of R&D outsourcing. It reduces the increase of product innovation performance resulting from raising the expenditures for R&D outsourcing but it allows reaching high levels of R&D outsourcing before its negative consequences occur. Therefore, establishing a dedicated R&D unit seems to be more appropriate for those firms that have significant expenditures for R&D outsourcing and need to manage and orchestrate a constant and extensive flow of technological knowledge coming from external sources.

Limitations and future research

This study has several limitations, which suggest future research efforts. First, it should be noted that the methodology only accounts for the quantitative aspect of product innovation, and not for its quality. The dependent variable could be improved by considering the impact that IOI has on the profitability of product innovation (e.g, by measuring the return on investment of a firm's new product development projects). This will likely capture other benefits associated with IOI, such as cost reduction and flexibility in internal R&D.

Second, this work may be at risk of aggregation bias as no distinction is made between R&D outsourcing agreements at different stages of the innovation value chain and with different partners. Also, the study focuses on outcomes at the firm level of analysis. A more fine-grained analysis at the individual project level may offer a deeper understanding of the moderating role played by the organization of R&D. Being binary variables, the measures for R&D organizational mechanisms are rather aggregate and do not allow capturing the nuances in the design and use of the same mechanisms. Also the data do not explicitly capture whether and how these mechanisms are used in the context of IOI, which is thus a strong, although reasonable, assumption.

Future research is encouraged to study the micro-dynamics through which R&D organizational mechanisms influence the firm's capabilities for managing IOI, not only at the firm level of analysis but also at the project and individual levels. Indeed, these capabilities appear to build on the knowledge and skills of individuals, on their interaction and on the tasks executed to transfer knowledge in well-defined projects. Going beyond the findings of this study, future research should adopt a contingency perspective to scrutinize under what contextual factors managers should apply each of the two organizational mechanisms.

Future studies should also broaden the scope of the analysis, including service sectors, other contractual forms for acquiring external technological knowledge, as well as other managerial and organizational levers that can be used to support IOI (e.g., types of incentives given to R&D employees). In so doing, the set of capabilities discussed in this article in relation to R&D outsourcing can be used as a starting point and extended to properly account for the peculiar challenges entailed by different IOI forms.

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APPENDIX

Because the dependent variable NP_{it} is a count outcome taking non-negative integers, a regression approach for Poisson data is suitable. However, the classical Poisson regression is sensitive to distributional assumptions (Cameron and Trivedi, 1986). Considering that the data show some overdispersion, a negative binomial model is used (Greene, 1999) estimated trough a fixed effects model. The model specification is the following:

$$NP_{it} = e^{X'_{it}\beta} \qquad \text{[A.1]}$$

where NP_{it} is the number of new products developed and commercialized by firm *i* in year *t* and X'_{it} is the matrix of regressors. The log-linear model of Equation [A.1] can be written as follows:

$$y_{it} = \sum_j \beta_j x_{it}^j + \varepsilon_{it} \qquad \text{[A.2]}$$

where y_{it} is the logarithm of NP_{it}, and x_{it}^j are the regressors included in the model.

All the models used in the study (Model A and Model B) are derived from Equation A.2 by introducing the independent variables, the moderating factors and the control variables described in Section 3.

TABLES

Table 1: A summary of the critical capabilities for managing IOI that are influenced by each R&D organizational mechanism.

	Capabilities for managing IOI
Capabilities that are influenced by the involvement of external consultants in R&D activities	Scouting and identifying potentially valuable providers of R&D outsourcing services
	Creating a trustworthy relationship with the external contractor
	Effectively negotiating the terms of the R&D outsourcing agreement
	Amplifying the transfer of knowledge during the collaboration with the external contractor, including both tacit and codified aspects
Capabilities that are influenced by the establishment of a dedicated R&D unit	Leverage learning effects about how external technology is acquired through R&D outsourcing and transformed
	Establishing formalized routines for the acquisition of external technological knowledge
	Understanding and anticipating the technological needs of the focal firm
	Combining and integrating external technological knowledge with the internal knowledge basis of the focal firm
	Establishing defined governance structures for R&D outsourcing agreements
	Monitoring the behavior of the contractor during the technology transfer process

Table 2: Sample overview

Industry	Number of firms	%	Number of firms with 3 consecutive years of observation	Number of firms with 4 consecutive years of observation	Number of firms with 5 consecutive years of observation	Number of firms with more than 5 consecutive years of observation	Average number of new products	Average R&D outsourcing expenditures as % of sales
Meat processing	49	2,64	15	13	12	10	2,81	0,06
Food and tobacco	177	9,54	80	64	62	47	2,12	0,09
Beverages	41	2,21	23	17	17	9	1,41	0,07
Textile	175	9,43	68	60	56	45	13,75	0,12
Leather and shoes	58	3,13	25	20	19	15	9,30	0,12
Wood and timber	65	3,50	15	13	11	8	0,53	0,16
Paper and printing products	59	3,18	21	17	16	12	2,80	0,03
Editing and graphical arts	98	5,28	25	22	21	16	7,32	0,04
Chemical products	131	7,06	88	71	69	52	3,20	0,45
Rubber and plastic products	93	5,01	52	43	43	34	2,50	0,14
Non-metallic mineral products	151	8,14	56	41	39	33	2,98	0,12
Metallurgy	57	3,07	28	25	25	20	1,78	0,10
Metal products	202	10,88	57	49	48	38	3,10	0,23
Machines and mechanical equipment	117	6,30	77	57	55	47	2,61	0,25
Office and data processing machines	26	1,40	14	8	7	5	2,88	0,57
Electric and electronic machinery	99	5,33	60	43	41	31	5,65	0,29
Motor vehicles	91	4,90	51	47	46	35	3,31	0,34
Other transport equipment	40	2,16	26	21	20	18	1,59	0,64
Furniture	90	4,85	45	41	40	33	4,10	0,04
Other manufacturing products	37	1,99	15	13	12	9	7,93	0,01
Total	**1,856**	**100**	**841**	**685**	**659**	**517**	**4.25**	**0.20**

Table 3: Means, standard deviations and correlations

		Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13
1	NP_{it}	4,254	19,336	1												
2	$R\&D\_Outsourcing_{it}$	0,205	0,587	0,015	1											
3	$R\&D\_Consultants_{it}$	0,445	0,497	0,050***	0,143***	1										
4	$R\&D\_Unit_{it}$	0,440	0,496	0,037***	0,203***	0,342***	1									
5	$R\&D\_Internal_{it}$	0,429	0,958	0,056***	0,479***	0,146***	0,317***	1								
6	$Existing\ products_{it}$	0,754	0,160	-0,005	0,011	0,024*	0,073***	0,025*	1							
7	$Patents_{it}$	0,109	0,312	0,001	0,180***	0,139***	0,217***	0,207***	0,039***	1						
8	$Patents\ stock_{it}$	0,444	0,958	0,005	0,257***	0,206***	0,259***	0,304***	0,018	0,634***	1					
9	$Export_{it}$	0,801	0,399	0,072***	0,085***	0,152***	0,279***	0,142***	0,048***	0,125***	0,164***	1				
10	$Export\ intensity_{it}$	0,178	0,245	0,017	0,177***	0,108***	0,207***	0,253***	0,010	0,057***	0,129***	0,361***	1			
11	$Subsidized_{it}$	0,184	0,387	0,026**	0,278***	0,237***	0,386***	0,355***	0,040***	0,225***	0,234***	0,172***	0,165***	1		
12	$Employees_{it}$	4,788	1,487	0,032**	0,157***	0,292***	0,474***	0,119***	0,098***	0,166***	0,230***	0,407***	0,239***	0,316***	1	
13	Age_{it}	3,075	0,846	0,024*	0,073***	0,057***	0,150***	0,093***	0,009	0,044***	0,097***	0,092***	0,118***	0,101***	0,219***	1

***, **, and * represent statistical significance of 1%, 5% and 10%, respectively.

Table 4: Negative binomial estimation model predicting *Product innovation performance*

Variable description	Coeff.	Baseline	Model_A1	Model_A2	Model_B1	Model_B2	Model_A3	Model_B3
Independent Variables								
$R\&D\_Outsourcing_{it}$	β_1	0.5829 ***	0.5283 ***	0.2671	0.4617 ***	0.8493 ***	0.4505 ***	0.5129 ***
		(0,123)	(0,124)	(0,199)	(0,124)	(0,24)	(-0,125)	(0,177)
$R\&D\_Outsourcing_{it}{}^2$	β_2	-0.1414 ***	-0.1285 ***	-0.0372	-0.103 ***	-0.1858 **	-0.1042 ***	-0.1104 *
		(0,038)	(0,038)	(0,065)	(0,038)	(0,079)	(0,038)	(0,058)
Moderating Variables								
$R\&D\_Consultants_{it}$	β_3		0.2414 ***	0.2082 ***				
			(0,054)	(0,059)				
$R\&D\_Outsourcing_{it} * R\&D\_Consultants_{it}$	β_4			0.3869 *				
				(0,229)				
$R\&D\_Outsourcing_{it}{}^2 * R\&D\_Consultants_{it}$	β_5			-0.1319 *				
				(0,076)				
$R\&D\_Unit_{it}$	β_3				0.727 ***	0.791 ***		
					(0,066)	(-0,071)		
$R\&D\_Outsourcing_{it} * R\&D\_Unit_{it}$	β_4					-0.5141 *		
						(0,268)		
$R\&D\_Outsourcing_{it}{}^2 * R\&D\_Unit_{it}$	β_5					0.1081		
						(0,088)		
$R\&D\_BothMechanisms_{it}$	β_3						0.5387 ***	0.5667 ***
							(0,058)	(0,065)
$R\&D\_Outsourcing_{it} * R\&D\_BothMechanisms_{it}$	β_4							-0.1288
								(0,22)
$R\&D\_Outsourcing_{it}{}^2 * R\&D\_BothMechanisms_{it}$	β_5							0.0161
								(0,072)
Control Variables								
$R\&D\_Internal_{it}$		0.1576 ***	0.1542 ***	0.1559 ***	0.1255 ***	0.1289 ***	0.1492 ***	0.1505 ***
		(0,03)	(0,03)	(0,03)	(0,03)	(0,03)	(0,03)	(0,03)
$Existing\ products_{it}$		0.1647	0.1573	0.1492	0.1845	0.1735	0.1313	0.126
		(0,147)	(0,148)	(0,148)	(0,147)	(0,147)	(0,148)	(0,148)
$Patents_{it}$		0.4151 ***	0.417 ***	0.4205 ***	0.3768 ***	0.3694 ***	0.411 ***	0.4065 ***
		(0,071)	(0,071)	(0,071)	(0,07)	(0,07)	(0,071)	(0,071)
$Patents\ stock_{it}$		0.0167	-0.0012	-0.0026	0.0066	0.0127	-0.0242	-0.0199
		(0,036)	(0,037)	(0,037)	(0,036)	(0,036)	(0,037)	(0,037)
$Export_{it}$		0.4159 ***	0.4052 ***	0.4032 ***	0.3913 ***	0.3849 ***	0.3767 ***	0.3758 ***
		(0,092)	(0,093)	(0,093)	(0,093)	(0,093)	(0,093)	(0,093)
$Export\ intensity_{it}$		0.3937 ***	0.3821 ***	0.3748 ***	0.3507 ***	0.3591 ***	0.3578 ***	0.3577 ***
		(0,131)	(0,131)	(0,132)	(0,131)	(0,131)	(0,131)	(0,131)
$Subsidized_{it}$		0.2427 ***	0.224 ***	0.2232 ***	0.1868 ***	0.1913 ***	0.204 ***	0.209 ***
		(0,059)	(0,059)	(0,059)	(0,059)	(0,059)	(0,059)	(0,059)
$Employees_{it}$		0.1091 ***	0.0929 ***	0.097 ***	0.0054	0.0006	0.0659 **	0.0615 **
		(0,029)	(0,029)	(0,029)	(0,03)	(0,03)	(0,029)	(0,029)

Age_{it}	-0.162	***	-0.1543	***	-0.1556	***	-0.1734	***	-0.1758	***	-0.154	***	-0.1549	***
	(0,044)		(0,044)		(0,044)		(0,045)		(0,045)		(0,045)		(0,045)	
Year dummies	Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Costant	-2.8723	***	-2.852	***	-2.8449	***	-2.4702	***	-2.4556	***	-2.6585	***	-2.6419	***
	(0,316)		(0,316)		(0,316)		(0,322)		(0,323)		(0,319)		(0,319)	
N. Observations	6161		6161		6161		6161		6161		6161		6161	
N. Firms	841		841		841		841		841		841		841	
Chi2	658.8946		678.7546		682.7442		762.5623		764.817		737.0165		738.3285	
p-value	0		0		0		0		0		0		0	
Log likelihood	-7230		-7220		-7220		-7170		-7160		-7190		-7180	

***, **, and * represent statistical significance of 1%, 5% and 10%, respectively.

Table 5: Moderating Effects

Variable description	Coeff.	Baseline		Model_A1		Model_A2		Model_B1		Model_B2		Model_A3		Model_B3	
No R&D organizational mechanisms															
$R\&D\_Outsourcing_{it}$	β_1	0.5829	***	0.5283	***	0.2671		0.4617	***	0.8493	***	0.4505	***	0.5129	***
		(0,123)		(0,124)		(0,199)		(0,124)		(0,24)		(-0,125)		(0,177)	
$R\&D\_Outsourcing_{it}{}^2$	β_2	-0.1414	***	-0.1285	***	-0.0372		-0.103	***	-0.1858	**	-0.1042	***	-0.1104	*
		(0,038)		(0,038)		(0,065)		(0,038)		(0,079)		(0,038)		(0,058)	
With R&D organizational mechanisms															
$R\&D\_Outsourcing_{it}$	$\beta_1 + \beta_4$					0.6539	***			0.3352	**			0.3841	**
						(0,1444)				(0,1387)				(0,1571)	
$R\&D\_Outsourcing_{it}{}^2$	$\beta_2 + \beta_5$					-0.169	***			-0.0776	*			-0.0943	**
						(0,0444)				(0,0426)				(0,0478)	

***, **, and * represent statistical significance of 1%, 5% and 10%, respectively.

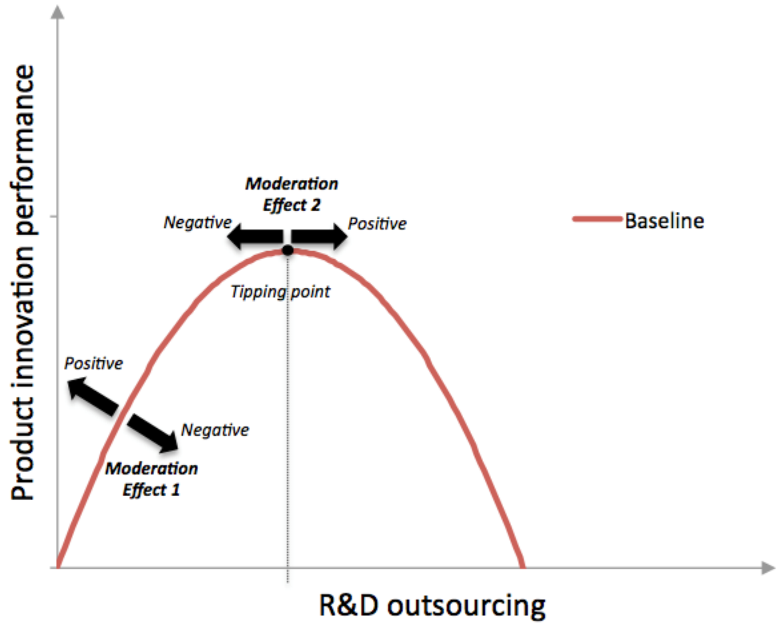
Table 6: Overview of the empirical results for the moderation effects

R&D organizational mechanisms	**Moderation Effect 1** Impact on the *elasticity* of the inverted U-shaped IOI-performance curve	**Moderation Effect 2** Impact on the *tipping point* of the inverted U-shaped IOI-performance curve
Involvement of external consultants in R&D activities	+	-
Establishment of a dedicated R&D unit	-	+

FIGURES

Figure 1: Moderation Effect 1 and 2.

a)



b)

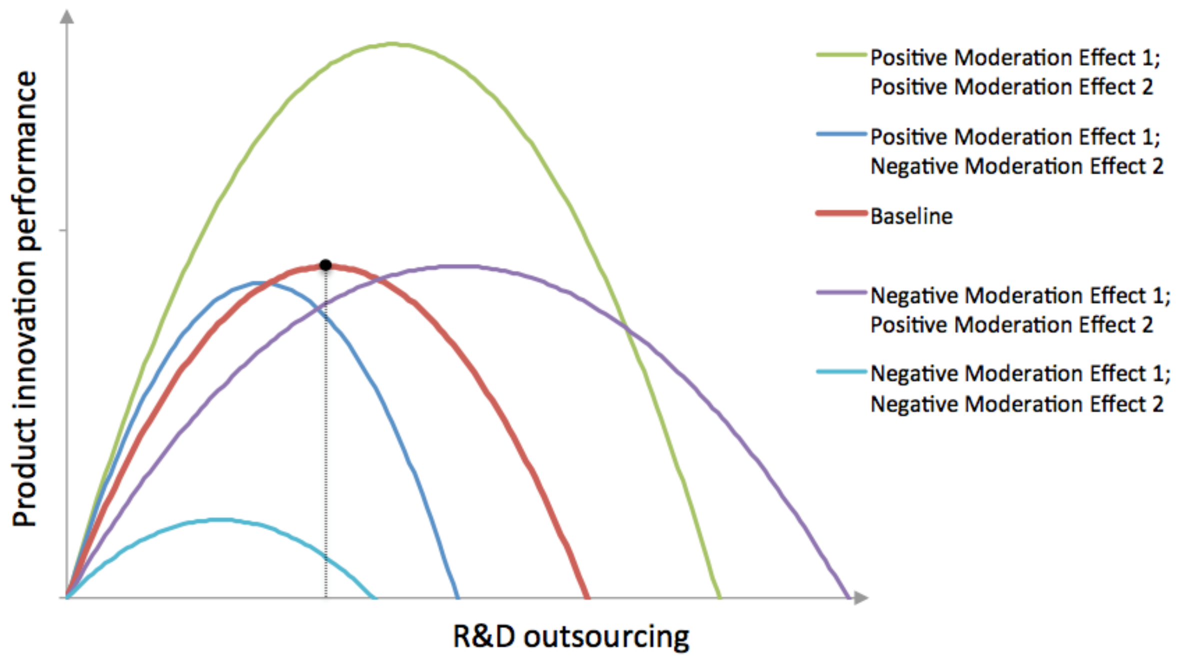
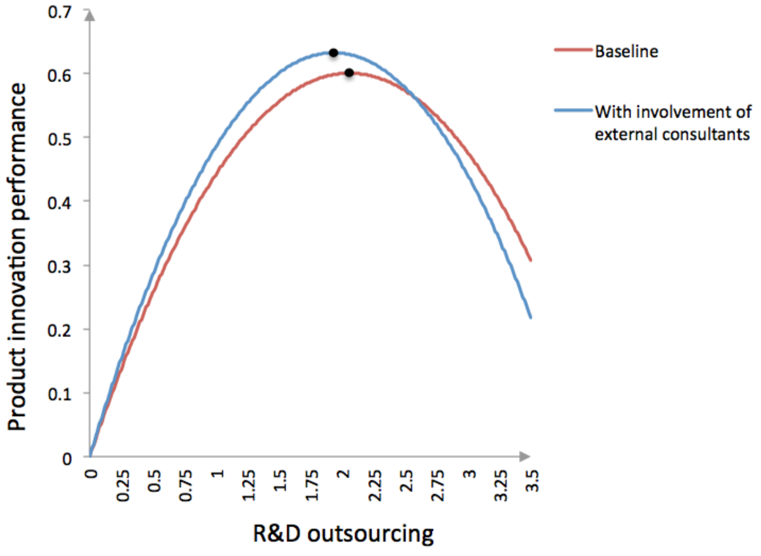
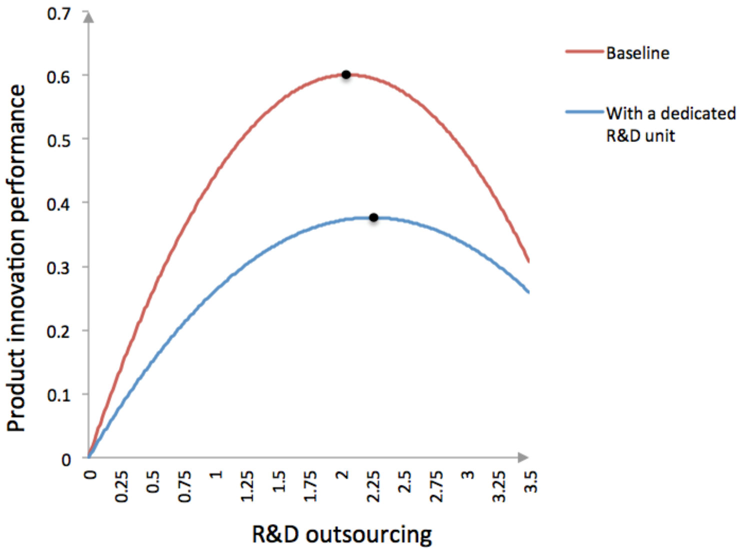


Figure 2: Moderating Effects by the R&D organizational mechanisms.

a)



b)



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[i] The questionnaire was administered in Spanish and the questions used to measure these variables are: Indique si en el año "t" la empresa dispuso de los siguentes mecanismos o realizó las siguentes acciones: (i) Utilizó asesores o expertos para informarse sobre tecnologias; (ii) Mantuvo una dirección o comité de Tecnología o I + D.

[ii] As robustness check, a different operationalization of the use of each R&D organizational mechanisms was applied. The moderating dummy variables are defined as taking value 1 if firm *i* uses the R&D organizational mechanism in each of the last three years. These estimates, which are very similar to those reported in the results section, are not included in the manuscript for the sake of concision, but are available from the authors upon request.