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"Breakthrough innovations: The impact of foreign acquisition of knowledge"

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Abstract

Based on the Spanish Technological Innovation Panel, this paper explores the role of R&D offshoring on innovation performance from 2004 to 2013. Specifically, we focus our attention on the impact of different types of offshoring governance models on the profitability of developing breakthrough innovations. Using a novel methodology for panel data sets, we control for the heterogeneity of firms as well as for the sample selection and endogeneity. Our study provides evidence that firms developing breakthrough innovations tend to benefit more from the external acquisition of knowledge than those engaged in incremental innovations. We also find evidence that acquiring knowledge from firms outside the group is more profitable than doing so with firms within the group. Moreover, the external acquisition of knowledge tends to present a higher return on breakthrough innovation in the case of taking such knowledge from the business sector rather than from universities or research institutions. Finally, the recent financial crisis has led to an increase in the return of the foreign acquisition of knowledge on the generation of breakthrough innovations.

Keywords: Endogeneity; Panel data; R&D offshoring; Spanish firms; Sample selection; Technological and organizational space

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1. Introduction

In recent years the innovation literature has widely accepted that innovation performance can be affected not only by the internal R&D effort but also by the decision to gain access to knowledge from outside the firm, either through cooperation agreements or through a contract (Arvanitis et al., 2015). With respect to the latter, outsourcing part of the innovation process allows an enterprise to gain access to a new source of well-prepared labor, as pointed out by Lewin et al. (2009), as well as to capture external knowledge cheaply. Another relevant advantage of outsourcing is the widening of the scope of internationalization of the firm, gaining access to new markets and new knowledge, increasing the efficiency of its internal capabilities and leading to an improvement in its competitiveness and a positive impact on its innovation capacity (Cassiman and Veugelers, 2006; Grimpe and Kaiser, 2010; Love et al., 2014; OECD, 2008, pp. 20, 91). These theoretical advantages of knowledge outsourcing are expected to be translated into a positive impact on innovation performance. Indeed, most of the papers providing empirical evidence reached the conclusion that external knowledge-sourcing strategies have a positive and significant impact on innovation performance (Laursen and Salter, 2006; Mihalache et al., 2012; Nieto and Rodríguez, 2011), while as pointed by Dachs et al. (2012, p. 10) studies that find a negative impact are very scarce.

When buying technology from others, firms can choose between firms and institutions that belong to the same country or ones that exist beyond their boundaries. In the present paper, we focus on the latter, which is known as R&D offshore outsourcing or R&D offshoring. Despite being a recent topic of research, R&D offshoring is not a strategy that has been developed recently by enterprises. Cantwell (1995) showed that in 1930 European and U.S. enterprises were conducting around 7% of their R&D abroad. Moreover, the relevance of the internationalization of the offshoring strategy stems from the fact that, while for some big companies it is easier to expand abroad, for small and medium enterprises this is not usually the case due to their lack of resources because of their reduced size. This could be avoided if firms – thanks to the new information and communication technologies – could gain access to the resources owned by foreign enterprises or foreign institutions as well as international talent (Youngdahl and Ramaswamy, 2008).

As highlighted by the OECD report (2008), the global tendency in the 1960s and 1970s was for firms to develop around 95% of their research projects internally in their own R&D labs. In the 1980s there was an increasing trend towards the internationalization of R&D, with a growing international acquisition of knowledge. Nowadays, the European Commission (Murphy and Siedschlag, 2015) stresses the recent increased trend and relevance of R&D offshoring for accessing knowledge from abroad. Focusing on European enterprises, around 70% of them have increased their R&D offshoring strategy during the last decade and approximately 87% see the foreign external acquisition of knowledge as an important step in fulfilling and increasing their innovation capacity (OECD, 2008, p. 20).

The previous literature, though, has not paid attention to the impact of the acquisition of external knowledge on the generation of breakthrough innovations. Breakthrough innovations are very important for the growth strategy of companies and may be the line that separates being a follower and being a leader in the market. Accessing foreign knowledge may play an important and decisive role in that, since the firm can take advantage of different technologies and business models, leading its competitors, which have greater difficulty in responding to such breakthrough innovations.

With the ideas surveyed above, this paper aims to provide empirical evidence on the role of the acquisition of knowledge from abroad in the generation of breakthrough innovations. Specifically, our contribution to the literature rests on the consideration of the extent to which outsourcing knowledge from foreign countries may have a positive and significant impact on innovation performance measured as sales due to new products and whether this impact is greater in the case of breakthrough innovations' performance than in the case of incremental innovations. While previous studies have focused their attention on product and/or process innovation, we are interested in the profitability of being a more/less innovative firm. In addition, we plan to examine this effect in greater depth and determine whether the role of R&D offshoring is different in the case that the acquisition of knowledge is made by firms belonging to the same company or outside as well as in case that it is made with research institutions instead of the business sector. The idea is that being in contact with different types of partners could imply better innovation and managerial skills (Martinez-Noya et al., 2012), facilitating future and improved offshoring relations with different agents, ending in a higher likelihood of achieving radical innovations. Besides, we plan to study whether the impact of R&D offshoring differs depending on the period of analysis, that is, comparing the pre-crisis period with the crisis one.

Another contribution in the paper refers to the use of a method of estimation that controls simultaneously for the heterogeneity of enterprises as well as for the sample selection and the endogeneity problem of our main variable of study in a panel data set. Past scholars have controlled the latter two but individually (see Cassiman and Veugelers, 2006; Cusmano et al., 2009; Love et al., 2014) and using mostly cross-sectional data. Our empirical evidence refers to Spanish firms in the period 2004–2013, including service enterprises and manufactures.

The outline of the paper is as follows. The second section provides a literature review and exposes the main hypotheses of the paper. Section 3 sketches the empirical model before section 4 presents the data. The main results are provided in section 5, and we discuss the results and conclude in section 6.

2. Literature review and hypotheses

Among the main reasons why the acquisition of foreign knowledge is important we find that of the reduction of costs that it implies as well as the access to a well-prepared labor force (Lewin et al., 2009; Youngdahl and Ramaswamy, 2008). People – scientists, researchers or engineers – are not perfectly mobile, and talent is an intangible good that is embedded in individuals, not easy to imitate and part of the knowledge base of an enterprise (Lewin et al., 2009). The European Union Survey (Tübke and Bavel, 2007) reported that the most important reason for offshoring R&D is the access to specialized R&D knowledge, cost reduction being the least important. The acquisition of external knowledge connects the firm with a variety of know-how and new knowledge that is necessary to develop new processes and products. This leads the enterprise not to be locked in and to gain access to new ideas. When the external knowledge comes from a different country, the firm comes into contact with a different national innovation system – with diverse technological paths or trajectories – providing it with an opportunity set that, combined with the internal R&D process, leads to new knowledge. Indeed, in recent studies researchers have found R&D offshoring to be an important step in gaining access to knowledge that is beyond the boundaries of the firm (Chatterji and Fabrizio, 2014). Enterprises know that radical or breakthrough innovations require the exploration of entirely new types of business models and technologies. This different knowledge might encourage a different perspective not only by implementing it but also by modifying the external technology into a new and different product.

Indeed, as enterprises move abroad geographically to acquire new technologies, it is feasible to take advantage of the different national innovation systems, which can be associated with differences in culture, market regulations, industry specialization, educational level, financial restrictions and a welfare state's laws or preferences (Filippetti and Archibugi, 2011; Phene et al., 2006). This could lead not only to an improvement in the adaption of existing products but also to the creation of new ones.

While studying how the external acquisition of knowledge affects the innovation performance of firms, it seems that the result may differ according to the type of innovation pursued, process or product innovation. Previous studies seem to have given support to the idea that external knowledge exerts a greater effect on product rather than process innovation. The reasoning behind this result comes from the fact that the kind of knowledge needed to achieve product innovations tends to be more explicit and easier to codify, so that it is more transferable across borders (D'Agostino et al., 2013). If the knowledge can be codified into a new product, there is no problem in acquiring it from others and even crossing a border. However, when the new knowledge requires coordination between the two parties at the organizational and knowledge levels, which is more usually the case in process innovations, the host firm will need skills that are very close to those of the foreign firm, and given the differences in culture, customers' demands, labor laws and so on, it can be more difficult to implement (Phene et al., 2006). In line with the latter, Nieto and Rodríguez (2011) found evidence that, in the Spanish case, the R&D offshoring strategy has a larger impact on product than on process innovations, a similar result to the one for France (Bertrand and Mol, 2013). With these previous results in mind, we focus our empirical research on the impact of R&D offshoring on product innovation.

However, our main concern is to identify the degree to which the acquisition of geographically external knowledge can affect the degree of novelty of the innovation achieved by a firm. Indeed, the new products obtained by a firm thanks to its innovation strategy can be associated with existing products/services that have been improved – incremental innovation – as well as products that are completely new to the market – radical or breakthrough innovations. Breakthrough product innovation can be understood as a novel and unique technological advance in a product category that significantly alters the consumption patterns in a market (Zhou and Li, 2012). This completely new product can generate a new platform or business domain that could imply new benefits and expansion into new markets (O'Connor et al., 2008).

To connect R&D offshoring and breakthrough innovation, we rely on the *tension theory* (Ahuja and Lampert, 2001; Weisberg, 1998), which emphasizes the importance of a wide search or combinations of different sources to implement and recombine dissimilar and distant knowledge to achieve a revolutionary innovation. A search in a small segment of innovative sources has a negative influence on enterprises' performance, promoting only incremental improvements. Indeed, Laursen and Salter (2006) highlighted that the search for knowledge from different sources can stimulate radical innovations, as the access to specialized labor communities in specific types of knowledge (Lewin et al., 2009) plays a fundamental role in enterprises' productivity (Belderbos et al., 2013). In fact, there is evidence that international outsourcing, when technological proximity exists, generates breakthrough innovations (Phene et al., 2006). The latter is related to the idea that firms are more efficient when implementing and recombining knowledge from sources that are close to their knowledge base or close to their research fields (Cohen and Levinthal, 1990). Thus, despite the technological proximity, differences in national innovation systems and in managerial capabilities – human capital, social capital and cognition[1] – guarantee the novel recombination of such distant knowledge, which could result in a breakthrough innovation (Phene et al., 2006).

Taking this evidence into account, we believe that, when a firm is associated with foreign enterprises that belong to different national innovation systems, the knowledge that can be acquired may have a stronger degree of novelty, so the likelihood that it will result in

[1] Beliefs and ways of solving problems that allow decision making in certain directions (see Phene et al., 2006).

the development of a product that is completely new and/or of greater economic value can be higher (Kaplan and Vakili, 2015; Phene et al., 2006). Therefore, we can pose the following hypothesis:

Hypothesis 1. *The acquisition of knowledge from abroad is expected to have a greater impact on breakthrough innovations than on incremental innovations*.

We turn now to the analysis of the behavior of R&D offshoring and its impact on innovation performance when disaggregating the acquisition of knowledge into two components: knowledge acquired from other firms within the group – known as captive offshoring – and that from firms outside the group – offshoring outsourcing. Following the *hollowing out* framework (Kotabe, 1989), the dependency on external knowledge implies a reduction of the internal capabilities of the firm, partly because of the substitution effect of the former over the latter but also because the company loses its control over the R&D process. However, this may encompass a lower quality of the technology/product acquired, since the contracting firm cannot follow all the steps of the process. All this could favor captive offshoring as a superior strategy instead of offshore outsourcing; the internal connection between the headquarters and its subsidiaries allows better control of the entire process. In such a case, internal modes of developing innovations – captive offshoring – might be a better option with the aim of retaining valuable resources and specific knowledge.

On the other hand, and relying on the *resource-based view* (Barney, 1991), external knowledge can lead to a change in the base knowledge of firms, increasing their efficiency and promoting changes in their routines. Furthermore, the international experience of the manager, better contractual clauses and formal/informal property rights (Buss and Peukert, 2015; Spithoven and Teirlinck, 2015) can allow firms to obtain a higher return on offshoring outsourcing over captive offshoring. In this sense, Spain being part of the European Union, with solid laws of intellectual property rights, the offshoring strategy with enterprises outside the group could imply greater profitability.

The *cognitive paradox* proximity (Boschma and Frenken, 2010) stresses that, when a firm engages in the acquisition of external knowledge, this should be similar to the knowledge base of the firm so that it can be understood and assimilated but not too similar to avoid redundant information. Regarding this, Fornahl et al. (2011) studied the role of public subsidies in private R&D collaborative projects in Germany and found that, to succeed in a collaboration agreement, enterprises need to be similar in some way so that they can understand the base knowledge but not too similar so that they can extract new ideas/technology from such collaboration. Regarding dissimilarity and according to the *tension theory*, there is a necessity to integrate dissimilar knowledge from different sources to achieve a revolutionary and new frontier that displaces earlier technology, leading to new quality and success of the new product. In this sense offshore outsourcing may be a better and more efficient strategy than captive offshoring when pursuing radical knowledge. This opens the firm to the wider source of innovation necessary to break with the established ideas and has a larger impact on breakthrough innovations.

Furthermore, R&D projects with foreign partners both in collaboration agreements and in outsourcing could be more profitable in the short run than locating a subsidiary abroad, due to the large pecuniary and time costs associated with the latter, when the purpose is to obtain access to the possibilities of the local market in a foreign country (Van Beers and Zand, 2014). Moreover, although subsidiaries work with the same organizational and management processes as the headquarters, which could facilitate the transference of knowledge of modular technology (D'Agostino et al., 2013), differences could exist in the culture or labor markets that can lead to higher transaction costs (Gertler, 1997), making outsourcing strategies more profitable than captive ones.

Following the arguments above, it seems sensible to argue that, to obtain knowledge that could lead to highly novel innovation, the new knowledge should come from a completely new environment. Therefore, acquiring it from abroad ensures that it comes from a different national system of innovation. If, in addition, it comes from enterprises outside the group, we expect it to be more dissimilar than if it comes from firms belonging to the same group, implying a higher degree of novelty of the resulting innovations. Using the above arguments, we build our second hypothesis:

Hypothesis 2. *The impact of foreign knowledge acquisition on radical innovations is greater when the knowledge comes from firms that do not belong to the same group.*

The variability of the impact of the external acquisition of knowledge on breakthrough innovations can also be studied from the viewpoint of the type of agent from which the knowledge is acquired. Taking a step further, we now want to surpass the technological boundaries of the firm and try to disentangle the different impacts of the offshoring strategy when companies acquire foreign knowledge from an industrial agent or from an institutional/scientific agent. It is widely accepted that the type of knowledge developed by universities and institutional research centers is, in most cases, not focused on market profitability. Indeed, they develop a more basic know-how with or without industrial application, which can incorporate novel knowledge that could lead to a more radical innovation, although this is not necessarily the case, since the knowledge could be far from what the market needs.

Certainly "the interaction between industry and science is one of the most prominent institutional interfaces for knowledge diffusion" (Robin and Schubert, 2013). Universities play an important role in innovation: they provide scientific research, produce knowledge with industrial applications and provide human capital (Schartinger et al., 2002). This is an important issue to bear in mind since, as suggested by Cohen and Levinthal (1990), the type of knowledge coming from scientific/technological agents is completely different from the type that can be understood and implemented according to the internal capabilities of enterprises. Consequently, this kind of relation between firms and public institutions allows enterprises to access a wider pool of knowledge, strengthening their knowledge base (Aschhoff and Schmidt, 2008). At the same time, this increased knowledge base could enable access to a higher degree of understanding and implementing of foreign technologies coming from other different partners, such as suppliers, customers and competitors, increasing the likelihood of generating radically new products.

Previous evidence on R&D cooperation has shown that enterprises collaborate more with foreign top universities than with less highly regarded local universities (Laursen et al., 2011). In fact, foreign universities like to partner highly innovative enterprises, meaning that links with universities are not restricted to national boundaries (Monjon and Waelbroeck, 2003). Besides, D'Este et al. (2013) found that the key point in taking advantage of the link with research institutions is the location of the enterprise in a cluster of firms, not the location of the university. The latter gives less importance to the spatial proximity between the two players. Furthermore, from the perspective of product innovation, geographical distance has been losing its relevance to firm–university collaboration (Maietta, 2015).

Additionally, the problem of geographical distance could be solved depending on the internal capabilities of the firm and the transmission of more standardized knowledge – scientific publications, patents and so on. The latter concerns the necessity of geographical proximity in the case of social science, contrary to the case of natural science research (Audretsch et al., 2005), leading to greater cognitive proximity for the latter, which could promote foreign contact between firms and universities.

Finally, in the case of outsourcing, evidence exists of an increased probability of outsourcing certain activities focused on knowledge specificity when the enterprise uses more complex knowledge and has a strong connection with universities (Spithoven and Teirlinck, 2015). All this, in fact, could give an advantage to firms seeking to improve their internal knowledge base through public organizations. Taking into account the latter, our third hypothesis arises:

Hypothesis 3. *The impact of the acquisition of external knowledge from an international research-based agent is expected to be greater than that acquired from an industrial-based one.*

Another interesting research point is to determine how the economic crisis in 2008 has affected the impact of R&D offshoring on breakthrough innovations. In the Spanish case, this is particularly relevant due to the strong impact of the crisis and the difficulties that firms faced in obtaining funding for innovation. On the one hand, the countercyclical approach states that innovation increases during recessions, as, with low demand, the opportunity costs of conducting innovation are lower than in periods of growth (Barlevy, 2004), the reasoning comes from the idea of the ease reallocation of internal capabilities from the production to R&D (Aghion and Saint-Paul, 1998; Schumpeter, 1939). Alternatively, the procyclical approach points out that financial constraints might prohibit firms from maintaining or increasing their R&D budget (Stiglitz, 1993) and that firms postpone innovation to periods of expansion to maximize the returns (Barlevy, 2004). Previous evidence has shown that the procyclical argument tends to prevail over the countercyclical one relative to innovation (Paunov, 2012), even though there are countries such as Sweden in which the response to the recent economic crisis was countercyclical (Makkonen, 2013).

For the case of Spain, Makkonen (2013) found that "according to government science and technology budgets, Spain was one of the European countries most affected by the crisis," and the projection of future R&D public expenditures does not seem to improve (OECD, 2012, p. 48). Regarding the accessibility of funds for Spanish enterprises and according to the INE (Spanish National Institute of Statistics), the rate of success of enterprises obtaining funding for their innovation projects was 80% in 2007 and 50% in 2010.[2] Meanwhile, with respect to the perception of the evolution of the relative access to funding between 2007 and 2010, only 1.1% answered that it was better and for 33.6% it was worse.[3]

Innovative firms have a propensity for risky business models, which are difficult for banks to value, so public subsidies – following the countercyclical argument – generally imply a relevant source to recover from the crisis "by stimulating business innovation giving rise to market novelties" (Beck et al., 2016). In accordance with that, Paunov (2012) found that firms with public financing are less likely to discontinue their projects, as they are useful in alleviating capital market imperfections.

In this sense we want to provide evidence showing whether the impact of the strategy of acquiring foreign R&D had a lesser or a greater impact on the generation of breakthrough innovations during this period of financial constraints. We do not have a clear hypothesis a priori since there are arguments for both results. On the one hand, since the access to funding for R&D activities is lower in crisis periods, if internal and external R&D expenses are reduced, and the two tend to be complementary (Añón Higón et al., 2014; Cassiman and Veugelers, 2006), we would expect that the return of each euro devoted to the external acquisition of knowledge would decrease. This is because, according to the complementary relationship, the marginal increase of adding one activity – offshoring – when already performing the other – internal innovation – is larger than the marginal increase from performing only one activity – offshoring. Therefore, when the internal innovation is reduced, the marginal effect of offshoring is expected to decrease.

However, one would expect that, in a crisis period with lower funding levels, firms would be more cautious about the resources that they spend on new innovation projects and try

[2] http://ine.es/jaxi/tabla.do?path=/t37/p231/a2010/l0/&file=01003.px&type=pcaxis&L=0
[3] http://ine.es/jaxi/tabla.do?path=/t37/p231/a2010/l0/&file=01013.px&type=pcaxis&L=0

to choose those with higher chances of success. In such a case, the return obtained from the offshoring strategy would be higher. Given the ambiguity of the different impacts of offshoring before and during the crisis, we aim to provide evidence showing which kinds of arguments have been more determinant in the Spanish case. We present the following two competing hypotheses:

Hypothesis 4a: *The economic crisis has led to an increase in R&D offshoring's return on breakthrough innovation*.

Hypothesis 4b: *The economic crisis has led to a decrease in R&D offshoring's return on breakthrough innovation*.

3. Methodology

We plan to regress firms' innovative performance as a function of the acquisition of foreign technology and firms' characteristics. This kind of analysis could lead to sample selection and endogeneity problems that need to be corrected. On the one hand, we are testing different hypotheses only for innovative firms – those which have positive expenditures on innovation – being this a possible source of sample selection posit by Heckman (1976) that can lead not only to bias but to inconsistent parameters (Wooldridge, 2010. p. 805). On the other hand, we are aware of possible endogeneity due to a simultaneity problem in our regression, since those firms having better innovation performance would probably tend to acquire more knowledge from abroad. Even though we decided to lag our offshoring measures one period in order to lessen simultaneity problems, this would not probably wipe it out, given the persistence that innovation variables tend to present (Raymond et al., 2010; Triguero and Córcoles, 2013). Specifically, if the company has made offshoring in a given year, it is very likely to follow doing it in subsequent years. Due to the above reasons we use a methodology that allows us to detect and correct both problems – sample selection and endogeneity – in the same estimation making use of the panel structure of the data, following two steps (Dustmann and Rochina-Barrachina, 2007; Semykina and Wooldridge, 2010):

(i) We perform a yearly probit model of the probability of being an innovative firm as a function of firms' characteristics plus some exclusion restrictions[4] and compute the yearly inverse Mill´s ratios. In order to detect the sample selection bias we perform a Wald test on the joint significance of all the inverse Mill´s ratios included in the main equation in the second step (Dustmann and Rochina-Barrachina, 2007).

(ii) We estimate the degree of novelty of the innovation performed by the firm with respect to the offshoring of innovation activities, our main equation, which is estimated by pooled 2SLS with bootstrap errors.[5] Specifically, in the first stage, we regress the R&D expenditures for the acquisition of foreign technology – offshoring – as a function of the exogenous variables, plus the instruments for offshoring and the inverse Mill´s ratios and compute the predicted values. Then, we use those predicted values for offshoring and the exogenous variables including again the inverse Mill´s ratios to study their impact on our measures of the novelty of innovation performance. With this strategy we are trying to lessen the negative consequences that could be caused by the potential sample selection and endogeneity problems in our regressions.

As we are using in our different specifications exogenous time invariant variables we cannot use the fixed effect model.[6] Besides, the random effect technique assumes no correlation among the observed characteristics of the firms and the unobserved heterogeneity, which seems not to be plausible in this case.[7] As we cannot deal with FE or RE, the way in which we can detect/correct for the unobserved heterogeneity of firms depends on the observable characteristics (Mundlack, 1978). Therefore, we follow Semykina and Wooldridge (2010) and take the mean values of the exogenous time varying variables and include them into the analysis.

The selection equation for the first step is specified as follows:

$$s_{it} = 1(Z_{it}\delta_t + \bar{Z}_i\xi_t + v_{it} > 0), \qquad v_{it}|Z_{it} \sim Normal(0,1)$$

where s_{it} is the probability of being an innovative firm, Z_{it} is a vector that include all the

[4] The excluded variables are presented in section 4.2. These exclusion restrictions guarantee the identification of the system avoiding problems of collinearity in the last step.

[5] We decided to use bootstrap errors because of the use of the generated variables (Mill´s ratios) in this second stage. As explained by Heckman (1979) the no inclusion of those ratios can be seen as an omitted variable problem due to the fact that the expected value of the endogenous variable depends on the selection term – the probability of being an innovative firm – leading to an inconsistency of the parameters of interest in the second stage (Wooldridge, 2010. p. 805).

[6] In such a case the correction for the unobserved heterogeneity also eliminates the exogenous time invariant variables.

[7] The exogenous variable could be correlated with managerial abilities which are unobserved.

variables in the second stage – without the endogenous one – plus the exclusion restrictions and instruments, and δ_t is the vector of their parameters. The mean values and their vector of parameter are represented by $\bar{Z}_i\xi_t$ and the error term v_{it} is assumed to be normally distributed. Conditioning on $s_{it} = 1$ our equation of interest will be.

$$E(y_{it}|X_{it}, \bar{Z}_i, \hat{\lambda}_{it}, s_{it} = 1) = X_{it}\beta + \bar{Z}_i\eta + \gamma_t\hat{\lambda}_{it}$$

where y_{it} will be our variable proxying for innovation performance, $X_{it}\beta$ will include our focal measures of the external acquisition of knowledge and the vector of control variables – without the exclusion restrictions – with their corresponding parameters. The mean values and their vector of parameters are represented by $\bar{Z}_i\eta$. Finally, $\gamma_t\hat{\lambda}_{it}$ is a vector of the inverse Mill´s ratios and their coefficients.[8] This equation is estimated using $Z_{it1}, \bar{Z}_i, \hat{\lambda}_{it}$ as instruments – where $Z_{it1} \subset Z_{it}$ including the instruments and the exogenous variables – and the validity of those instruments guarantees the identification of this procedure.[9] The variables in all the models, that is, the exclusion restrictions and the instruments were lagged two periods while the controls were lagged one period in order to lessen simultaneity problems and allow for the necessary time from the start of a R&D investment until the generation of profits.

4. Data set, variables and descriptive analysis

4.1 Data set

The data set used in this paper is taken from the PITEC (*Technological Innovation Panel*), a yearly survey with around 450 variables on the innovation activity carried out by Spanish enterprises. Our sample covers the period from 2004 to 2013, and we account for around 86,000 observations relating to 12,000 enterprises throughout the period. However, after deleting missing values and taking into account only companies with more than 10 workers that have declared positive expenditures on innovation and on product innovation, we finish with around 35,000 observations.

As stressed before, being part of the European Union gives the advantage of solid laws of intellectual property rights, leading to high profitability of offshoring strategies in

[8] We interact the inverse Mill´s ratios with time dummies in order to allow γ to be different across t.
[9] The instruments used are explained in section 4.2.

Spain.[10] At the same time, Spain is at the middle of the technological ranking, below the mean R&D over GDP expenditure in Europe – 1.22% for Spain in 2014 but 2.08% for the UE-15[11] – and most of the productive sector is based on small and medium enterprises. The public sector is the main source of knowledge, with the largest share of R&D workers, around 56% in 2014 – 19.4% for public research centers and 36.7% for universities. In addition, Spain suffered one of the biggest and most negative impacts of the financial and economic crisis at the end of 2008, making the Spanish case a potentially interesting study.

4.2 Variables

Dependent variables

We focus our empirical research on the impact of offshoring on product innovation and how this has an effect on firms' sales. Indeed, obtaining a new product does not imply that the sales are consequently increased; at least, not all new products imply an equal increase in the sales. In the PITEC survey, firms are asked whether they have developed product innovations in the current year or in the previous two years, being either products that are only new to the firm or products that are new to the market. The firms are also asked about the economic impact of these innovations in the current year with respect to their sales. Using this information we developed three different endogenous variables.

New Sales accounts for the share of sales that the firm declares are due to its new products in its total sales (Cassiman and Veugelers, 2006; Tsai and Wang, 2009). *New Firm* proxies for incremental innovation, since it reflects the share of sales due to product innovations that are only new to the firm, whereas *New Market* proxies for radical or breakthrough innovations through the consideration of the share of sales that are due to product innovations that are new to the market (Grimpe and Kaiser, 2010).[12] Moreover, *Innovation*, which is our selection variable, captures whether the firm is innovative or not.

Independent variables

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[10] Most R&D offshoring of European firms is conducted between firms within the European Union (Tübke and Bavel, 2007).

[11] http://www.ine.es/jaxi/Datos.htm?path=/t14/p057/a2014/l0/&file=02009.px

[12] In all the cases, we develop the ratio between the percentage of sales over one minus such a percentage of sales taking the logs of the ratio, for which we used a winsorizing process for the extreme values. As our variable is censored between 0 and 1, we use this transformation to close to a normal distribution (Robin and Schubert, 2013).

We construct our focal independent variables using different measures for the acquisition of foreign knowledge. For the study of hypothesis 1, we use the variable *Offshoring*, measuring the expenditures on technology from abroad over sales. Many studies have found a positive relationship between the purchase of external knowledge and innovation performance – both as a dummy. However, we do not have previous evidence of the impact of the amount of expenditure for the external acquisition of knowledge on the profitability of innovations. To test our second hypothesis, we split the offshoring measure into two: the external acquisition of knowledge from inside the multinational group of firms (*Offgroup*) and that from outside the holding (*Offnogroup*). Finally, for hypothesis 3 we consider external purchases from foreign research institutes (*Offpublic*) and purchases from foreign private companies (*Offprivate*).

Exclusion restrictions

Consistent with the literature, in our first stage the variable *Group* tries to capture the effect of belonging to a group of enterprises (Vega-Jurado et al., 2009). In this case, belonging to a group could affect the likelihood of being an innovator through more internal contact with the rest of the company facilitated by a lower risk of appropriation and an increased amount of internal sources of innovation. Moreover, *Cooperation* has an important role in product innovation (Robin and Schubert, 2013), capturing whether the enterprise cooperates with another organization.

Instruments

As we incorporate five different variables for R&D offshoring into our analysis, the difficulty lies in finding valid instruments for all of them. As the literature on this issue is scarce, we rely first on the economic validity of the instruments and second on the statistical validity, as explained in the results.

To instrument *Offshoring* in our first hypothesis, we decide to focus in the case of exporter enterprises (*Export*). In this case, firms have access not only to their national markets but also to the global one due to the adaptation of their products to differences in preferences, laws, culture and so on, being forced to innovate to consider foreign-market characteristics. Following García-Vega and Huergo (2011), exporter enterprises are more likely to adopt offshoring strategies than those that are not exporters to have lesser financial restrictions. Considering the above, *Export* captures the experience of the company in external markets, implying more experience of the offshoring strategy. Another relevant aspect is if the enterprise belongs to a multinational, which we measure as those firms with more than 50% of its capital from abroad (*Foreign*). Indeed, we expect it to have more resources that can complement internal innovation, leading to a positive impact on the external acquisition of knowledge. Moreover, a multinational company has easier access to foreign environments and different national innovation systems, so the access to such external knowledge could be more profitable (Belderbos et al., 2013).

For our second hypothesis, and considering the internal capacity of firms, *R&D Personnel* measures the ability of firms to understand and absorb external knowledge. This has been proved to be relevant for explaining the offshoring strategy as pointed by Spithoven and Teirlinck (2015) who stresses the importance of having more than one component of the internal capacity of enterprises for explaining the acquisition of knowledge, being the opposite an oversimplification. In this case, we also make use of *Foreign* and *Export*.

Furthermore, the consideration of whether the firm has developed applied research (*Applied*) rests on the idea that firms usually undertake applied research to obtain market benefits, unlike research institutions, which are more focused on the research base. In this case firms could be interested in acquiring only those projects/technologies from research institutions that are more focused on market profitability, increasing the likelihood of offshoring this kind of project. The latter, jointly with *Foreign* and *Export* are used for our third hypothesis.

Finally, to instrumentalize R&D offshoring in the pre-crisis and crisis periods, we follow Wooldridge's strategy (2010, p. 133) and assume that the crisis period is exogenous to the firm. That is, we create a measure for each instrument – *Foreign* and *Export* – before the crisis and another one for after the crisis.

Controls

To control for relevant firm characteristics, *R&D intensity* captures the effect of the internal capabilities of the enterprise, which have been recognized as an important complement for R&D offshoring, and the degree of novelty of the innovation (Cassiman and Veugelers, 2006; Spithoven and Teirlinck, 2015). We also account for the *Size* of the firm and for its square term, trying to capture non-linearities in the variable. *Permanent* measures whether the company develops internal R&D efforts continuously, whereas the

Openness variable measures the number of sources of information that the company has: internal sources, market sources and institutional sources. Finally, *Demand Pull* is a variable that measures the objectives of product innovations (accessing new markets, gaining market share or having greater quality of products). For a detailed description of the variables, see Table A5 in the Appendix.

4.3 Descriptive analysis

Table 1 provides summary statistics for the dependent and explanatory variables used in the empirical analysis for innovative firms. We observe that the average share that the firm declares to be the result of its product innovation – *New Sales* – is 19.8%, with a higher percentage for enterprises declaring incremental innovation (11.7%) than for those developing radical innovation (8.15%). Around 4.45% of innovative firms follow an offshoring strategy. Firms tend to perform more offshoring with firms outside the group (3.35%) and with private organizations (4.16%) instead of research institutions or universities (0.6%). On average, around 40% of the innovative firms conduct internal R&D continuously, while internal R&D expenditures represent around 5.6% of the total sales.

[Insert Table 1 around here]

Interesting differences can be extracted when comparing firms that carry out R&D offshoring with those that do not. Offshoring enterprises have a larger share of sales from new products, whereas they double the amount of sales due to breakthrough innovations and have a larger share of their sales due to incremental innovations. Furthermore, they spend three times more on internal R&D resources as a percentage of their total sales as well as more than double that of enterprises that innovate constantly in comparison with those that do not engage in R&D offshoring. They use more than double the external sources of information, while 90% of them are exporters. In fact, they usually cooperate more with other institutions; finally, they are bigger in terms of the number of workers.

5. Regression results

Table 2 contains the regressions that examine the impact of different offshoring strategies on our measures of innovative performance. The table shows the results of our second stage, that is, our main equation of interest. Time and technological sectorial dummies are included, being jointly significant in all the specifications. Relative to Heckman's correction – see Table A1–A4 in the appendix for the first stages – we find strong evidence of the sample selection's problem, as concluded from the Wald test on the joint significance of the inverse Mill's ratios (Dustmann and Rochina-Barrachina, 2007), which are significant in all the specifications, indicating the necessity of such correction in the analysis.[13]

Regarding endogeneity, the tests of exogeneity of all our different offshoring variables in the different specifications reject the null hypothesis, stressing the necessity for controlling for double causality. In all the cases, the test of weak identification highlights that our instruments are not weak; that is, following the rule proposed by Staiger and Stock (1997), an F-Statistic for the joint significance of the instruments below a value of 10 is an indication of weak instruments. In our case our values are in the range of 12.03–250.1 and above the critical values of Stock and Yogo (2005), concluding that our instruments are not statistically weak. Furthermore, to compute whether the system is over-identified, we perform the Sargan test, which does not reject the null hypothesis of over-identification (see Baum et al., 2007), pointing to the exogeneity of our instruments. All these tests guarantee proper use of the methodology proposed and the statistical validity of our instruments. Regarding the Mundlack approach to controlling the possible correlation among our exogenous variables and the unobserved heterogeneity, we find joint significance of these terms in all our specifications, indicating the necessity of controlling for such unobserved heterogeneity.

[Insert Table 2 around here]

Table 2 displays the results of our baseline model in column 1, in which we observe that *R&D Offshoring* has a positive and significant impact on the share of sales due to new products. However, we wonder whether this significance could be due to the fact that innovation offshoring may affect breakthrough innovation more clearly than in the case of incremental innovation. To conclude on this, we disaggregate our measure of innovative performance into the share of sales due to products that are *new to the firm*

[13] Since the small within variability of our sample leads to the risk of high collinearity among the exogenous variables and their mean values, we decided to use only those mean values with less correlation.

and those that are due to products that are *new to the market*, proxying for *incremental* and *radical innovations*, respectively. This is shown in columns (2) and (3) of Table 2. As hypothesized, the coefficient for *Offshoring* is positive and highly significant for *breakthrough innovations*, while it is not significant for *incremental innovations*, giving full statistical support to our first hypothesis: there is a clearer impact of foreign acquisition of knowledge on *radical innovations* than on incremental ones. Thus, we focus on the latter from now on.

In column (4) we consider the disaggregation of *Offshoring* into offshoring with enterprises inside the group – *Offgroup* – and offshoring with firms outside the group – *Offnogroup*. We find a positive and significant impact of both *offshoring outsourcing* and *captive offshoring* on *breakthrough innovation* but with a smaller effect for the latter. The Wald test – at the bottom of table 2 – rejects the null hypothesis of equality between the parameters and confirms statistically the difference between the two coefficients at the 5% level. This evidence gives support to our second hypothesis, in which the different types of knowledge coming from firms outside the enterprise's group should have a greater impact on innovative performance than those coming from enterprises with the same organizational and management strategies.

The results in column (5) provide evidence against our third hypothesis, which concerns the effect of the external acquisition of knowledge separating research-based knowledge from business-based knowledge. We find that the impact of knowledge coming from the business sector from abroad is positive and highly significant, whereas the knowledge coming from public research centers or universities from abroad is not. Although viewed from a different perspective, this result is in line with that obtained in the study of the impact of cooperation agreements in Spanish firms by Vega-Jurado et al. (2009), who found that the impact of cooperation with science-based agents is smaller than that of cooperation with private enterprises in a supplier-dominated sector.[14]

Finally, but no less important, we would like to see how the current economic crisis is affecting the R&D offshoring undertaken by Spanish firms and specifically whether the impact of such a strategy had different effects before and during the crisis period. A

[14] We should also be aware, though, that the share of firms that purchase technology from foreign research centers or universities is very small compared with that from the business sector.

descriptive analysis through time shows that Spanish firms have exerted slightly lower effort in offshoring strategies during the crisis than before it. Indeed, the share of firms offshoring innovation in 2004 was 5.0%, whereas in 2009 it was 4.48% and in 2013 it was 4.04%. Since our sample decreases over time because some firms may report a major issue,[15] we test our predictions on a balanced panel of firms that are present during the whole period from 2004 to 2013.[16] The results in column 6 show that the parameter for the offshoring variable for the period before the crisis was not significant while it is during the crisis. This result gives support to our hypothesis 4.a, meaning that the crisis implied higher profitability from seeking new knowledge abroad.

With respect to the control variables, Table 2 also shows interesting results. Regarding *Internal R&D Intensity*, the coefficient has a positive impact on the profitability of breakthrough innovations. This supports the internal capabilities theory: the firm needs internal resources – personal, equipment and instruments – with a high degree of knowledge to access, understand and implement new knowledge (Cohen and Levinthal, 1990). We also find evidence of a negative non-linear relationship for the firms' size, meaning that small firms are the ones with greater innovation performance, among other reasons due to the facts that they can benefit more from introducing radically new products (Cusmano et al., 2009; Grimpe and Kaiser, 2010) and that they are less restricted by complexities in their organizational processes. Indeed, big enterprises may have larger management problems than small ones due to the complexity of monitoring tasks, which increases more than proportionately with size (Baier et al., 2015).

Developing internal R&D activity continuously (*Permanent*) shows the expected positive sign while having a wide variety of information sources for the external acquisition of knowledge (*Openness*) do not imply having a better innovation performance in the Spanish case. Whereas *Demand Pull* (having the objective of accessing new markets, gaining market share or having greater quality of products when innovating) will affect positively the innovativeness performance of the enterprise.

[15] The possible issues reported are: a firm belonging to a sector with high employment turnover; acquired firm; change in the unit of reference; change or abandonment of activity; firm remaining from an acquisition process (not part of the acquisition); in liquidation; merged; firm that has employees ceded by other firms; consequence of the crisis; and firm that cedes employees to other firms.

[16] The time frame for the pre-crisis period is 2004–2008, while the crisis period is 2009–2013. The reasoning comes from the fact that the crisis started to show its impact in 2009 (Hud and Hussinger, 2015).

6. Discussion and conclusions

R&D offshoring is a relatively recent topic in the innovation literature, which is partly due to the recent process of purchasing innovations from abroad. While being an innovative firm could make the difference between being a leader and being a follower in an industry, it is also important to access wider and different types of knowledge, such as those in foreign countries, to increase the market power of a firm and to obtain a lower-cost and highly prepared labor force (Lewin et al., 2009), among other benefits.

Our research contributes to the empirical analysis of the impact of the knowledge that comes from beyond the geographical boundaries of the firm and even the country where the firm is located and extends the previous literature by analyzing its effect on breakthrough innovation, that is, on the most novel knowledge leading to products that are new to the market. The evidence provided in this paper refers to Spanish firms from 2004 to 2013, making use of estimation methods that take into account sample selection bias and endogeneity problems.

Firstly, we found evidence that the acquisition of external knowledge has a significant impact on product innovation, at least on our proxy that extends beyond a dichotomous variable and tries to capture the profitability of product innovations. In this sense our result is in line with previous studies pointing to a positive impact of acquiring foreign knowledge on product innovations (Nieto and Rodríguez, 2011).

However, we undertook a deeper analysis of the issue and considered radical and incremental innovations separately, extending the findings of previous research that did not make such a differentiation (Cassiman and Veugelers, 2006; Mihalache et al., 2012). The results point to R&D offshoring having a significant and positive impact on breakthrough innovations but not on incremental ones. It therefore seems that R&D offshoring activities, far from deterring the firms in a country from innovating, allow them to increase their innovative performance, this especially being the case for those innovations that incorporate more novelty. As stated before, it seems that, when acquiring foreign knowledge embedded with differences in human capital, state laws, industrial organization and so on, such knowledge brings a greater degree of novelty that, combined with the knowledge within the company or country, leads to greater profitability.

Taking a step forward, we analyzed which type of technological offshoring may have a larger impact on the more radical innovations obtained by Spanish firms. Our results give support to the hypothesis that the technology purchased from a very different type of agent, that is, firms from outside the group, has a higher impact on *radical* innovation than that obtained from firms within the group. Indeed, R&D offshoring implies access to specific resources from other countries (Youngdahl and Ramaswamy, 2008). If, in addition to that, offshoring with enterprises outside the group could imply a more effective way of innovating due to increased management experience and internal capabilities (Grimpe and Kaiser, 2010; Martinez-Noya et al., 2012), it explains why acquiring foreign knowledge from a different organizational structural firm has a greater impact on breakthrough innovation.

Additionally, we conclude that knowledge coming from a foreign business organization has a greater impact on breakthrough innovations than that from foreign research-based institutions. The logic behind this result can be related to the small amount of Spanish enterprises that have a contractual relation with research institutes/universities, as stressed by Gutiérrez Gracia et al. (2007), as well as to the perception by Spanish firms that the knowledge acquired from research organizations entails a smaller chance of real applicability (Nieto and Santamaría, 2007). This idea was also highlighted by Vega-Jurado et al. (2009), who stressed that Spanish enterprises are more focused on obtaining funds from the Government when developing research projects with public institutions than concentrating on product innovations. Besides, the innovation carried out by the business sector is generally more market-oriented and can have, as a consequence, a more direct impact on the share of sales due to products that are new to the market.

Finally, we contribute to the existing literature with an analysis of the impact of the R&D offshoring strategy before and within the crisis period, thanks to the availability of data until 2013, which cover the worst years of the crisis. Our findings suggest a greater impact of the offshoring strategy on breakthrough innovations during the crisis than before the crisis. The latter is interesting since we show that the amount of Spanish enterprises doing R&D offshoring has been reduced for the entire period[17] – a conclusion that also holds

[17] Not only the amount of enterprises, even the amount of money allocated to this strategy has been reduced among those enterprises doing R&D offshoring in all the period.

for the balanced panel – while the return they obtain has been increased. This suggest that even the R&D strategy itself is procyclical, the return may be countercyclical as pointed by (Aghion and Saint-Paul, 1998) which is in line with the findings of D´Agostino and Moreno (2016) for the cooperative strategy of Spanish enterprises. This could be due to the fact that firms would be more cautious in times of financial constrains about the resources that they spend on new innovation projects trying to choose those with higher chances of success.

Policy and management implications

The above evidence has important implications for management and policy makers. First, policy makers should not focus mainly on innovation agreements between national firms and public research institutes; at least, they should not been encouraged at all costs. Instead, they also need to pay attention to the contractual agreements among private organizations, specifically those outside the geographical boundaries of the country, to obtain a higher novelty degree of the innovations obtained.

Second, our results shed light on the effect of R&D offshoring on the profitability of innovation in periods of financial constraints. As stressed by the OECD report (2012, p. 48), the Spanish Government diminished the budget devoted to R&D, resulting in a decrease in the funds reserved for private R&D projects. However, as observed in our results, purchasing R&D from foreign countries can allow firms to achieve a good innovation performance even in the middle of crises. Therefore, it would be desirable that governments had greater commitment to maintaining expenditures on innovation in order not to deteriorate the firms' R&D strategies.

Additionally, our results have interesting insights for management relative to the R&D offshoring strategy. In this sense managers should be aware of the benefits of seeking new and different knowledge abroad. This kind of strategy may imply a stronger degree of novelty in their products with a direct positive impact on their profits, giving them an advantage in terms of greater productivity, an increased internal knowledge base and access to new markets, among other advantages. Offshoring allows firms to achieve more breakthrough innovations; that is, the contractual acquisition of foreign knowledge can produce higher returns in the long term while improving the likelihood of being the market leader and leading the competitors, which have greater difficulty in responding to such breakthrough innovations. Our research has also demonstrated that having a contractual partner outside the enterprise's group implies a higher level of profitability of those products that break with the established technology in a market.

Limitations & Future Research

Our study has some limitations that should be taken into account in future research. As far as possible, we tried to analyze the offshoring strategy from a geographical point of view, arguing for the existence of differences in the knowledge coming from other national innovation systems, which could have a substantial impact on breakthrough innovations. It would be interesting to identify which type of knowledge, with respect to its geographical origin, could be more profitable in terms of offshoring: either that from a technological leader country, such as the United States, or that from a country that is not at the technological frontier, such as India. Another limitation comes from the lack of different categories of offshoring available in the data, such as R&D, design and marketing, among others, to account for their different impacts. We would also like to analyze the extent to which the regional environment of the firm is important, with the aim of determining whether belonging to one region or another could imply a different impact of the offshoring strategies carried out by firms.

Table 1. Descriptive statistics of the variables in the analysis

	Full Sample		No R&D Offshoring		R&D Offshoring	
VARIABLES	mean	sd	mean	sd	mean	sd
Dependent Variables						
Innovation	0.61	0.48	0 .59	0.49	1	0
New Sales	19.85	33.14	19.34	33.00	30.73	34.26
New Firm	11.70	25.42	11.47	25.36	16.64	26.17
New Market	8.152	20.80	7.875	20.59	14.08	24.03
Main Variables						
Offshoring	0.04	0.21				
Offgroup	0.01	0.12			0.32	0.45
Offnogroup	0.03	0.18			0.75	0.43
Offpublic	0.01	0.08			0.14	0.34
Offprivate	0.04	0.20			0.93	0.25
Exclusion Restrictions						
Cooperation	0.37	0.48	0.35	0.48	0.64	0.48
Group	0.43	0.50	0.41	0.49	0.70	0.46
Instruments						
R&D Personnel	8.58	32.97	7.33	28.99	35.35	74.99
Export	0.64	0.48	0.63	0.48	0.91	0.29
Applied	0.32	0.47	0.31	0.46	0.63	0.48
Foreign	0.11	0.32	0.10	0.30	0.29	0.46
Controls						
Internal R&D	0.06	0.22	0.05	0.20	0.17	0.40
Size	349.1	1,57	346.0	1,59	415.2	1,11
Permanent	0.40	0.49	0.38	0.49	0.80	0.40
Openness	3.80	3.26	3.68	3.25	6.33	2.25
Demand Pull	0.64	0.48	0.63	0.48	0.77	0.42

Table 2. Effect of R&D offshoring on product, incremental and breakthrough innovation.

	(1)	(2)	(3)	(4)	(5)	(6) Balanced Panel
VARIABLES	New Sales	New Firm	New Market	New Market	New Market	New Market
$Offshoring_{t-1}$	0.381**	0.093	0.554***			
	(0.148)	(0.145)	(0.132)			
$Offgroup_{t-1}$				0.576**		
				(0.249)		
$Offnogroup_{t-1}$				1.863***		
				(0.356)		
$Offpublic_{t-1}$					2.335	
					(2.516)	
$Offprivate_{t-1}$					0.915***	
					(0.225)	
$Offprecrisis_{t-1}$						0.012
						(0.361)
$Offcrisis_{t-1}$						0.732**
						(0.328)
Internal $R\&D_{t-1}$	0.594**	-0.404	0.913***	0.488	0.726*	0.585
	(0.272)	(0.247)	(0.279)	(0.339)	(0.388)	(0.421)
$Size_{t-1}$	0.095	0.662***	-0.667***	-1.016***	-0.739***	-0.745***
	(0.211)	(0.182)	(0.177)	(0.201)	(0.191)	(0.242)
$Size^2_{t-1}$	0.036***	-0.012	0.068***	0.072***	0.069***	0.059***
	(0.012)	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)
$Permanent_{t-1}$	0.648***	0.516***	0.399***	-0.092	0.333**	0.031
	(0.197)	(0.172)	(0.153)	(0.163)	(0.012)	(0.178)
$Openness_{t-1}$	0.013	0.022	0.015	-0.022	-0.006	-0.054**
	(0.024)	(0.020)	(0.019)	(0.019)	(0.012)	(0.021)
Demand $Pull_{t-1}$	1.638***	0.975***	1.432***	1.289***	1.494***	1.143***
	(0.097)	(0.084)	(0.078)	(0.085)	(0.083)	(0.083)
Constant	1.727	-5.348***	-0.640	16.458***	22.494	-6.032
	(1.850)	(1.815)	(1.613)	(3.245)	(22.815)	(3.990)
Observations	35,038	35,038	35,038	35,038	35,038	22,860
Endogeneity Test[a]	0.009	0.373	1.14e-05	0	2.15e-06	0.014
Sargan p-value	0.082	0.092	0.228	0.194	0.491	0.794
Weak id	250.1	250.1	250.1	101.6	12.03	26.24
Test F lambda	115.1***	86.72***	133***	102.5***	125.68***	91.00***
Wald test Sectors Chi2(4)	65.19***	123.70***	21.83***	36.42***	24.67***	33.04***
Wald test Mundlack Chi2(6)	43.79***	54.68***	219.05***	121.79***	202.72***	113.04***
Wald test time dummies chi2(7)	137.40***	60.95***	103.56***	86.06***	86.71***	33.22***
Comparison test $\beta_{offgroup} = \beta_{offnogroup}$: $\chi^2 = 6.31^{**}$						

[a] Endogeneity test report the p-value. Bootstrap error in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table A1. First stage Sample selection and IV. Hypothesis 1

VARIABLES	(2006) Innovation	(2007) Innovation	(2008) Innovation	(2009) Innovation	(2010) Innovation	(2011) Innovation	(2012) Innovation	(2013) Innovation	IV $Offshoring_{t-1}$
Export $_{t-2}$	-0.121	-0.034	-0.202**	-0.189*	0.072	-0.177	-0.021	-0.170	0.372***
	(0.094)	(0.093)	(0.100)	(0.108)	(0.106)	(0.107)	(0.123)	(0.124)	(0.026)
Foreign $_{t-2}$	0.268	-0.271	-0.042	0.003	0.086	-0.262	-0.155	-0.064	0.558***
	(0.183)	(0.197)	(0.185)	(0.176)	(0.183)	(0.199)	(0.221)	(0.219)	(0.033)
Group $_{t-2}$	-0.088	-0.160	0.102	-0.060	0.116	0.239	-0.154	-0.027	
	(0.113)	(0.113)	(0.122)	(0.130)	(0.145)	(0.146)	(0.156)	(0.145)	
Cooperation $_{t-2}$	0.197***	-0.115*	-0.019	0.015	-0.061	-0.034	0.057	0.074	
	(0.073)	(0.065)	(0.069)	(0.077)	(0.079)	(0.077)	(0.079)	(0.076)	
Internal R&D $_{t-1}$	1.249*	-0.079	0.822*	1.439***	2.349***	0.861**	0.639	1.187***	0.285***
	(0.661)	(0.309)	(0.440)	(0.460)	(0.705)	(0.403)	(0.426)	(0.419)	(0.079)
Size $_{t-1}$	0.154	-0.133	0.083	-0.153	0.095	0.275	0.999***	0.429	0.222***
	(0.208)	(0.190)	(0.236)	(0.280)	(0.328)	(0.312)	(0.294)	(0.290)	(0.059)
$Size^2_{t-1}$	-0.013	0.022	0.005	0.026	0.037	0.027	-0.051*	0.015	-0.002
	(0.025)	(0.022)	(0.029)	(0.032)	(0.036)	(0.033)	(0.029)	(0.031)	(0.003)
Permanent $_{t-1}$	0.354***	0.503***	0.449***	0.362***	0.510***	0.682***	0.979***	0.776***	0.268***
	(0.078)	(0.068)	(0.074)	(0.079)	(0.081)	(0.078)	(0.079)	(0.078)	(0.054)
Openness $_{t-1}$	-0.070***	-0.029***	-0.021**	-0.025**	-0.029**	-0.001	0.011	0.025**	0.014**
	(0.012)	(0.010)	(0.010)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)	(0.006)
Demand Pull $_{t-1}$	0.151**	0.113*	-0.027	0.217***	0.218***	0.121*	0.207***	0.256***	0.048*
	(0.070)	(0.061)	(0.062)	(0.065)	(0.067)	(0.065)	(0.067)	(0.070)	(0.027)
Constant	-1.117***	-0.742***	-1.354***	-1.768***	-2.206***	-2.242***	-1.867***	-1.185***	-12.203***
	(0.277)	(0.247)	(0.254)	(0.253)	(0.251)	(0.251)	(0.270)	(0.280)	(0.156)
Observations	5,451	6,849	6,498	6,146	5,982	5,722	4,983	4,514	35,038

Bootstrap error in parentheses. Industry dummies and means fixed effect included. *** p<0.01, ** p<0.05, * p<0.1

Table A2. First stage Sample selection and IV. Hypothesis 2

VARIABLES	(2006) Innovation	(2007) Innovation	(2008) Innovation	(2009) Innovation	(2010) Innovation	(2011) Innovation	(2012) Innovation	(2013) Innovation	IV $Offgroup_{t-1}$	IV $Offnogroup_{t-1}$
Export $_{t-2}$	-0.121	-0.035	-0.195*	-0.186*	0.075	-0.176	-0.026	-0.178	0.063***	0.173***
	(0.094)	(0.093)	(0.101)	(0.109)	(0.106)	(0.108)	(0.123)	(0.125)	(0.010)	(0.015)
Foreign $_{t-2}$	0.269	-0.268	-0.053	-0.029	0.081	-0.262	-0.153	-0.026	0.380***	-0.031*
	(0.183)	(0.198)	(0.188)	(0.179)	(0.184)	(0.200)	(0.222)	(0.222)	(0.013)	(0.018)
R&D Personnel$_{t-2}$	-0.000	0.002	-0.011***	-0.007***	-0.009***	0.001	0.001	0.012***	0.001***	0.002***
	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.000)	(0.000)
Group $_{t-2}$	-0.088	-0.164	0.100	-0.055	0.113	0.235	-0.153	-0.021		
	(0.113)	(0.113)	(0.123)	(0.130)	(0.145)	(0.146)	(0.156)	(0.146)		
Cooperation $_{t-2}$	0.198***	-0.114*	0.005	0.033	-0.049	-0.033	0.053	0.055		
	(0.073)	(0.066)	(0.070)	(0.078)	(0.079)	(0.078)	(0.079)	(0.076)		
Internal R&D $_{t-1}$	1.263*	-0.071	1.024**	1.352***	2.338***	0.835**	0.643	1.127***	0.148***	0.141***
	(0.669)	(0.310)	(0.444)	(0.465)	(0.705)	(0.403)	(0.427)	(0.421)	(0.032)	(0.045)
Size $_{t-1}$	0.155	-0.143	0.015	-0.154	0.021	0.275	0.996***	0.409	-0.013	0.195***
	(0.208)	(0.191)	(0.238)	(0.281)	(0.329)	(0.312)	(0.295)	(0.291)	(0.024)	(0.033)
$Size^2_{t-1}$	-0.013	0.023	0.014	0.025	0.048	0.027	-0.051*	0.014	-0.002	-0.005***
	(0.025)	(0.023)	(0.030)	(0.033)	(0.037)	(0.033)	(0.029)	(0.031)	(0.001)	(0.002)
Permanent $_{t-1}$	0.355***	0.500***	0.481***	0.375***	0.523***	0.678***	0.970***	0.751***	-0.030	0.207***
	(0.078)	(0.068)	(0.075)	(0.079)	(0.081)	(0.079)	(0.079)	(0.079)	(0.021)	(0.030)
Openness $_{t-1}$	-0.069***	-0.029***	-0.018*	-0.024**	-0.027**	-0.001	0.011	0.024**	0.001	0.007**
	(0.012)	(0.010)	(0.010)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)	(0.002)	(0.003)
Demand Pull $_{t-1}$	0.151**	0.113*	-0.025	0.221***	0.219***	0.119*	0.208***	0.246***	0.005	0.007
	(0.070)	(0.061)	(0.062)	(0.065)	(0.067)	(0.065)	(0.068)	(0.070)	(0.011)	(0.016)
Constant	-1.118***	-0.742***	-1.270***	-1.698***	-2.151***	-2.181***	-1.805***	-1.038***	-9.135***	-9.513***
	(0.277)	(0.248)	(0.256)	(0.256)	(0.253)	(0.254)	(0.273)	(0.286)	(0.062)	(0.088)
Observations	5,451	6,849	6,498	6,146	5,982	5,722	4,983	4,514	35,038	35,038

Bootstrap error in parentheses. Industry dummies and means fixed effect included. *** p<0.01, ** p<0.05, * p<0.1

Table A3. First stage Sample selection and IV. Hypothesis 3

VARIABLES	(2006) Innovation	(2007) Innovation	(2008) Innovation	(2009) Innovation	(2010) Innovation	(2011) Innovation	(2012) Innovation	(2013) Innovation	IV $Offpublic_{t-1}$	IV $Offprivate_{t-1}$
Export $_{t-2}$	-0.145	-0.040	-0.185*	-0.193*	0.063	-0.161	-0.029	-0.169	0.024***	0.221***
	(0.095)	(0.094)	(0.102)	(0.109)	(0.106)	(0.108)	(0.123)	(0.125)	(0.006)	(0.016)
Foreign $_{t-2}$	0.280	-0.314	-0.045	0.001	0.062	-0.254	-0.176	-0.086	-0.008	0.344***
	(0.185)	(0.200)	(0.187)	(0.179)	(0.185)	(0.200)	(0.222)	(0.220)	(0.007)	(0.021)
Applied $_{t-2}$	-0.294***	-0.047	-0.319***	-0.304***	-0.435***	-0.014	-0.085	0.047	0.023***	0.001
	(0.068)	(0.060)	(0.067)	(0.071)	(0.077)	(0.075)	(0.080)	(0.079)	(0.005)	(0.021)
Group $_{t-2}$	-0.097	-0.160	0.077	-0.088	0.091	0.243*	-0.143	0.002		
	(0.114)	(0.113)	(0.124)	(0.131)	(0.147)	(0.146)	(0.156)	(0.146)		
Cooperation $_{t-2}$	0.192**	-0.097	0.005	0.029	-0.039	-0.038	0.055	0.058		
	(0.075)	(0.066)	(0.070)	(0.078)	(0.080)	(0.078)	(0.079)	(0.076)		
Internal R&D $_{t-1}$	1.156*	-0.134	0.867**	1.273***	2.364***	0.761*	0.585	1.142***	0.083***	0.184***
	(0.640)	(0.308)	(0.442)	(0.454)	(0.709)	(0.402)	(0.424)	(0.417)	(0.018)	(0.052)
Size $_{t-1}$	0.093	-0.211	0.009	-0.205	-0.008	0.221	0.999***	0.424	0.037***	0.151***
	(0.212)	(0.193)	(0.242)	(0.284)	(0.331)	(0.315)	(0.295)	(0.291)	(0.013)	(0.038)
$Size^2{}_{t-1}$	-0.008	0.032	0.014	0.030	0.045	0.031	-0.051*	0.014	-0.002***	-0.001
	(0.025)	(0.023)	(0.030)	(0.033)	(0.037)	(0.034)	(0.029)	(0.031)	(0.001)	(0.002)
Permanent $_{t-1}$	0.359***	0.485***	0.487***	0.405***	0.555***	0.710***	0.986***	0.783***	0.019	0.188***
	(0.080)	(0.069)	(0.076)	(0.080)	(0.082)	(0.079)	(0.079)	(0.079)	(0.011)	(0.033)
Openness $_{t-1}$	-0.061***	-0.023**	-0.014	-0.021*	-0.024**	-0.000	0.014	0.026**	0.001	0.014***
	(0.012)	(0.010)	(0.011)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)	(0.001)	(0.004)
Demand Pull $_{t-1}$	0.157**	0.110*	-0.031	0.215***	0.215***	0.111*	0.211***	0.252***	-0.009	0.026
	(0.071)	(0.062)	(0.063)	(0.065)	(0.068)	(0.065)	(0.068)	(0.070)	(0.006)	(0.018)
Constant	-1.162***	-0.900***	-1.479***	-1.874***	-2.313***	-2.344***	-1.922***	-1.232***	-9.260***	-9.572***
	(0.282)	(0.252)	(0.259)	(0.256)	(0.254)	(0.254)	(0.271)	(0.282)	(0.035)	(0.101)
Observations	5,451	6,849	6,498	6,146	5,982	5,722	4,983	4,514	35,038	35,038

Bootstrap error in parentheses. Industry dummies and means fixed effect included. *** p<0.01, ** p<0.05, * p<0.1

Table A4. First stage Sample selection and IV. Hypothesis 4.

VARIABLES	(2006) Innovation	(2007) Innovation	(2008) Innovation	(2009) Innovation	(2010) Innovation	(2011) Innovation	(2012) Innovation	(2013) Innovation	IV $Offprecrisis_{t-1}$	IV $Offcrisis_{t-1}$
Export pre-crisis $_{t-2}$	-0.015	-0.093	-0.258*	-0.093	0.180				0.186***	0.144***
	(0.124)	(0.149)	(0.153)	(0.154)	(0.150)				(0.026)	(0.032)
Foreign pre-crisis $_{t-2}$	0.507**	-0.314	-0.101	-0.209	0.012				0.342***	0.152***
	(0.236)	(0.253)	(0.230)	(0.216)	(0.223)				(0.030)	(0.037)
Export crisis $_{t-2}$						-0.064	0.013	-0.200	0.009	0.248***
						(0.144)	(0.156)	(0.154)	(0.036)	(0.045)
Foreign crisis $_{t-2}$						-0.229	-0.210	-0.214	-0.037	0.431***
						(0.229)	(0.250)	(0.256)	(0.037)	(0.046)
Group $_{t-2}$	-0.104	-0.139	0.149	0.067	0.074	0.220	-0.141	0.144		
	(0.147)	(0.167)	(0.177)	(0.188)	(0.196)	(0.192)	(0.188)	(0.173)		
Cooperation $_{t-2}$	0.163*	-0.089	-0.062	-0.102	0.059	-0.104	0.091	0.117		
	(0.092)	(0.094)	(0.097)	(0.109)	(0.104)	(0.098)	(0.097)	(0.090)		
Internal R&D $_{t-1}$	3.359**	-0.160	1.044	4.313***	4.177***	5.537***	2.277**	6.537***	0.366***	-0.215**
	(1.517)	(0.591)	(0.891)	(1.283)	(1.278)	(1.396)	(1.014)	(1.293)	(0.073)	(0.091)
Size $_{t-1}$	0.385	-1.002*	0.655	0.104	0.505	0.590	1.576***	1.226***	0.008	0.363***
	(0.499)	(0.578)	(0.593)	(0.695)	(0.625)	(0.499)	(0.409)	(0.426)	(0.050)	(0.062)
$Size^2{}_{t-1}$	-0.045	0.118**	-0.063	-0.012	-0.010	-0.007	-0.104***	-0.053	-0.006*	-0.004
	(0.050)	(0.060)	(0.060)	(0.069)	(0.061)	(0.048)	(0.037)	(0.043)	(0.003)	(0.003)
Permanent $_{t-1}$	0.387***	0.376***	0.565***	0.377***	0.423***	0.550***	0.947***	0.694***	0.035	0.189***
	(0.102)	(0.103)	(0.113)	(0.119)	(0.110)	(0.103)	(0.100)	(0.096)	(0.041)	(0.050)
Openness $_{t-1}$	-0.066***	-0.035**	-0.027*	-0.036**	-0.036**	-0.014	0.010	0.030**	0.006	0.004
	(0.015)	(0.014)	(0.015)	(0.016)	(0.015)	(0.013)	(0.014)	(0.013)	(0.005)	(0.006)
Demand Pull $_{t-1}$	0.213**	0.143	-0.086	0.327***	0.176**	0.136*	0.142*	0.185**	0.023	-0.022
	(0.087)	(0.087)	(0.089)	(0.091)	(0.088)	(0.081)	(0.083)	(0.083)	(0.020)	(0.024)
Constant	-0.715*	-0.720*	-1.619***	-2.372***	-2.778***	-2.354***	-2.075***	-1.462***	-11.547***	-1.039***
	(0.419)	(0.400)	(0.402)	(0.401)	(0.381)	(0.366)	(0.363)	(0.381)	(0.124)	(0.153)
Observations	3,655	3,746	3,714	3,678	3,730	3,773	3,458	3,288	22,860	22,860

Bootstrap error in parentheses. Industry dummies and means fixed effect included. *** p<0.01, ** p<0.05, * p<0.1

Table A5. Definition of the variables included in the empirical analysis

Variables	Definitions
Dependent Variables	
Innovation	1 if the firm declare to have expenditures (internal or external) in R&D, 0 otherwise
New sales	Sales share of new or significantly improved products (log[new sales/(1-new sales)])
Incremental Innovation	Sales share of new or significantly improved products for the firm (log[new to the firm sales/(1-new to the firm sales)])
Breakthrough Innovation	Sales share of new or significantly improved products for the market (log[new to the market sales/(1-new to the market sales)])
Main Variables	
Offshoring	Log[expenditure on purchased R&D/Sales]
Offshoring group	Log[expenditure on purchased R&D from firms inside the group/Sales]
Offshoring no group	Log[expenditure on purchased R&D from firms out of the group/Sales]
Offshoring public	Log[expenditure on purchased R&D from public institutions/Sales]
Offshoring private	Log[expenditure on purchased R&D from private firms/Sales]
Offshoring pre-crisis	Log[expenditure on purchased R&D/Sales]*time dummy (equal 1 if time<=2008 and 0 otherwise)
Offshoring crisis	Log[expenditure on purchased R&D/Sales]*time dummy (equal 1 if time>2008 and 0 otherwise)
Independent Variables	
RD	Ratio between intramural R&D expenditure and turnover
Size	Logarithm of number of employees (and its squared term)
Permanent	1 if the firm reported that it performed internal R&D continuously; 0 otherwise
Openness	Number of information sources for innovations that a firm reported it had used (from within the firm or group, suppliers, clients, competitors, private R&D institutions, conferences, scientific reviews or professional associations) going from 0 (any) to 8 (it uses all type of information).
Demand pull	1 if at least one of the following demand-enhancing objectives for the firm's innovations is given the highest score [number between 1 (not important) and 4 (very important)]; 0 otherwise: extend product range; increase market or market share; improve quality in goods and services
Exclusion Restrictions	
Cooperation	1 if the firm reported engagement in collaborative agreements with partners; 0 otherwise
Group	1 if the firm belongs to a group of enterprises; 0 otherwise
Instruments	
Foreign	1 if the headquarter of the firm is outside Spain and it has at least a 50% of foreign capital; 0 otherwise
Export	1 if the enterprise sells its products to other countries and zero otherwise
Applied	1 if the enterprise do applied research and zero otherwise
R&D Personnel	Total amount of R&D workers
Foreign pre-crisis	Foreign*time dummy (equal 1 if time<=2008 and 0 otherwise)
Foreign crisis	Foreign*time dummy (equal 1 if time>2008 and 0 otherwise)
Export pre-crisis	Export* time dummy (equal 1 if time<=2008 and 0 otherwise)
Export crisis	Export* time dummy (equal 1 if time>2008 and 0 otherwise)

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