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LEARNING FROM R&D OUTSOURCING VS. LEARNING BY R&D OUTSOURCING

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Abstract: We analyze how research and development (R&D) outsourcing influences product innovation. We propose a separation between learning *from* R&D outsourcing, whereby the firm improves its ability to innovate by using outsourced R&D directly in new products, from learning *by* R&D outsourcing, whereby the firm indirectly uses outsourced R&D by integrating it with internal R&D to create new products. Building on the knowledge-based view, we argue that learning from R&D outsourcing is likely to have an inverse U-shaped relationship with product innovation, because the initial benefits of using outsourced component R&D knowledge to innovate products is eventually outweighed by the hollowing out of the firm's ability to innovate. In contrast, we propose that learning by R&D outsourcing is likely to have a U-shaped relationship with product innovation, because the initial challenges of integrating internal and external R&D are eventually overcome, resulting in more innovations. Finally, we distinguish between domestic and foreign R&D outsourcing and propose a liability of foreignness in R&D outsourcing as it has a lower impact on new products than domestic R&D outsourcing. The empirical analysis shows that outsourced R&D has an inverted U-shaped relationship with the number of new products, while the interaction between outsourced R&D and internal R&D has a U-shaped relationship with the number of new products. It also shows that domestic outsourced R&D has a higher positive impact on the number of new products than foreign outsourced R&D.

Keywords: R&D outsourcing, internal R&D, learning from R&D outsourcing, learning by R&D outsourcing

1. Introduction

We analyze how research and development (R&D) outsourcing influences product innovation. The combination of diverse knowledge is critical for generating innovation (Antolín-López et al., 2015; Cuervo-Cazurra, Nieto and Rodríguez, 2018; Lee, Wu and Pao, 2014; Nieto and Santamaria, 2007). Firms typically cannot create all the necessary knowledge needed for innovation internally. Hence, they search for knowledge from external sources to innovate (Ceccagnoli, Higgins and Palermo, 2014; Frank, Cortimiglia, Ribeiro, and Oliveira, 2016; Martini, Neirotti, and Appio, 2016; Tsai and Wang, 2008). Firms use different means to search for external knowledge, such as by purchasing or outsourcing R&D knowledge from external providers (Frank et al., 2016; Teirlinck and Spithoven, 2013; Un, 2017).

Despite the growing importance and use of outsourced R&D to help the firm innovate, there is a debate on the impact of R&D outsourcing on innovation. On the one hand, analyses of knowledge outsourcing propose that it has a negative effect on a firm's innovation, because the firm does not learn how to create knowledge once it relies on others for R&D (e.g., Bettis, Bradley and Hamel, 1992; Grimpe and Kaiser, 2010; Weigelt, 2009). On the other hand, managers continue to outsource R&D to other companies, with the view that their company may gain knowledge created by other firms that help it innovate more (Frank et al., 2016; Nieto and Rodriguez, 2011).

Building on the knowledge-based view of the firm (Grant, 1996; Kogut and Zander, 1992; Nonaka and von Krogh, 2009), we provide a solution to this debate by proposing a separation between two effects that may have been confounded in previous studies: learning *from* R&D outsourcing and learning *by* R&D outsourcing. First, in learning from R&D outsourcing, the firm incorporates outsourced R&D directly into new products. We propose that learning from outsourcing has an inverse U-shaped relationship with innovation. The reason is that the initial

benefits of integrating outsourced component R&D in the creation of new products are outweighed at higher levels of R&D outsourcing by the challenge of hollowing out the ability of the company to innovate as it increasingly relies on others for R&D. Second, in learning by R&D outsourcing, the company uses outsourced R&D indirectly by integrating it with firm-internal R&D knowledge to create new products. We propose that learning by R&D outsourcing is likely to have a U-shaped relationship with innovation. The reason is that the challenges of understanding and integrating external and internal R&D at low levels of integration, which limit innovativeness, are overcome at higher levels as employees interact more frequently with R&D providers, leading to higher innovativeness. Finally, we analyze the influence of the location of R&D outsourcing on innovation, differentiating between foreign and domestic R&D outsourcing. Building on the idea of cognitive distance (Nooteboom, 2000), we propose the existence of a liability of foreignness in foreign R&D outsourcing. We argue that foreign R&D outsourcing has a lower impact on innovation than domestic R&D outsourcing, because of the higher challenges of using and integrating more distant knowledge.

We test these ideas on a sample of manufacturing firms. We find that R&D outsourcing has an inverse U-shaped relationship with the number of new products. The coefficient of R&D outsourcing is positive and statistically significant while the coefficient of the square of R&D outsourcing is negative and statistically significant. We also find that the interaction between R&D outsourcing and internal R&D has a U-shaped relationship with the number of new products. The coefficient of the interaction between internal R&D and R&D outsourcing is negative and statistically significant, and the coefficient of the interaction between internal R&D and the square of R&D outsourcing is positive and statistically significant. Finally, we find that domestic R&D outsourcing has a statistically significant U-shaped relationship with the number of new products

and the interaction between domestic R&D outsourcing and internal R&D has an inverse U-shaped relationship with the number of new products. In contrast, foreign R&D outsourcing has a limited relationship with the number of new products.

These ideas and findings contribute to two lines of research: the literature on R&D outsourcing and the knowledge-based view. First, we contribute to the literature on R&D outsourcing by providing one solution to the debate of the impact of R&D outsourcing on innovation. Other studies discuss whether R&D outsourcing has a positive or a negative effect on learning (Buss and Peukert, 2015; Frank et al., 2016; Grimpe and Kaiser, 2010; for a recent review, see Un, 2017). In contrast, we separate two influences of R&D outsourcing on innovation: learning from R&D outsourcing and learning by R&D outsourcing. We propose and explain that they have competing effects on innovation. Additionally, we contribute to a better understanding of the location of R&D outsourcing (Bertrand and Mol, 2013; Contractor et al., 2010; Larsen, Manning and Pedersen, 2013) by providing a novel comparison and finding. Foreign R&D can help the firm innovate, but relative to domestic R&D outsourcing, foreign R&D outsourcing may suffer from additional challenges that limit its impact on the innovativeness of the firm.

Second, we contribute to the knowledge-based view (Grant, 1996, 2013; Kogut and Zander, 1992) by explaining the direct and indirect mechanisms by which R&D outsourcing influences product innovation. First, we explain how the firm can use outsourced R&D knowledge directly to innovate products and explain the limits of relying on external knowledge. Second, we explain how, alternatively, the firm can use outsourced R&D knowledge indirectly to create new products by integrating outsourced and internal R&D, but that to achieve this the firm needs to address the coordination and integration challenges with the R&D providers.

These ideas also contribute to managers' decision on how to direct their R&D outsourcing efforts to those areas that seem to have a more promising impact on the firm's ability to innovate products. Outsourced R&D knowledge helps firms generate new products not only via its direct integration in new products, but also via its indirect integration with internal R&D to create new products. Therefore, when selecting which particular R&D to outsource, managers can consider both methods to ensure a higher innovativeness in the firm, designing mechanisms that facilitate an optimal degree for each of the methods. They can redesign the innovation process to use directly outsourced R&D to innovate, with the understanding that there is a limit to the benefit of this method. They can redesign the interaction and integration process to use indirectly outsourced R&D via its integration with internal R&D, taking into account that the benefit of such integration emerge once integration challenges have been addressed. Finally, when considering the use of domestic or foreign outsourced R&D, managers may want to opt for domestic as it seems to be easier to use and integrate into the innovation processes of the firm.

2. Theoretical background

2.1. R&D outsourcing and innovation

There is an expanding literature analyzing the outsourcing of high value-added activities, such as R&D, to external providers. Although the literature has considered many mechanisms that support the firms' acquisition of external knowledge, such as acquisitions (Ahuja and Katila, 2001), alliances (Nieto and Santamaria, 2007) and foreign direct investments (Cantwell and Mudambi, 2005), in this paper, we focus only on R&D outsourcing. R&D outsourcing is an increasingly important activity that companies are doing both at home and from other countries, benefiting from the comparative advantage of other locations (Bertrand and Mol, 2013; Rodriguez and Nieto, 2016; Santangelo, Meyer and Jindra, 2016). In both cases, the literature has discussed

several reasons for why firms engage in R&D outsourcing (Cuervo-Cazurra and Un, 2010; Tamayo and Huergo, 2017; Un, 2017).

There is a debate in the literature on the benefits and challenges of R&D outsourcing (Dibbern, Winkler, and Heinzl, 2008; Larsen, Manning and Pedersen, 2013). On the one hand, some studies have argued that R&D outsourcing is beneficial for the company because it provides it with access to the specialized knowledge of R&D providers that can complement the knowledge created within the company (Cassiman and Veugelers, 2006; Frank et al., 2016; Tsai and Wang, 2008). Cassiman and Veugelers (2006), for example, argue that there is complementarity between external R&D and internal R&D in generating innovations. Tsai and Wang (2008) argue that technology outsourcing does not necessarily influence innovation performance *per se*, but when complemented with firm internal R&D their joint effect has a positive impact on innovation performance. Frank et al. (2016) also find support for the joint effect of internal and external R&D on innovation output.

On the other hand, other studies have argued that outsourcing R&D creates a challenge to the company by reducing its ability to innovate. R&D is at the core of the competitive advantage of the company and its ability to create new products (Cuervo-Cazurra and Un, 2010; Helfat, 1997; Un and Rodriguez, 2017). Therefore, if the company relies on others for R&D, it may end up undermining its own ability to innovate because it is not learning to create the knowledge being outsourced (Becker and Zirpoli, 2017; Bettis et al., 1992; Grimpe and Kaiser, 2010; Weigelt, 2009; Zirpoli and Becker, 2011). Bettis et al. (1992), for example, argue that firms that outsource reduce their innovative capabilities because they do not develop the knowledge and skills of employees to create the knowledge being outsourced. Grimpe and Kaiser (2010) argue that the gain from R&D outsourcing is typically at the expense of the firm's integrative capabilities and managerial

attention. Zirpoli and Becker (2011) argue that firms become less innovative as they increase their R&D outsourcing because the more they outsource, the less component knowledge they have for undertaking architectural innovation of the products.

2.1. The knowledge-based view

We use the knowledge-based view to address the previous debate and explain how and why R&D outsourcing influences product innovation. We use this theory because R&D outsourcing deals with the acquisition of external knowledge to create new knowledge, innovation in our case.

The knowledge-based view argues that knowledge is a strategic asset that explains the existence of firms, differences among firms, and why some firms are better than others. First, firms exist because they are more efficient than markets in creating new knowledge as they can provide an organizational context, training and incentives for employees to search for and integrate knowledge to create new knowledge (Grant, 1996; Kogut and Zander, 1992; Nonaka and von Krogh, 2009). Second, these mechanisms result in firms creating different types of knowledge. As a result, knowledge varies across individuals, firms, and countries (Hayek, 1945). Third, firms that are better at searching for and integrating external knowledge with internal knowledge to create new knowledge develop an advantage over others (Grant, 1996, 2013; Leonard-Barton, 1995). Moreover, firms that can search for and integrate knowledge from sources within and across countries are likely to have superior innovative capabilities (Cantwell and Mudambi, 2005).

2.2. Learning from R&D outsourcing and learning by R&D outsourcing

Building on the knowledge-based view, we address the theoretical debate over the benefits of R&D outsourcing by proposing the separation of two methods for using outsourced R&D that enable firms to generate more new products: learning from and learning by R&D outsourcing. In

learning from R&D outsourcing, the company uses outsourced R&D directly in the innovation of products. In learning by R&D outsourcing, the company uses outsourced R&D indirectly via integration with internal R&D to innovate products. Thus, these two methods differ in two ways. First, in the way outsourced R&D is used, directly and indirectly. Second, in the relationship between the firm and the source of R&D. In the case of learning from R&D outsourcing, the firm takes the leading role in the development of innovations and relies on others for specific areas of expertise to facilitate innovations. In the case of learning by R&D outsourcing, the firm takes a collaborative role in the development of innovations and works with others to integrate expertise and co-develop innovations.

2.2.1. R&D outsourcing and innovation: Learning from R&D outsourcing

The firm can use learning from R&D outsourcing and innovate products by directly incorporating knowledge it has obtained from external R&D providers into its new products. When a company uses outsourced R&D directly to innovate its products, it decides the type of R&D it needs to outsource, uses a process of modularity and partitioning of R&D between itself and external R&D providers, and relies on the specialized innovative capabilities of R&D providers. Takeishi (2002), for example, argues that firms can improve their new product development by separating development tasks between those that require component knowledge and those that require architectural knowledge. The firm can outsource the former and keep the latter in-house. The firm relies on external providers of R&D to create new knowledge to innovate components, obtaining from them R&D and knowledge that is more easily specified and used directly to create new products. It then creates new knowledge through the architectural innovation of the products, focusing its innovation effort on the development of knowledge that requires underlying tacit knowledge for its specification, transfer, and integration (Funk and Luo, 2015; Jaspers, Prencipe,

and Ende, 2012; Magnusson and Pasche, 2014; Pil and Cohen, 2006). This partitioning of R&D between the firm and R&D providers enables the company to generate more new products more effectively and efficiently, because it benefits from the innovative capabilities of R&D providers and its own. The firm maintains its own sources of innovativeness by focusing on architectural innovation. It can select to specialize in certain areas in which it has superior expertise and rely on external R&D providers for new ideas and innovations in areas in which it is not a leader. This can help it create products that are more innovative than those of firms that focus on innovating all aspects of the products in-house. For example, the US technology firm Apple designed much of the system architecture of the media player iPod in-house and it simultaneously outsourced the rest of the more than four hundred intermediate components to a variety of firms (Lo, 2011). Thus, the firm specializes in distinct areas of knowledge, designing products in a way that highlights its own internally developed expertise and relies on the expertise of others to complement its own (Lau, Yam and Tang, 2011; Magnusson and Pasche, 2014).

However, using increasingly high levels of outsourced R&D directly in the innovation of new products has the downside that it may potentially result in the hollowing out of the firm's innovativeness. Even if the firm only outsources its R&D component knowledge, increasing its level of R&D outsourcing can reduce its positive effect on product innovation by eroding the firm's architectural knowledge (Grimpe and Kaiser, 2010). At very high levels of R&D outsourcing used directly to innovate products, the firm may not have adequate levels of component knowledge to be able to understand how the different components fit together architecturally in making new products (Steinberg, Procher and Urbig, 2017). Moreover, since the component knowledge and its underlying tacit knowledge resides mainly in the external R&D providers, the firm may eventually become unable to interact with external providers, and even worse it may be unable to understand

how the different components interact with each other and help improve the innovativeness of the products of the company. As a result, the firm may end up eventually outsourcing its architectural knowledge to R&D providers, further eroding its internal knowledge (Zirpoli and Becker, 2011). For this reason, Takeishi (2002) proposes that when firms undertake highly innovative product development projects, they may want to rely more on their internal component knowledge or allow external providers to develop some architectural knowledge. This downside to R&D outsourcing is consistent with studies that have argued that knowledge outsourcing has a negative effect on the firm's innovative capabilities (e.g., Bettis et al., 1992; Grimpe and Kaiser, 2010; Weigelt, 2009).

As a result of these two processes, we propose that learning from R&D outsourcing, in which the firm uses outsourced R&D directly to innovate products, results in an inverse U-shaped relationship between R&D outsourcing and product innovation. There is a positive effect of R&D outsourcing on the firm's product innovation at lower levels of R&D outsourcing as external knowledge is incorporated directly into the products, but this effect decreases at higher levels of R&D outsourcing as the firm's innovative capabilities are hollowed out. Formally, we hypothesize that:

Hypothesis 1. R&D outsourcing has an inverse U-shaped relationship with the firm's number of new products.

2.2.2. R&D outsourcing and innovation: Learning by R&D outsourcing

The firm can use learning by R&D outsourcing and innovate products by integrating outsourced R&D with its internal R&D. However, at low levels of R&D outsourcing, this integration may have a limited impact on product innovation, because the coordination and integration challenges between the firm and R&D providers are not fully solved. To be able to integrate external and internal R&D for innovation effectively, the company and their R&D

providers need to develop some understanding of their knowledge bases since common understanding of sources and recipients of knowledge facilitates knowledge integration (Subramaniam, 2006; Nonaka and Takeuchi, 1995; Leonard-Barton, 1995). At low levels of R&D outsourcing, this understanding may not be established, because the firm and their R&D providers may not interact frequently enough to share knowledge, learn about each other's knowledge bases, and establish mechanisms to integrate their knowledge. The integration of external R&D may create conflicts with established practices within the firm due to the not-invented-here syndrome (Antons and Piller, 2015). R&D employees in the firm and the R&D provider might not see the importance of altering their mindsets and routines and invest in understanding each other when the outsourced R&D is low. Employees may consider that the cost of investing in building a relationship with R&D providers is not worth the effort, because the outsourced R&D that will be integrated may be relatively low. In extreme cases, at low levels of R&D outsourcing, the firm and its R&D providers may even establish mechanisms to protect and prevent the unwanted transfers of knowledge via spillovers. Studies on R&D outsourcing typically discuss how firms reduce knowledge spillover by limiting their interaction (e.g., Buss and Peukert, 2015; Martinez-Noya, Garcia-Canal and Guillen, 2013; Tiwana, 2008). This reduction may be more prevalent when the R&D providers are also competitors (Henttonen, Hurmelinna-Laukkanen, and Ritala, 2016), because their interaction tends to have a negative effect on the number of product innovations (Nieto and Santamaria, 2007; Un, Cuervo-Cazurra and Asakawa, 2010). These coordination and integration challenges typically result in firms incurring hidden and extra costs, which result in them not achieving the expected benefits of their outsourcing (Dibbern et al., 2008; Larsen et al., 2013).

Nevertheless, at higher levels of integration of outsourced R&D with internal R&D, the firm is more likely to have solved coordination and integration challenges with external R&D providers and, thus, innovate. At high levels of R&D outsourcing, the firm and providers interact more frequently and develop the mechanisms to achieve success in their knowledge integration, resulting in more innovations (Martini et al., 2016). With higher levels of outsourced R&D that becomes integrated with internal R&D, the interaction between providers' of R&D and firm's internal R&D increases. This provides managers and employees the willingness to adapt and modify their mindsets and practices to facilitate integration as they increasingly build social relationships. This willingness results in managers and employees of the firm and its R&D providers learning about each other's knowledge bases, developing a common understanding of each other's knowledge, and establishing mechanisms to share their knowledge more effectively. The more intense interactions between the firm's R&D personnel and those of external providers enables the integration of outsourced knowledge to create new knowledge, extending their own knowledge sets (Leonard and Swap, 1999; Michael and Palandjian, 2004; Nonaka and Takeuchi, 1995). Employees involved in internal R&D and its integration with external R&D have a better understanding of how the outsourced knowledge has been developed, why, how to apply it, and why it works. The integration of internal R&D with external R&D generates tacit knowledge that only employees involved in the creation and integration of that knowledge can understand, as much of knowledge is complex and systemic (Kogut and Zander, 1992; Nonaka and Takeuchi, 1995; Tsoukas, 1996). With higher levels of integration, the firm retains employees with an expanded knowledge set after the creation of product-related knowledge, which can help it generate additional knowledge in the future (Leonard-Barton, 1995; Nonaka and von Krogh, 2009). Employees and managers can more easily adapt and alter that knowledge to new uses later, because

they have an expanded understanding of the conditions governing its behavior, enabling the firm to innovate products as new conditions emerge.

In sum, we argue that learning by R&D outsourcing, in which the firm uses outsourced R&D knowledge indirectly by integrating it with internal R&D, results in a U-shaped relationship between learning by R&D outsourcing and innovation. At low levels of R&D outsourcing that is integrated with internal R&D, the firm faces coordination and integration challenges that have a detrimental impact on innovation, while at high levels of R&D outsourcing that is integrated with internal R&D, the firm has both the willingness and coordination mechanisms that facilitate integration and subsequent innovations. Formally, we hypothesize that:

Hypothesis 2. The interaction between R&D outsourcing and internal R&D has a U-shaped relationship with the firm's number of new products.

2.3. Domestic and foreign R&D outsourcing and innovation: The liability of foreignness in outsourced R&D

We provide additional depth to this discussion by separating R&D outsourcing by its location into foreign and domestic outsourced R&D and proposing a liability of foreignness in R&D outsourcing. For the sake of brevity, we will not repeat the explanations behind learning from and learning by R&D outsourcing for both domestic and foreign R&D outsourcing. The same explanations we presented before apply. We expect an inverted-U shaped relationship between domestic outsourced R&D and the number of new products, and between foreign outsourced R&D and the number of new products. We also expect a U-shaped relationship between the interaction of domestic outsourced R&D and internal R&D on the number of new products, and between the interaction of domestic outsourced R&D and internal R&D on the number of new products.

We propose that there is a difference in magnitude in the proposed relationships, with learning from and by foreign R&D outsourcing having a lower impact on the number of new products than learning from and by domestic R&D outsourcing. We term this relative difference the liability of foreignness in R&D outsourcing, and define it as the lower direct and indirect effect that foreign outsourced R&D has on innovation in comparison to the effect of domestic outsourced R&D. This concept is inspired by the liability of foreignness (Zaheer, 1995) from the international management literature. However, the concepts differ. That concept compares subsidiaries of foreign firms and domestic firms, whereas we compare foreign and domestic outsourced R&D.

We explain the existence of a liability of foreignness in R&D outsourcing as the outcome of the additional cognitive distance that arises from differences in knowledge across countries and the additional challenges of using foreign knowledge in comparison to domestic one. Foreign knowledge is developed under particular assumptions on the interactions with its environment (Kogut and Zander, 1993). Different countries have different innovative capacities, i.e., the ability to create new knowledge (Furman et al., 2002). Its determinants include the country-level investments in R&D, R&D scientists, intellectual property right protection, openness to international trade, technology specialization, and their firms' abilities to commercialize their new-to-the-world knowledge. Firms in some countries focus more on creating new-to-the-world knowledge, while firms in other countries focus more on creating new-to-the country knowledge (Hu and Mathews, 2005). Moreover, some countries have stronger intellectual property rights protection to encourage innovation and a national culture that supports entrepreneurial activities more than others (Shane, 1993).

Although firms in the same country have different cognitions or ways of thinking and doing, these cognitions differ more between firms located in different countries; this makes the

integration of foreign knowledge more difficult than the integration of domestically sourced knowledge. Nooteboom (2000) argues that firms have a unique cognition that includes a broad range of mental activity, such as the assumptions they have about their operating environment, their sense-making, and their value judgments, all of which tend to build on each other. A firm's cognition is typically developed and shaped by firm-specific factors, such as internal R&D investment and management practices. It is also shaped by country-specific factors, such as national culture, politics, economics, and the national innovation system (for a review of national innovation systems, see Watkins, Papaioannou, Mugwagwa, and Kale, 2016).

When a firm uses foreign outsourced R&D, it has to manage not only firm-specific but also country-specific differences, making it more difficult to use foreign outsourced R&D directly and indirectly than domestic outsourced R&D. The higher the cognitive distance between the firm and the sources of R&D, the more different their knowledge is, and the more difficult it is to use such knowledge (Nooteboom et al., 2007). This incompatibility with the firm's knowledge results in challenges in its integration without adapting it for use in the firm in the country (Carluccio and Tally, 2013; Singhal and Singhal, 2002). This adaptation can be arduous because the firm lacks the tacit knowledge underlining the outsourced knowledge to de-contextualize the country-specific aspect of the outsourced knowledge and re-contextualize it for use in the country of the firm (Kim, 1998). In some cases, the use of foreign knowledge requires extensive de-contextualization and re-contextualization, making the knowledge itself becoming an innovation (Kim, 1998; Westney, 1987). Without the necessary understanding of how and why the knowledge was created and what are its possible uses, the firm is less able to use the foreign knowledge to innovate. As a result, studies on foreign sourcing typically find that there are extra and hidden costs that firms do not incur with domestic outsourcing (Dibbern et al., 2008; Larsen et al., 2012). These include post-

contractual extra costs in requirements specification and design, knowledge transfer, control, and coordination (Dibbern et al., 2008). In projects that require a high level of buyers specific knowledge about idiosyncratic internal processes of the firm, these extra costs are even higher than in projects where more general knowledge was needed. Larsen et al. (2012) find that firms tend to underestimate the cost of the implementing offshore outsourcing and that these hidden costs are driven by task- and transaction-related factors. Malik and Zhao (2013) find that the higher the cultural distance between the sources and recipients of knowledge, the longer is the delay of cross-border knowledge transfer.

In sum, we propose the existence of a liability of foreignness that results in lower learning from and by foreign outsourced R&D than domestic outsourced R&D, as a result of the higher cognitive distance between the firm and foreign outsourced R&D relative to domestic outsourced R&D. In formal terms, we hypothesize that:

Hypothesis 3a. The inverted-U shaped relationship between foreign outsourced R&D and the number of new products is a weaker relationship than the inverted-U shaped relationship between domestic outsourced R&D and the number of new products.

Hypothesis 3b. The U-shaped relationship between the interaction of foreign outsourced R&D and internal R&D investment on the number of new products is a weaker relationship than the U-shaped relationship between the interaction of domestic outsourced R&D and internal R&D investment and the number of new products.

3. Research design

3.1. Data

We test the hypotheses on a sample of 761 manufacturing firms operating in Spain in the period 1990-2002. Spain is an appropriate empirical setting because it is representative of many

countries in the world. It is at neither the forefront of technological development nor the bottom among countries in technological sophistication (OECD, 2017). Hence, a firm in Spain can not only benefit from technologies developed by firms in more advanced countries but also generate technologies. Therefore, findings from this study apply to firms in most countries in the world, except those in the few technology leaders, such as the United States or Japan, or technological laggards, such as the least developed countries.

Data come from a survey of manufacturing firms conducted by the Foundation State-Owned Enterprise (*Fundación Empresa Pública*) in Spain and covers the years 1990-2002. The Ministry of Commerce, Tourism, and Industry in collaboration with the Foundation State-Owned Enterprise compiled the data. These organizations chose the firms for the survey based on size. All firms with more than 200 employees were included in the sample. Firms with between 10 and 200 employees were selected through a random stratified sample. The survey was collected through a detailed questionnaire of 107 questions with 500 fields designed to capture all aspects of the strategy of the firm. Firms in the database operate in 21 industries and are representative of the underlying population of manufacturing firms in Spain.

The way in which data were collected and distributed helps reduce biases inherent in any survey and increases confidence in data quality. First, the survey was explicitly collected for research purposes. Therefore, there are few incentives for respondents to present the state of the firm in a better light to obtain subsidies or to present the state of the firm in a worse light to avoid tax liabilities. Second, data were collected under a confidentiality agreement. This helps reduce the incentive of misrepresentation by managers and improves the accuracy of the responses. Unfortunately, since the database does not contain variables that would help identify the firms, this limits our ability to collect additional information or verify the data because we do not know

the identity of the firm. Third, the survey uses detailed questions about the variables. It reduced response bias by not using Likert-type scales on the perception of the respondent about a particular variable. Fourth, data collected in one year is checked for errors and discrepancies with previous years to ensure its quality and comparability across time. Additional information on the dataset is available at SEPI (2017a).

This database has been used to analyze various topics, such as learning by exporting, R&D investment, and diversification. A list of papers that have used it is available at SEPI (2017b).

3.2. Variables and measures

The dependent variable is the number of new products. We used the number of new products that the firm introduced in the year as the measure of innovation (e.g., Salomon and Jin, 2010; Un, 2016). The survey defined new products as those products that were new to the firm. This measure is different from previous studies on R&D offshore outsourcing that typically used dichotomous measure (e.g., Bertrand and Mol, 2013; Nieto and Rodriguez, 2011).

The independent variables of interest are R&D outsourcing and internal R&D. Consistent with prior studies (e.g., Bertrand and Mol, 2013; Cuervo-Cazurra et al., 2018), the measure of outsourced R&D is based on the amount of money that the firm paid for outsourced R&D. This is the amount of money paid to technology providers to obtain new scientific or technological knowledge or to develop commercially viable innovations for the firm. As such, it captures the idea of R&D outsourcing as the payments made to sources outside the firm for the development of the technologies rather than developing them in-house. R&D outsourcing is measured as the amount paid for external R&D divided by sales and multiplied by one thousand. Foreign outsourced R&D is measured as the expenditure paid to foreign providers of technology; domestic outsourced R&D is measured as the difference between total R&D outsourcing and foreign

outsourced R&D; both measures are divided by sales and multiplied by one thousand. Internal R&D is measured as the amount spent on internal R&D divided by sales and multiplied by one thousand.

We control for alternative influences on innovation traditionally discussed in the literature. We organized these into three different categories: resources, scope, and competition. First, we control for resources in several ways. We control for internal R&D since it is likely to influence innovation on its own (Cohen and Levinthal, 1990). We control for employees' skills because they influence the firm's ability to learn and innovate (Leiponen, 2005). We measure this with the percentage of employees with a university or technical college degree. We control for size because bigger firms are more likely to generate more innovations and achieve higher performance (Schumpeter, 1942). We measure size with the value of total sales in millions. Second, we control for scope. We control for diversification because diversified firms may have to generate more new products (Garcia-Vega, 2006). We measure this with a dichotomous indicator that the main business line represents less than seventy percent of sales. We control for internationalization because firms that export are more likely to generate more innovations and perform better than firms that do not (Salomon and Jin, 2010). We measure this with a dichotomous indicator that the firm has foreign sales. Third, we control for competition. We control for the concentration of competition because this affects learning and performance (Schumpeter, 1942). We measure this with an indicator of the percentage of sales in the industry accounted for by the largest four firms. We control for other unobserved industry effects because issues of appropriability may result in different innovation and performance (Levin, Cohen and Mowery, 1985). We use a dichotomous indicator of the industry of the firm's main activity at the two-digit level. Lastly, we control for year because annual effects may affect innovation. We use a dichotomous indicator for each year.

3.3. Methods of analysis

Since the dependent variable is a count measure with an overdispersion of zeroes, we use a negative binomial to analyze the relationships. We lag the independent variables and controls by one year as actions taken in the previous year are likely to affect innovation in the subsequent year. We control for unobserved firm heterogeneity using random effects; fixed effects are not appropriate because firms with no innovations and controls that do not vary in the period would drop out of the analysis. In line with previous research (e.g., Behmiri and Manera, 2015; Ghosh and Vogt, 2012) we exclude observations with an outlier number of new products, more than 300 new products in our case, or 0.6% of observations.

The specification we use to test hypotheses 1 and 2 is the following:

$$\textit{Number of new products} = \beta_0 + \beta_1 * \textit{R\&D outsourcing}_{it-1} + \beta_2 * \textit{R\&D outsourcing squared}_{it-1} + \beta_3 * \textit{R\&D outsourcing} * \textit{Internal R\&D}_{it-1} + \beta_4 * \textit{R\&D outsourcing squared} * \textit{Internal R\&D}_{it-1} + \beta_5 * \textit{Internal R\&D}_{it-1} + \beta_6 * \textit{Size}_{it-1} + \beta_7 * \textit{Skills}_{it-1} + \beta_8 * \textit{Diversification}_{it-1} + \beta_9 * \textit{Internationalization}_{it-1} + \beta_{10} * \textit{Competition}_{it-1} + \beta_{11} * \textit{Industry}_{it-1} + \beta_{12} * \textit{Year}_{it-1} + e$$

Hypothesis 1 is supported if β_1 is positive and statistically significant and β_2 is negative and statistically significant. Hypothesis 2 is supported if β_3 is negative and statistically significant and β_4 is positive and statistically significant.

To test hypotheses 3a and 3b, we run the same relationships separating domestic outsourced R&D and foreign outsourced R&D. Hypothesis 3a is supported if the coefficient of foreign outsourced R&D and its square are statistically significantly smaller than the coefficient of domestic outsourced R&D. Hypothesis 3b is supported if the coefficient of the interactions of foreign outsourced R&D and its square with internal R&D is statistically significantly smaller than the coefficients of the interactions of domestic outsourced R&D and its square with internal R&D.

4. Results

Table 1 shows the descriptive statistics and correlation matrix. Overall, there are limited high correlations among the predictors, reducing the possible collinearity problems. The variance inflation matrix analysis reveals no collinearity problems, with the main variance inflation factor of 2.44, which is below the recommended cut-off point (see O'Brien, 2007 for a review).

*** Insert Table 1 about here ***

Table 2 shows the results of analyzing the impact of R&D outsourcing on product innovation, and of analyzing the separate impact of foreign and domestic R&D outsourcing on product innovation. To test hypothesis 1 and 2, we discuss the full model that appears in Model 2.1, and the marginal effects with the coefficients computed with the other variables at their means that appear in Table 3, Model 3.1. Model 2.2 and 2.3 are partial models, presented to show limited problems in collinearity.

These results seem to support Hypothesis 1. In Hypothesis 1 we argued that there is an inverted-U shaped relationship between R&D outsourcing and the number of product innovations. We find that this seems to be the case, because the coefficient of R&D outsourcing is positive and statistically significant and the coefficient of R&D outsourcing squared is negative and statistically significant. Thus, it appears that learning from R&D outsourcing helps a firm innovate although at a decreasing rate.

The results also seem to support Hypothesis 2. In hypothesis 2 we proposed that there is a U-shaped relationship between the interaction of R&D outsourcing and internal R&D and the number of product innovations. We find that this appears to be supported, because the coefficient of the interaction of internal R&D and R&D outsourcing is negative and statistically significant and the coefficient of the interaction of internal R&D and R&D outsourcing squared is positive

and statistically significant. Thus, it seems that learning by R&D outsourcing helps a firm innovate only at high levels of outsourced R&D when the firm has overcome the challenges of coordinating and integrating external and internal R&D.

*** Insert Table 2 and Table 3 about here ***

Figure 1 provides a graph of the results to illustrate the relationships further. Learning from R&D outsourcing is computed by multiplying the coefficients of outsourced R&D and outsourced R&D squared by the actual values that outsourced R&D takes in the sample (from zero to 98 per thousand) and adding them. Learning by outsourcing is computed by multiplying the coefficient of outsourced R&D by the average of internal R&D and the coefficient of outsourced R&D squared by the average of internal R&D by the actual values that outsourced R&D takes and adding them. Over the actual values that R&D takes, we observe a positive influence of learning from R&D outsourcing but at a decreasing rate, and a negative influence of learning by R&D outsourcing but at a decreasing rate. However, over the full range of values that outsourced R&D can take (which in principle could run to being up to one thousandth per thousandth of sales, although this would be a very extreme case), learning from R&D outsourcing achieves an inflection point at 178 per thousand of outsourced R&D. After this inflection it takes a negative slope, thus following the inverted-U shape discussed in hypothesis 1. Also over the full range of values that outsourced R&D can take, learning by R&D outsourcing reaches an inflection point at 158 per thousand of outsourced R&D after which it takes a positive slope, and as a result, it shows the U-shaped relationship as predicted in hypothesis 2.

*** Insert Figure 1 about here ***

To test hypotheses 3a and 3b we compare the results of the full model that appears in Model 2.5 and the marginal effects run with the other variables at their means that appear in Model 3.2,

in which we separate outsourced R&D into a domestic and foreign component. These results seem to provide some support for 3a but weakly. The coefficient of domestic outsourced R&D and domestic outsourced squared are positive and negative and statistically significant. They are larger than the coefficient of foreign R&D outsourcing and its square, which are not statistically significant. However, the tests of differences of coefficients are not statistically significant. Thus, it appears that whereas firms benefit from learning from domestic R&D outsourcing, they do not seem to benefit from learning from foreign R&D outsourcing, but only weakly.

The results also show some support for hypothesis 3b, although weakly. The coefficient of the interaction between domestic outsourced R&D and its square with internal R&D are respectively negative and positive, as expected. The coefficient of the interaction between foreign outsourced R&D and internal R&D is not statistically significant. The coefficient of the square of foreign outsourced R&D and internal R&D is positive and statistically significant. However, the tests of differences of coefficients are not statistically significant. It appears that while firms can learn from domestic R&D outsourcing, they also learn from foreign R&D outsourcing but only at high levels of foreign outsourced R&D, although the differences are small. These findings are important because they help provide one solution to the debate on the benefits of R&D outsourcing for innovation, by separating its impact into a direct and an indirect effect. On the one hand, we find that R&D outsourcing has a direct effect in helping the firm become more innovative. R&D outsourcing provides the company with new modularized ideas and components that can be directly incorporated into its products to innovate them. However, at higher levels of outsourcing, this positive effect diminishes, because the increased reliance on external R&D may hollow out the architectural innovation and innovativeness. On the other hand, we also find that the interaction between external providers' R&D and the firm's internal R&D seems to have a counteractive effect

at low levels of R&D outsourcing. Different knowledge bases of employees of the firm and R&D provider limit mutual understanding and innovation. However, at higher levels of R&D outsourcing, the interaction of R&D outsourcing and internal R&D has a positive impact on innovation as employees develop the willingness, abilities, and coordination mechanisms that facilitate the integration of external and internal R&D for innovation.

It is interesting to note the statistical significance of the coefficients of some of the control variables. Consistent with the literature, internal R&D investment, competition, and internationalization have a positive impact on innovation, while diversification has a negative impact.

5. Conclusions

We studied the impact of R&D outsourcing on product innovation. The increase in R&D outsourcing in recent times, both domestically and internationally, has been accompanied by a growing debate regarding its benefits. One camp has argued for a positive effect (Cassiman and Veugelers, 2006; Frank et al., 2016) and another for no or even a negative effect (Bettis et al., 1992; Tsai and Wang, 2008; Weigelt, 2009). We helped clarify this debate by distinguishing between two mechanisms: learning from R&D outsourcing, whereby a firm improves its innovativeness by incorporating outsourced R&D directly into its products; and learning by outsourcing, whereby a firm increases its innovation indirectly by combining outsourced R&D with internal R&D.

We proposed and found that learning from R&D outsourcing has an inverted-U shaped relationship with the number of new products. It appears that companies incorporate ideas and technologies from the outsourced R&D directly into their products to innovate them, but there are

diminishing innovation benefits of incorporating increasing levels of outsourced R&D as the result of the hollowing out of the firm's innovative capabilities.

We also argued and found that learning by R&D outsourcing has a U-shaped relationship with the number of new products. It appears that the interaction between outsourced R&D and internal R&D has an initial diminishing impact on innovation at low levels, reflecting the challenges of coordinating and integrating knowledge with external R&D providers. However, this interaction results in a positive effect on innovation at higher levels of the interaction, because employees develop the willingness and ability to integrate external and internal R&D to innovate.

Finally, it appears that domestic outsourced R&D is more beneficial for achieving innovation than foreign outsourced R&D because the former has a lower cognitive distance with the knowledge of the company, and thus, it is easier to use directly and indirectly by the firm. This finding does not mean that foreign outsourced R&D is not beneficial to the firm, but that its benefits are more limited than those achieved by domestic outsourced R&D.

5.1. Theoretical contributions

The paper makes several important and novel contributions to the R&D outsourcing literature. We provide one solution to the debate on the benefits of R&D outsourcing (Bettis et al., 1992; Bertrand and Mol, 2013; Dibbern et al., 2008; Gobble, 2013; Grimpe and Kaiser, 2010; Larsen et al., 2013; Un, 2017). By separating learning from R&D outsourcing and learning by R&D outsourcing, we have a better understanding of how and why R&D outsourcing has a positive or negative effect on innovation. Whereas learning from R&D outsourcing helps the company improve its innovativeness via the direct integration of external R&D into new products but with diminishing effects, learning by outsourcing helps the company improve its innovativeness via the

integration of external R&D with internal R&D but only at high levels. These ideas help reconcile the two different views on the impact of R&D outsourcing on the firm's innovativeness.

Additionally, the study further contributes to the literature on R&D outsourcing by introducing the liability of foreignness in R&D outsourcing. Different from some studies that have looked at the likelihood that foreign R&D outsourcing results in innovation (Bertrand and Mol, 2013; Nieto and Rodriguez, 2011; Steinberg et al., 2017), we separate foreign and domestic R&D outsourcing and compare their independent impact on the firm's innovativeness. We argue that the additional cognitive distance with foreign outsourced R&D results in a liability of foreignness of R&D outsourcing.

Second, the paper extends previous arguments of the knowledge-based view. The knowledge-based view has recognized that access to external knowledge is critical for learning and thus performance (Grant, 1996, 2013; Kogut and Zander, 1992; Nonaka and von Krogh, 2009; Spender and Grant, 1996). We highlight how in the case of outsourced R&D the firm can benefit in two ways: from its direct integration into the firm's products, and also from its indirect integration with internal R&D. The firm needs to manage knowledge differently to realize these benefits. In the first case, the management of knowledge involves the partitioning and development of modularity and architectural connections among pieces of knowledge. In the second case, the management of knowledge involves the coordination and integration of knowledge from external and internal knowledge and the development of the appropriate integration mechanisms.

5.2. Managerial contributions

The ideas and findings of this study can help guide managerial decisions in two ways. For managers who wish to undertake R&D outsourcing to improve their firms' innovativeness, the study indicates two alternative paths to achieve this: innovate directly from integrating R&D

outsourcing into products, or innovate indirectly by facilitating the integration of outsourced R&D with internal R&D. The study also indicates that these two paths have different curvilinear relationships with product innovation. Thus, in selecting how to outsource R&D, managers may want to do it strategically. They can undertake low levels of outsourcing of R&D that can be used directly in innovating products without having to be modified by the internal R&D efforts of the firm. Alternatively, they can focus on outsourcing high levels of R&D that are then integrated with internal R&D to innovate products.

Second, for managers tackling the decision from where, at home or abroad, to outsource R&D to innovate products, the study suggests that they should undertake R&D outsourcing to domestic rather than foreign sources. There is an increasing movement among companies to outsource R&D to foreign providers under the notion that R&D can be done more cost effectively abroad. However, foreign outsourced R&D has a higher cognitive distance and may have a more limited impact on the innovativeness of the firm. R&D outsourced domestically is easier to understand and better adapted to the conditions of the home country, and thus can more easily help the firm innovate.

5.3. Limitations and outlook

The paper has several design limitations that open avenues for future studies. First, we study one particular way of obtaining external knowledge to innovate products: subcontracting R&D to other firms. There are other ways to obtain external knowledge, such as acquiring companies that are developing the technologies (Ahuja and Katila, 2001), forming R&D collaborations with external providers to develop the technologies jointly (Nieto and Santamaria, 2007), or undertaking foreign direct investments in R&D in other countries to acquire knowledge and develop technologies there (Cantwell and Mudambi, 2005). Future studies can analyze the

relative impacts of these different ways to obtain knowledge on innovation, and whether it is their direct effect or the indirect effect via their interaction with internal R&D that supports the firm's innovativeness.

Second, we analyzed firms in a country that is neither a leader nor a laggard in R&D, and the findings can apply to similar countries. The findings may not be generalizable to firms in the few countries that are at the forefront of technological development, for which knowledge outsourcing may have a different impact on innovation. The arguments may also not generalize to firms in countries with very weak innovation systems, for which most outsourced R&D may not be up to par with the firm's efforts. Hence, future studies can analyze how the different levels of technological development of countries affect the impact of R&D outsourcing on innovation.

Third, we do not have the data for the mechanisms that we proposed in explaining the impact of R&D outsourcing on product innovation. Although the mechanisms and relationships are plausible and logical, and the mechanisms differ across hypotheses, these are not fully accounted for in the empirical analysis. In this same line of limitation, we do not have specific details on the type of external R&D that the firm engages in, particularly the types of knowledge being outsourced (component vs. architectural knowledge and their degrees of difficulty for use directly and indirectly). Therefore, future studies with appropriate measures can go deeper into the mechanisms and test the relative influence of each of them on the impact of R&D outsourcing on product innovation, separating learning from R&D outsourcing and learning by R&D outsourcing.

Despite these caveats, the study contributes to a better understanding of the impact of R&D outsourcing on innovation. It provides a solution to the debate on the benefits of R&D outsourcing by separating the effect of learning from R&D outsourcing from the effect of learning by R&D

outsourcing on innovation. Future studies can follow this line of thinking and separate these effects for their variables of interest.

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Table 1. Summary statistics and correlation matrix

		Mean	Std Dev	1	2	3	4	5	6	7	8	9
1	Number of new products	2.502	13.131	1.000								
2	Outsourced R&D	3.700	14.612	0.029*	1.000							
3	Domestic outsourced R&D	1.944	11.122	0.012	0.791*	1.000						
4	Foreign outsourced R&D	1.756	8.936	0.033*	0.649*	0.050*	1.000					
5	Internal R&D	4.766	16.127	0.062*	0.242*	0.239*	0.098*	1.000				
6	Size	5.103	11.931	0.030*	0.111*	0.054*	0.115*	0.154*	1.000			
7	Skills	8.494	15.763	0.019	0.100*	0.064*	0.084*	0.153*	0.115*	1.000		
8	Diversified	0.526	0.499	-0.045*	-0.027*	0.008	-0.055*	-0.009	-0.120*	-0.089*	1.000	
9	Exporter	0.614	0.487	0.090*	0.127*	0.062*	0.130*	0.141*	0.237*	0.125*	-0.231*	1.000
10	Competition	31.992	37.166	-0.011	0.083*	0.036*	0.091*	0.038*	0.191*	0.061*	-0.093*	0.143*

Significance level: * $p<0.05$

Table 2. Results of the negative binomial analysis of the impact of R&D outsourcing on innovation

	Dependent variable: Number of new products									
	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6	Model 2.7	Model 2.8	Model 2.9	Model 2.10
Outsourced R&D	0.010*** (0.002)	0.005*** (0.002)	0.003*** (0.001)	…	…	…	…	…	…	…
Outsourced R&D squared	-0.00003* (0.000)	0.000 (0.000)	…	…	…	…	…	…	…	…
Outsourced R&D by internal R&D	-0.0001** (0.000)	…	…	…	…	…	…	…	…	…
Outsourced R&D squared by internal R&D	0.0000005* (0.000)	…	…	…	…	…	…	…	…	…
Domestic outsourced R&D	…	…	…	…	0.014*** (0.003)	0.008*** (0.002)	0.007** (0.002)	0.002* (0.001)	…	…
Domestic outsourced R&D squared	…	…	…	…	-0.00003** (0.000)	-0.00001+ (0.000)	-0.00001+ (0.000)	…	…	…
Domestic outsourced R&D by internal R&D	…	…	…	…	-0.0002** (0.000)	…	…	…	…	…
Domestic outsourced R&D squared by internal R&D	…	…	…	…	0.0000005* (0.000)	…	…	…	…	…
Foreign outsourced R&D	…	…	…	…	0.007 (0.004)	0.002 (0.003)	…	…	0.001 (0.003)	0.005** (0.002)
Foreign outsourced R&D squared	…	…	…	…	0.000 (0.000)	0.000 (0.000)	…	…	0.000 (0.000)	…
Foreign outsourced R&D by internal R&D	…	…	…	…	-0.0001+ (0.000)	…	…	…	…	…
Foreign outsourced R&D squared by internal R&D	…	…	…	…	0.000001* (0.000)	…	…	…	…	…
Internal R&D	0.007*** (0.001)	0.006*** (0.001)	0.006*** (0.001)	0.006*** (0.001)	0.008*** (0.001)	0.006*** (0.001)	0.006*** (0.001)	0.006*** (0.001)	0.007*** (0.001)	0.006*** (0.001)
Size	0.003 (0.002)	0.005*** (0.001)	0.003 (0.002)	0.003 (0.002)	0.003 (0.002)	0.005*** (0.001)	0.005*** (0.001)	0.003 (0.002)	0.005*** (0.001)	0.003 (0.002)
Skills	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)
Diversified	-0.222*** (0.053)	-0.284*** (0.043)	-0.227*** (0.053)	-0.226*** (0.053)	-0.226*** (0.053)	-0.287*** (0.043)	-0.288*** (0.043)	-0.227*** (0.053)	-0.282*** (0.043)	-0.228*** (0.053)
Exporter	0.444*** (0.070)	0.780*** (0.055)	0.454*** (0.070)	0.459*** (0.070)	0.452*** (0.070)	0.783*** (0.055)	0.788*** (0.055)	0.461*** (0.070)	0.788*** (0.055)	0.446*** (0.070)
Competition	0.003*** (0.001)	0.003*** (0.001)	0.0033*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)
Industry	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Year	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Constant	-1.941*** (0.232)	-0.126 (0.170)	-1.946*** (0.232)	-1.951*** (0.233)	-1.953*** (0.232)	-0.133 (0.170)	-0.135 (0.170)	-1.956*** (0.232)	-0.134 (0.170)	-1.933*** (0.233)
Chi squared	471.700	961.500	454.400	445.600	511.500	964.200	960.300	450.000	950.700	456.300

Note: Standard errors appear in parenthesis. Significance levels: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Table 3. Marginal effects of the analysis of the impact of R&D outsourcing on innovation with other variables taken at their means

	Dependent variable: Number of new products	
Variable	Model 3.1	Model 3.2
Outsourced R&D	0.010*** (0.002)	
Outsourced R&D square	-0.00003* (0.00001)	
Outsourced R&D by internal R&D	-0.00015** (0.00005)	
Outsourced R&D square by internal R&D	0.000001* (0.000000)	
Domestic outsourced R&D		0.014***
		(0.003)
Domestic outsourced R&D squared		-0.00003**
		(0.000)
Domestic outsourced R&D by internal R&D		-0.0002**
		(0.000)
Domestic outsourced R&D squared by internal R&D		0.0000005*
		(0.000)
Foreign outsourced R&D		0.007
		(0.004)
Foreign outsourced R&D squared		0.000
		(0.000)
Foreign outsourced R&D by internal R&D		-0.0001+
		(0.000)
Foreign outsourced R&D squared by internal R&D		0.000001*
		(0.000)

Note: Other variables are taken at their means and excluded from the models. Standard errors appear in parenthesis. Significance levels: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Figure 1. Predicted number of new products from learning from outsourcing and learning by outsourcing