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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 2012. Specifically, we focus our attention on the impact of different types of offshoring governance models into the profitability of developing a breakthrough innovation. Our study provides evidence that firms developing a breakthrough innovation tend to benefit more from the external acquisition of knowledge than those engaged on incremental innovations. We also find evidence that acquiring knowledge from firms outside the group is more profitable than in case they do it with firms within the group. Finally, 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 and not from universities or research institutions.

Keywords: Breakthrough Innovation; R&D offshoring; Geographical location; Technological and Organizational space; Spanish firms.

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1 Introduction

The study of innovation is not a recent topic. As signaled by Krugman and Wells (2009, chapter 8) the idea that the internal R&D effort made by the firm offers the opportunity to improve its innovativeness performance comes from the XIX century when the first R&D laboratory was created by Thomas Edison in Menlo Park New Jersey with the aim of creating new ideas year after year. However, one of the first economists pointing out the importance of knowledge external to the firm was Alfred Marshall, who highlighted the necessity of firms for clustering in order to benefit from the ideas that were in the air (Marshall, 1890). After him, many authors have stressed the relevance of the acquisition of knowledge outside the boundaries of the enterprise itself so as to improve their products and processes of production and even to get new knowledge to allow obtaining new products.

In recent years, innovation literature widely accepts that innovation performance can be affected not only by the internal effort on R&D but also by the decision to get access to knowledge from outside the firm, either through cooperation agreements or through acquiring technology from outside the firm. With respect to the latter, outsourcing part of the innovation process allows the enterprise to gain access to a new source of well prepared labor force as pointed by Lewin et al. (2009) as well as to catch external knowledge in a cheap way. Another relevant advantage of outsourcing is the widening of the scope of internationalization of the firm getting access to new markets and new knowledge, increasing the efficiency of its internal capabilities (Cassiman and Veugelers, 2006; Grimpe and Kaiser, 2010; among others). These theoretical advantages of knowledge outsourcing are translated into a positive impact on innovation performance, since most of the papers providing empirical evidence arrive to the conclusion that external knowledge sourcing strategies have a positive and significant impact on innovation performance (Laursen and Salter 2006; Mihalache et al. 2012; Cassiman and Veugelers 2006; Grimpe and Kaiser 2010, among others).

When buying technology from others, firms can choose between firms and institutions that belong to the same country or beyond its boundaries. In the present paper we focus on the latter, which is known in some papers as offshore outsourcing or offshoring. The relevance of the internationalization of the offshoring strategy comes from the fact that while for some big companies it is easier to go abroad, for small and medium enterprises it is not usually the case due to the lack of resources because of their size that harm their internationalization strategy. This could be avoided if firms get access to the resources owned by foreign enterprises or foreign institutions. While on the other hand, this allows them to gain access to international talent (Lewin et al. 2009).

Previous literature has not paid attention, though, on the impact of the acquisition of external knowledge on the generation of breakthrough innovations. This breakthrough innovation is really important for the growth strategy of companies and may be the line that separates the difference between being a follower or a leader in the market. Accessing to foreign knowledge may have an important and decisive role on that, since the firm can take advantage from different technologies and business models leading the competitors having greater difficulty in the response to such breakthrough innovations.

With the ideas surveyed above, this papers aims at providing empirical evidence on the role of the acquisition of knowledge from abroad on the generation of breakthrough innovations. Specifically, we will consider to what extent 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 higher in the case of breakthrough innovations than imply products new to the market. In addition, we plan to go deeper in this effect and disentangle if the role of offshoring innovation is different in case the acquisition of knowledge is made from firms belonging to the same enterprise or in case it is with research institutions instead of the business sector. Our empirical evidence will refer to Spanish firms in the period 2004-2012.

The outline of the paper is as follows. The second section provides a literature review and exposes the main hypothesis of the paper. Section 3 sketches the empirical model whereas the data are presented in section 4. The main results are given in section 5 and we finally conclude in section 6.

2 Literature Review and Hypothesis

The acquisition of external knowledge connects the firm with a variety of know-how and new knowledge that is necessary to obtain new processes and products. This leads the enterprises not to lock in and to access to new ideas. When the external knowledge comes from a different country, the firm gets in contact with a different national innovation system, providing with an opportunity set that combined with the internal R&D process would lead to the obtainment of new products or production processes. Indeed, in recent studies, researchers have found R&D offshoring as an important step in order to get access to a knowledge that is beyond the boundaries of the firm. Since the perspective of multinational companies, the idea of an internationalization strategy followed as a main purpose the adaptation of their products to local conditions (Cantwell and Mudambi, 2005). However, the internationalization strategy goes further and tries not only to get access to a local market, but more importantly, to a local knowledge that is specific of the host

location. In conjunction with the last statement, D´Agostino et al. (2013) study the role of captive offshoring among multinationals in the host OECD countries and their subsidiaries in emerging countries, finding evidence of a positive role of captive offshoring on innovation performance and the existence of complementarity between internal R&D and the external acquisition of knowledge in the medium/low technology (see also D'Agostino and Santangelo, 2012).

One of the main reasons why the acquisition of the foreign knowledge is important is because of the reduction of costs it implies as well as the access to a well prepared labor force (Lewin et al. 2009). However, recent contributions highlight the fact that an over-outsourcing strategy can lead to a decrease of the marginal return of this external R&D acquisition. This comes from the fact that when a firm relies strongly on external knowledge, it can lose the firm specific resources hampering its internal capabilities (Grimpe and Kaiser 2010). Studying the same non-linear behavior from outsourcing but from a managerial approach, Baier et al (2015) found a threshold level of outsourcing beyond which organizational management is more complex (see also Mihalache et al. 2012).

Another line of research has focused on the relationship between the internal capabilities of firms and their external acquisition of knowledge. While the literature is not conclusive, some researchers have found a complementarity relation, that is, that the marginal return of R&D offshoring increases with the amount of internal R&D capabilities. In an extensive study, Cassiman and Veugelers (2006) found evidence of such complementarity (see also D'Agostino et al. 2013) for Belgian enterprises, while some other authors did not found such a complementary relation at all. Even in a study for British enterprises relating the external sources of information for the acquisition of new knowledge with the innovation performance of the firm, Laursen and Salter (2006) found evidence of a substitution effect between them. Indeed, in a research for Spanish firms developed by Vega-Jurado et al. (2009), they realized that not only the offshoring strategy has no effect on product or process innovation but also that there is not even complementarity among internal and external knowledge. In fact what they found was only a positive role of the acquisition of knowledge embodied into machinery and equipment on process innovation (see also Santamaría et al. 2009).

In addition, while studying how the external acquisition of knowledge impacts on the innovation performance of the firm, it seems that the result may differ according to the type of innovation pursued, process or product innovations. Previous studies seem to give support to the idea that external knowledge exerts a higher effect on product rather than on process innovation. The reasoning behind this result comes from the fact that the kind of knowledge needed for getting product innovations tend to be more explicit and easier to be codified, so that it is more transferable across borders (D'Agostino, 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 at the organizational and knowledge level between both parts, which is more usually in the case of process innovations, the host firm will need skills very close to those of the foreign firm and given the differences in culture, customers' demands, labor laws, etc., it is more difficult to implement. In line with the latter, Nieto and Rodriguez (2011) found evidence that for the Spanish case the offshoring innovation strategy has a bigger impact on product than on process innovations.

With these previous results in mind, we focus our empirical research on the impact of offshoring on product innovation and how this has an effect on the firm's sales, which is a real measure for innovation performance. Indeed, obtaining a new product does not imply that the sales are increased consequently, or at least not all new products would imply equal increase of the sales. Therefore, we understand that a measure such as of the share of sales the firm states are due to new products developed by the firm should be a better proxy for the innovative performance of firms. Thus, in a first step, we want to provide evidence on whether, according to the theoretical reasons surveyed above, the acquisition of knowledge from abroad is positively associated with innovation performance in terms of the share of sales the firm says are due to new products developed by the firm. We are interested in this first finding since evidence for Spain seems to be controversial since several papers have found that the offshoring strategy does not have a clear impact on economic performance since the impact seems to be different when disentangling the offshoring strategy. And in fact, this is the first attempt to consider an endogenous variable that not only accounts for the fact of having obtained or not a product innovation but taking into account the profitability of such innovation.

However, our main concern in this research is to disentangle until which degree the acquisition of a geographically and technologically external knowledge can affect the degree of novelty of the innovation made by the 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, but also products that are completely new to the market. The latter can be understood as a novel and unique technological advance in a product category that significantly alters the consumption patterns in a market (Zheng and Bingxin, 2012). This completely new product can generate a new platform or business domain which could imply new benefits and the expansion into new markets (O'Connor et al. 2008).

The advantages of communications and the pattern of globalization around the whole world have made possible the access to knowledge sources from abroad. As the enterprises moved geographically outside the national boundaries of the firm for the acquisition of new technologies, it is feasible to take advantages of the different national innovation systems which can be asso-

ciated with differences in culture, market regulations, organizational managements or preferences that could lead not only to an improvement in the adaption of existing products but also to the creation of new ones. It is clear that going further in the internationalization of the acquisition of knowledge has an incorporated cost, since wider differences in organizational and internal capabilities lead to a more difficult understanding of the foreign knowledge. However, the acquisition of a foreign and different knowledge in conjunction with the internal R&D capabilities can lead to increase the likelihood of discovering a new idea in a highly technological field leading to radical innovations. The idea is that when the firm associates with foreign enterprises that belong to a different national innovation system, the knowledge that can be acquired may have a stronger novelty degree, so that the likelihood that it ends up in the development of a product completely new can be higher. Therefore, we would expect that the impact of acquiring knowledge from abroad will be higher for radical innovations than for incremental innovations.

Considering the above arguments we propose our first hypothesis:

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

In the recent literature on the acquisition of international knowledge some authors have paid attention to the behavior of offshoring innovation 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). Nieto and Rodriguez (2011) study the impact of these two strategies on the development of product and process innovations for Spain in 2004-2007, arriving to the conclusion that captive offshoring has a higher impact on product innovation than offshoring outsourcing. Cusmano et al. (2009) when studying the effect of offshoring outsourcing and captive offshoring, manage to divide the effect of offshoring onto R&D, design and services, concluding that there is a positive effect of captive offshoring on R&D and design activities while a negative one for non-affiliated enterprises (Cusmano et al. 2009).

The cognitive paradox proximity (Fornahl et al. 2011) stresses that when a firm engages in the acquisition of external knowledge, it should be similar to the knowledge base of the firm in order to understand and assimilate it, but not too much so as to avoid redundant information. For example, in an study for the biotechnology industry in Germany, Fornahl et al. (2011) study the role of public subsidies for private R&D collaborative projects and found that in order to succeed in the collaboration agreement, the enterprises need to be similar in some way so as to understand the base knowledge but not too much similar in order to really extract new ideas/technology from such collaboration. Furthermore, R&D projects with foreign partners both in collaboration agreements or in outsourcing could be more profitable at 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 get access to the possibilities of the local market in a foreign country. Even more, although subsidiaries work with the same organizational and management processes than the headquarters, there could exist differences in culture, labor markets or financial constraints that can lead to high transaction costs (Gertler, 1997), making outsourcing strategies more profitable.

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

Hypothesis 2. The impact of external knowledge acquisition on radical innovations is higher when the knowledge comes from firms not belonging 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. Going a step further, we now want to surpass the technologically boundaries of the firm and try to disentangle the different impact 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 of the cases, not focused on market profitability. Indeed, they develop a more basic know-how with or without industrial application, which could lead to a more radical innovation, although it is not necessarily the case since the knowledge could be far from what the market needs. This is an important approach to take in mind since, as suggested by Cohen and Levinthal (1990), the type of knowledge coming from scientific/technological agents is completely different from the one that can be understood and implemented according to the internal capabilities of the enterprises. However, those institutional research centers are seen by governments as drivers of radical improvements when considering their relation with enterprises (Hagedoorn et al. 2000).

As far as we know, there is no previous evidence on the impact of different types of agents from which external knowledge from abroad is outsourced. Similarly, but for the case of technological cooperation, Robin and Schubert (2013) study the effect of collaborative agreements between private and public institutes for a sample of firms in Germany and France, finding evidence that the one with public research centers has a positive impact on product innovation but not on process innovation. In another study, Aschhoff and Schmidt (2008) obtain evidence of a positive and significant impact of cooperation with public research institutes on radical innovation while a

positive and significant impact of cooperation with competitors in the case of process innovation. Taking into account the above reasons our third hypothesis arises:

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

Another interesting research point is to disentangle how the economic crisis of 2008 is affecting the innovation performance taking into account the impact of R&D offshoring. In the Spanish case this is very relevant due to the strong impact of the crisis and the difficulty in obtaining funding for innovation. Indeed, according to the INE (National Institute of Statistics in Spain) the rate of success of the enterprises obtaining funding for their innovation projects was 80% in 2007 and 50% in 2010[1], while the perception on the evolution of the relative access to funding between 2007 and 2010, only 1.1% answered it was better whereas 33.6% said it was worse[2].

It is a fact that the crisis has affected many firms that had to exit the market. However, as far as we know, nothing has been done about the effect of R&D offshoring on innovation performance in the crisis period, neither for Spain nor for other international contexts. Our first idea is to analyze if the crisis has implied a decrease in the amount of R&D offshoring done in Spain as a consequence of the reduction in funding for innovation projects. Even more, we want to provide evidence on whether the impact of the strategy of acquiring foreign R&D had a lower or a greater impact on the innovation performance during the crisis period. We do not have a clear hypothesis a priori since there are arguments for both results. On the one hand, since the access for funding for R&D activities is lower in crisis periods, if internal and external R&D expenses are reduced, and both tend to be complementary (Cassiman and Veugelers, 2006), we would expect that the return of each euro devoted to external acquisition of knowledge would decrease. This is so because, according to the complementary relationship, the marginal increase of adding one activity (offshoring) when already performing the other (internal innovation) is higher 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 with the resources they spend in new innovation projects and try to choose those with higher chances of success. In such a case, the return obtained from the offshoring strategy made would be higher. Given the ambiguity of the different impact of offshoring before and during the crisis, we aim at providing with evidence of which kind of arguments have been more determinant in the Spanish case.

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

3 Methodology

Our empirical approach follows the study of firms' innovative performance as a function of the acquisition of foreign technology and some control variables. As we are testing different hypothesis only for innovative firms (those which have positive expenditures on innovation), we face the selection sample problem posit by Heckman (1976) that can lead to an inconsistency problem of the parameters (Wooldridge, 2010). As we are dealing with a panel dataset we need to follow the approach of Heckman (1979) and Wooldridge (1995, 2002) for correcting the sample selection bias in a panel. This methodology is a two-step process: in the first step we perform a pooled probit model of the probability of being an innovative firm as a function of some exclusion restrictions and computed the yearly inverse Mill´s ratios. In a second step, for correcting the selection problem, we include these ratios in our main equation which is estimated by pooled OLS with bootstrap errors[3].

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

$$s_{it} = 1\left(X_{it}\psi + v_{it} > 0\right), \quad v_{it}|X_{it} \sim Normal\left(0,1\right) \tag{1}$$

where s_{it} is the probability of being an innovative firm, X_{it} is a vector of the exclusion restrictions, ψ is the vector of the parameters and the error term v_{it} is assumed to be distributed as a normal distribution. Conditioning on $s_{it} = 1$ our equation of interest will be

$$E(y_{it}|Z_{it},\ X_{it},\ s_{it} = 1) = Z_{it}\beta + X_{it}\theta + \gamma_t\lambda_t + u_{it} \tag{2}$$

where y_{it} will be our variable proxying for innovation performance, $Z_{it}\beta$ will be our focal measures of the external acquisition of knowledge and the vector of their parameters, $X_{it}\theta$ is the vector of control variables and their corresponding parameters, $\gamma_t\lambda_t$ is a vector of the inverse Mill´s ratios and their coefficients and finally, u_{it} is the error term.

Moreover, the variables in all the models were lagged one period in order to reduce simultaneity problems.

[3]We decided to use bootstrap errors in order to obtain consistent estimates of the standard errors (Cameron and Trivedi, 2009). As proved by Wooldridge (2002), the estimation by fixed effect could lead to inconsistency of the parameters.

4 Dataset, variables and descriptive analysis.

4.1 Dataset

The dataset used in this paper is taken from PITEC (Technological Innovation Panel) which is a yearly survey with around 450 variables starting in 2003 for the study of the innovative performance of Spanish enterprises. The survey is carried out by the National Institute of Statistics (INE) under the guidance of the FECYT (the Spanish Foundation for Science and Technology) and the COTEC (Foundation for Technical Innovation) on the basis of the Spanish response for the Community Innovation Survey (CIS). Our sample covers from 2004 to 2012, since we decided to drop 2003 because of an important methodological limitation: the survey in this year only takes into account firms with more than 200 workers and firms with internal R&D expenditures. The sample includes manufacture and service sectors following the CNAE-1993 and CNAE-2009 classification with the breakpoint in 2008. We account for around 90.000 observations over 12.000 enterprises, and after deleting the missing values and taking into account only companies which have more than ten workers[4], have declared to have positive expenditures on innovation and also a product innovation, we finish with around 30.000 observations.

Spain is at the middle of the technological ranking, behind other countries like South Korea or the United States which are at the forefront of the list. It is also below the mean R&D expenditure in Europe and small and medium enterprises are more highly represented with respect to multinationals holding. All these reasons give an interesting study case.

4.2 Variables

4.2.1 Dependent Variables

In the PITEC survey the firm is asked if it has developed product innovations in the current year or in the previous two years, being they either products only new to the firm or new to the market. The firm is also asked on the economic impact of these innovations with respect to the firm's sales. Using this information we developed three different endogenous variables.

New sales accounts for the development of a product innovation by the firm. Contrary to other studies, we do not use a dummy variable in case the firm developed a product innovation but we give a step forward and proxy for how profitable such new products were for the firm. This way, we consider the share of sales the firm declares are due to their new products over total sales.

[4]Although the survey includes firms with more than 10 workers, there are some cases in which an enterprise starts with 10 or more workers but finish having less than 10 workers.

New Firm is our second measure, which proxies for incremental innovation since it reflects the share of sales due to products only new for the firm. Finally, *New Market* proxies for radical or breakthrough innovations through the consideration of the share of sales that are due to products new to the market. In all the cases the variables are taken in logs.

To our knowledge, these measures reflect better the innovation performance of the enterprise than others used in previous literature. Using a dummy variable only reveals if the firm is engaged into the innovative strategy; but a deeper information is to what extend this strategy is important for the firm's success. Another possibility would be to use the information on the number of innovations patented, but as pointed out by some authors this measure captures codified knowledge and not tacit knowledge embedded on organizational/management processes and also in some cases the patented technological innovation is not developed (Phene et al. 2006).

4.2.2 Independent Variables

We constructed our focal independent variables using different measures for the acquisition of foreign knowledge. For the study of hypothesis 1 we used the variable *offshoring*, constructed as a dummy equal to 1 if the company has purchased technology from abroad and zero otherwise. Many studies have found a positive relationship between the purchase of external knowledge and innovation performance, but we do not have previous evidence on the impact on breakthrough innovations. For testing our second hypothesis we split the offshoring measure into two: the external acquisition of knowledge from inside the multinational group of firms (*offgroup*) and from outside the holding (*offnogroup*). Whereas the first one is a dichotomous variable equal to 1 if the company has bought foreign knowledge from firms inside the group and zero otherwise, the second one is a dummy equal to 1 if the enterprise acquires external knowledge from companies and institutions outside the holding and zero otherwise.

For hypothesis 3 we developed a similar approach by splitting the offshoring variable into the external purchases from foreign research institutes (*offpublic*) and those purchases done from foreign private companies (*offprivate*). Finally, for checking the impact of the crisis on the return to offshoring we performed two approaches: (i) we divided the sample in two periods (before and in the crisis period) and (ii) we constructed two measures for the external purchases of technology: the first one is a dichotomous variable that equals 1 for all those companies that bought foreign knowledge before the crisis and zero in case of buying knowledge in the crisis period or not performing offshoring at all (*offpre08*), and a second one for all those enterprises that have purchased foreign knowledge in the crisis period and zero in case of buying knowledge before the crisis or not performing offshoring at all (*offcrisis08*).

Controls

R&D intensity is measured as internal R&D expenditures over total sales and is trying to capture the effect of the internal capabilities of the enterprise that have been recognized as an important complement for the external acquisition of knowledge and the degree of novelty of the innovation (Spithoven 2015; Cassiman and Veugelers 2006). *Size* is measured as the log of the number of workers. *Permanent* measures how frequently the company develops internal R&D efforts, being constructed as a dichotomous variable equal to 1 if the firm declares to do it permanently and zero otherwise. *Foreign* is a dichotomous variable that takes the value 1 if the company belongs to a multinational holding with at least 50% of the capital being from abroad. This variable tries to capture the idea that a firm belonging to a multinational group has more resources that can complement the strategy of offshoring innovation and is expected to have a positive impact on innovation performance. The *Openness* variable follows the idea that the more sources of information the company has, the higher the degree of innovation it obtains. PITEC provides us with information on the use of different sources of information: internal sources, market sources and institutional sources. We follow the approach given by Laursen and Salter (2006) and measure the openness variable as the sum of all the sources of information that take values from 0 to 8. The variable for openness is calculated so that a firm gets a value of zero if it did not use any type of information source and the value of eight if it used all types of sources.

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 of innovative sales for firms performing product innovations (New Sales) are 28%, with a higher percentage for enterprises performing incremental innovation (16%) than for those performing radical innovation (12%). Around 7.23% of innovative firms develop an offshoring strategy while the percentage changes depending on the organizational and technological distance with respect to other firms/institutions. The pattern reflects that firms tend to perform more offshoring with firms outside the group (5.43%) and even more with private organizations (6.75%) instead of research institutions or universities (0.9%). On average, more than 50% of the innovative firms do internal R&D frequently while internal R&D expenditures represent around 9% over total sales.

[Insert Table 1 around here]

Table 2 displays the distribution of offshoring strategies by organizational and technological categories and their pattern in 2006 and 2012 –before and within the crisis- for firms engaged

in radical and incremental types of innovation. It is clear that the amount of firms doing R&D offshoring is higher for those performing a breakthrough innovation (8.8% in 2006 and 8.7% in 2012) than an incremental innovation (5.6% in 2006 and 7% in 2012). It is also a fact that the growth rate of the amount of enterprises doing offshoring between 2006 and 2012 has favored more the ones performing an incremental innovation than those performing a radical innovation. The pattern is the same no matter if the firm offshores innovation from enterprises outside the group or within the group. The same pattern is also observed irrespective of the nature of the institution, business or research oriented.

[Insert Table 2 around here]

5 Regression Results

Table 3 contains our six specifications that examine the impact of different offshoring strategies on our measures of innovative performance. The table shows the results of our second stage for the Heckman´s correction in which all of our specifications are jointly statistically significant as indicated by the Wald test. Time and sectoral dummies were used, being jointly and highly significant in all the specifications. Relative to the Heckman´s correction, we found strong evidence of the sample selection´s problem as shown by the Wald test of the inverse Mill´s ratios which are significant in all the specifications indicating the necessity of such approach in the analysis.

[Insert Table 3 around here]

Table 3 displays the results for our baseline model, where we observe that *offshoring innovation* has a positive impact on the share of sales due to new products, although it is not significant. However, we wonder whether this lack of significance could be due to the fact that offshoring innovation may affect more clearly breakthrough innovation but not so much in the case of incremental innovation whereas our proxy is taking both of them at the same time. In order to shed more light on this issue, we disaggregate our measure of innovative performance into the share of *sales due to products which are new to the firm* and the share of sales due to products *new to the market, proxying for incremental* and *radical innovations*, respectively. This is done in columns (2) and (3) of Table 3. 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 clearer impact of foreign acquisition of knowledge on *radical innovations*. The highest degree of novelty for breakthrough innovation involves the pursuit of a wide amount of knowledge beyond the internal sources of the firm and foster new ways

to combine and use disparate knowledge to achieve unique product advances (Zheng and Bingxin, 2012).

In column (4) we include the disaggregation of *offshoring* into offshoring inside the group (*offgroup*) and offshoring outside the group (*offnogroup*). We found a positive and significant impact of *offshoring outsourcing* (outside the group) on *breakthrough innovation* while it is not the case for *captive offshoring* (inside the group), since the variable seems not to have any significant causal relationship with our measure of innovation performance. This evidence gives support to our second hypothesis in which the different type of knowledge coming from firms outside the enterprise´s group should have a higher impact on the most 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, in which we studied the effect of the external acquisition of knowledge separating the research-based from the business-based one. We obtain that the impact of the knowledge coming from the business sector (private enterprises) is significant whereas the knowledge coming from a public research center or university is not. Although with a different perspective, this result is in line with the one obtained by Vega-Jurado (2009) in the study of the impact of cooperation agreements in Spanish firms, who obtained that the impact of cooperation with science-based agents is lower than cooperation with private enterprises. However, we should also be aware that the share of firms that purchase technology from foreign research centers or universities is very scarce, compared to the one with the business sector (see previous Table 2).

Finally, but not less important, we would like to see how the current economic crisis is affecting the *offshoring of innovation* made by Spanish firms and, specifically, whether the impact of such strategy had a different impact before and in the crisis. After performing a descriptive analysis along time we arrived to the conclusion that firms are developing at least the same effort in the offshoring strategy after the crisis than before. Indeed, the share of innovative firms offshoring innovation in 2004 was 7.58%, whereas in 2009 it was 7.48%, and 7.74% in 2012. Despite this fact, we found evidence that the impact of R&D offshoring was higher before the crisis than in the crisis period, taking into account the non-significance of the second. In a second approach we also divided the sample in two subsamples –before the crisis and within it - and perform two regressions separately. The results are not shown to save space, but the parameter for the offshoring variable for the period before the crisis was 0.330 and in the crisis was 0.235, both significant but of a higher magnitude in the first case.

With respect to the control variables, internal *R&D intensity* has a highly and positive impact on innovation performance giving support to the internal capabilities theory: the firm needs internal resources (personal, equipment and instruments) with a high degree of knowledge in order to access,

understand and implement the knowledge that comes from outside the firm. Also, the bigger the firm (*Size*), the greater the firm's innovation performance, suggesting that big companies can avoid the financial constrains that small firms face and have the infrastructure and the internal R&D resources in order to engage more easily in the innovation process. Unsurprisingly, developing the internal R&D activity frequently (*Permanent*) is good for the firm, which in conjunction with the internal *R&D intensity* can be understood as follows: not only it is important to devote a certain amount of resources to internal R&D but it is also important to do it frequently. Our results also suggest that belonging to a multinational group (*Foreign*) does not seem to have a significant relationship with innovation performance. On the contrary, having a wide variety of information sources for the external acquisition of knowledge (*Openness*) implies having a better innovation performance in the Spanish case. Finally, *demand pull*, a variable that measures the objectives of product innovations, is positive and significant, pointing to the fact that if the innovation is highly focused on one objective (e.g. accessing new markets, gaining market share or having greater quality of products) this will affect positively the innovativeness performance of the enterprise.

Robutstness Check

We are aware of a possible endogeneity 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 the innovation variables tend to present. 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 and in line with previous studies in the field (Cassiman and Veugelers, 2006; Cusmano et al. 2009) we performed an Instrumental Variables (IV) approach in two steps. In the first one, we estimate the offshoring of innovation activities with respect to its main determinants. Specifically, we regressed the probability of offshoring as a function of the exogenous variables which are the instruments for themselves plus the instruments for offshoring. In the second stage we used the predicted values for offshoring[5] and the exogenous variables to study their impact on the degree of novelty of the innovation performed by the firm (Cameron and Trivedi, 2009; Wooldridge 2002, 2010).

With this strategy, we are trying to lessen the negative consequences that would be caused by the potential endogeneity in our regressions. In this sense, we are giving more importance to the consistency of the parameters although we are aware of a possible loss of efficiency when carrying

[5]The threshold used to construct the predicted value is the average of the number of firms that performed offshoring strategies over the total number of firms in the sample.

out this methodology. However, in order to gain efficiency, we compute the bootstrap errors in the IV estimation[6].

We initially perform an analysis to test the validity of our instruments. The first stage suggests that instruments are weak since the R^2 has a value of 0.14. However, following the rule proposed by Staiger and Stock (1997), an F-Statistic for the joint significance of the instruments in the first stage below a value of 10 is an indication of weak instruments, which is not our case since we obtain an F-Statistic of 229.41 which clearly indicates that our instruments are strong (Cameron and Trivedi, 2009)[7].

In our first stage (Table 4), the variable *Cost* tries to capture the obstacles to innovation relative to financial constrains (internal and external lack of finance and high costs to innovation) and it is measured as 1 minus the sum of the previous three measures - that were scaled from 1 (high) to 4 (not important) - and rescaled from 0 (unimportant) to 1 (crucial) (Badillo and Moreno, 2014). The regression seems to capture the expected negative effect that financial constraints should have on the *offshoring* strategy. *Risk* measures the obstacles due to uncertain demands of product innovations and markets dominated by established companies and was equally rescaled from 0 (unimportant) to 1 (crucial). As observed, these factors seem not to have any significant impact on the acquisition of the foreign knowledge. *FACneed* is constructed following the same approach as before and captures the effect of the factors not needed for previous innovations and not needed because of lack of demand. Again, we found evidence that obstacles to innovation affected the geographically and technologically different purchases of knowledge. All the above factors have being found to have a significant impact on the external acquisition of knowledge in previous studies. Spithoven and Teirlinck (2015) found a negative impact of the obstacles to innovation although not significant in all their specifications which is in line with the results in García-Vega and Huergo (2011) who found a negative and significant effect on R&D *offshoring*, as we did.

Market share is measuring to what extent the firm has market power in the sector and was constructed as the share of the firm's sales over total sales in the industry. Surprisingly, having more power market does not imply a greater acquisition of external knowledge since the coefficient is not significant. This is in line with Love and Roper (2001) who managed to divide the offshoring strategy into seven different strategies, founding evidence of no impact of the market share of

[6]In order to do this, we are not taking into account the Mills' ratios since, as far as we know, there is not a direct use of the IV method of estimation correcting for sample selection in panel data, everything at the same time. In any case, with this robustness check we are examining the relevance of a potential endogeneity problem that could be biasing our main results.

[7]There is no critical value for the F-Statistic because it depends on the criteria used, the number of endogenous variables and the number of over-identified restrictions.

the firm on the measure of product identification offshoring, a positive and significant impact on production engineering offshoring while a negative one on marketing strategy offshoring. The variable *Group* tries to capture the effect of belonging to a group of enterprises, being a dichotomous variables taking a value of 1 if the firm belongs to a group and zero otherwise. As in other research studies, ours suggests a positive and significant impact of the fact of belonging to a group on the probability of *offshoring* (Love and Roper, 2001). The two final variables are *Appropriation* and *Patent* which account for informal and formal appropriation, respectively, measuring the idea that if the firm can protect the results of its innovation process, then the incentives to offshore increase. *Appropriation* is measured as a dichotomous variable taking value of 1 if the enterprise has developed property rights, trademarks or registered utility models and zero otherwise. *Patent* is measured as a dummy equal to 1 if the company has applied for patents and zero if not. Both variables have the expected positive effect suggesting that if the firm protects its innovation the probability of offshoring is higher (Spithoven and Teirlinck, 2015; Lewin et al. 2009; Cassiman and Veugelers, 2006).

[Insert Table 4 around here]

The second stage of the IV process includes additionally the fitted value of the *offshoring* variable according to the parameters computed in the first stage. Our results suggests that the impact of *offshoring* on *breakthrough innovations* is in line with our previous results although now the parameter is slightly lower which gives us a hint on the presence of endogeneity for which we are trying to control for. Some endogeneity exists but it is very limited, since all parameters continue having the same signs and significances, with the only difference of a slightly lower magnitude of the parameter estimated. We can conclude, therefore, that our results are pretty robust even in the case of correcting for endogeneity problems. We do not present the results of the rest of Table 4 since this implies not correcting for sample selection. Since the endogeneity problem does not seem to pose any serious concern on our estimates, we take the results in Table 3 as valid, although the significant parameters presented there could be slightly upward biased.

6 Conclusions

R&D offshoring is one of the most recent topics in the innovation literature, which in part is due to the recent process of purchasing innovation from abroad. While being an innovative firm could make the difference between being a leader or a follower in an industry, it is also important to access to a wider and different type of knowledge, such as the one in foreign countries, to increase

the market power of a firm, and to access to a lower costly and highly prepared labor force, among other benefits. The evidence provided in this paper refers to Spanish innovative firms from 2004 to 2012 for which we had into account the sample selection bias from the beginning of the analysis.

Our research contributes to the empirical analysis of the impact of the knowledge that comes from beyond the geographical and technologically boundaries of the firm and even the country where the firm is located, and extends it by analyzing its effect on breakthrough innovation, that is, on the most radical knowledge leading to products new to the market. Firstly, we found evidence that the acquisition of external knowledge does not always have a significant impact on product innovation, at least not on our proxy that goes beyond a dichotomous variable and tries to capture the profitability of the product innovation. However, we went deeper on the analysis and split our innovative performance measure into two measures for radical and incremental innovation extending the findings of previous research which did not make such 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 seems therefore that offshoring innovation activities, far from deterring the innovation performed by the firms in a country, allows them to increase their innovative performance and this is specially the case of those innovations that incorporate more novelty.

Giving a step forward, we want to analyze which type of technological offshoring can have a higher 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* innovations. This can be understood as the benefit of acquiring knowledge from enterprises which are not too similar in knowledge in order to obtain a higher degree of novelty from the acquired knowledge. Additionally, our results indicate that knowledge coming from a business organization has a higher impact on breakthrough innovations than that coming from research-based institutions. The logic behind this result could be related to the little amount of Spanish enterprises having a contractual relation with research institutes/universities, as stressed by Gutierrez et al. (2007), but also to the fact that the knowledge acquired from the business sector is generally more market-oriented and can have, as a consequence, a more direct impact on the share of sales that are 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 till 2012 which cover the worst years of the crisis. Our findings suggest a higher impact of the offshoring strategy before the crisis on breakthrough innovations than in the crisis period. This is an interesting discovering since the internal R&D has been found complementary of the external acquired R&D (Cassiman and Veugelers, 2006) and knowing that financial constrains are high for Spanish

firms due to the special impact of the crisis, this can put down the internal innovation expenditures ending in a lower effect of the external R&D on the radical innovation in the crisis period. The supermodularity approach would say that the marginal increase of adding offshoring when the internal innovation carried out by the firm has decreased, would be lower than the marginal increase in case internal innovation would have not been reduced.

The above evidence has two important implications. First, policy makers should not only focus on innovation agreements between Spanish firms and public research institutes, which should be seen as a long term policy, but they also need to pay attention on the contractual agreements among private organizations, and specifically with those outside the geographical boundaries of the country in order to obtain a higher novelty degree of the innovation obtained. And second, it would be important to incentivize the acquisition of knowledge from outside the group of companies to which the firm belongs to.

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 on the existence of differences in the knowledge coming from other national innovation systems which could have a high 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 from a technological leader country such as the United States or from a country not in the technological frontier as India. Another limitation comes from the fact of not having different categories of offshoring available on the data, such as R&D, design, marketing, among others, in order to account for their different impact. We also would like to analyze to what extent the regional environment of the firm is important, in the sense of whether belonging to a region or another could imply a different impact of the offshoring strategies carried out by firms.

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Table 1. Summary statistics on the variables used in the econometric analysis

	Mean	S.D.	Min	Max
Dependent Variables				
New Sales	0.284	0.360	0.0001	0.9999
New Firm	0.163	0.281	0.0001	0.9999
New Market	0.122	0.242	0.0001	0.9999
Explanatory Variables				
Panel A. Main equation				
Offshoring	0.072	0.259	0	1
Offgroup	0.023	0.150	0	1
Offnogroup	0.054	0.227	0	1
Offpublic	0.009	0.098	0	1
Offprivate	0.067	0.251	0	1
Offpre08	0.038	0.192	0	1
Offcrisis08	0.034	0.183	0	1
Internal R&D	0.090	0.272	0	2
Size (log)	4.381	1.398	2.303	10.63
$Size^2$ (log)	21.14	14.12	5.302	113.1
Permanent	0.652	0.476	0	1
Foreign	0.111	0.314	0	1
Openness	5.524	2.501	0	8
Demand Pull	0.690	0.462	0	1
Panel B. Selection and First stage equation				
Cost	0.609	0.295	0	1
Risk	0.521	0.297	0	1
FACneed	0.198	0.244	0	1
Market share	0.006	0.026	1.86e-09	0.909
Group	0.436	0.496	0	1
Appropriation	0.288	0.453	0	1
Patent	0.168	0.374	0	1

Table 2. Percentage of firms with offshoring strategies by degree of novelty of innovation and time period

	Innovative firms in 2006						Innovative firms in 2012					
	Radical=0 Incremental=1		Radical=1 Incremental=0		Radical=1 Incremental=1		Radical=0 Incremental=1		Radical=1 Incremental=0		Radical=1 Incremental=1	
VARIABLES	N	mean	N	mean	N	mean	N	mean	N	mean	N	mean
Offshoring	1,899	0.056	1,120	0.087	1,611	0.088	1,104	0.070	613	0.086	996	0.111
Offgroup	1,899	0.019	1,120	0.025	1,611	0.031	1,104	0.028	613	0.024	996	0.031
Offnogroup	1,899	0.039	1,120	0.066	1,611	0.065	1,104	0.051	613	0.068	996	0.090
Offpublic	1,899	0.008	1,120	0.014	1,611	0.013	1,104	0.007	613	0.016	996	0.012
Offprivate	1,899	0.051	1,120	0.081	1,611	0.080	1,104	0.067	613	0.078	996	0.106
Offpre08	1,877	0.063	1,106	0.086	1,601	0.088	1,098	0	609	0	984	0
Offcrisis08	1,877	0	1,106	0	1,601	0	1,098	0.066	609	0.083	984	0.115

Table 3. Governance specifications of offshoring on different innovation outcomes

VARIABLES	(1) New sales	(2) New firm	(3) New market	(4) New market	(5) New market	(6) New market
Offshoring $_{t-1}$	0.022	-0.034	0.256***			
	(0.104)	(0.096)	(0.092)			
Offgroup $_{t-1}$				0.184		
				(0.153)		
Offnogroup $_{t-1}$				0.209**		
				(0.106)		
Offpublic $_{t-1}$					-0.003	
					(0.268)	
Offprivate $_{t-1}$					0.231**	
					(0.099)	
Offpre08						0.329**
						(0.141)
Offcrisis08						0.197
						(0.121)
Internal R&D $_{t-1}$	1.360***	0.073	1.242***	1.239***	1.240***	1.243***
	(0.162)	(0.143)	(0.148)	(0.152)	(0.151)	(0.149)
Size $_{t-1}$	-0.470***	0.236**	-0.720***	-0.752***	-0.753***	-0.721***
	(0.114)	(0.107)	(0.102)	(0.103)	(0.093)	(0.101)
Size^2 $_{t-1}$	0.037***	-0.023**	0.072***	0.075***	0.075***	0.072***
	(0.011)	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)
Permanent $_{t-1}$	0.433***	0.168	0.357***	0.332***	0.332***	0.357***
	(0.127)	(0.115)	(0.100)	(0.099)	(0.093)	(0.099)
Foreign $_{t-1}$	0.142	-0.013	0.066	0.059	0.057	0.066
	(0.233)	(0.219)	(0.199)	(0.195)	(0.207)	(0.199)
Openness $_{t-1}$	0.083***	0.106***	0.092***	0.094***	0.094***	0.091***
	(0.015)	(0.014)	(0.011)	(0.012)	(0.012)	(0.011)
Demand pull $_{t-1}$	0.457***	0.218**	0.258***	0.272***	0.272***	0.258***
	(0.112)	(0.102)	(0.082)	(0.085)	(0.085)	(0.082)
Wald-Test Sectors Dummies chi2(48)	524.90***	422.43***	531.12***	555.56***	684.91***	540.90***
Wald-Test Mill´s Ratios chi2(7)	28.42***	28.11***	12.17*	13.52*	14.79**	12.17*
Wald-Test Time Dummies chi2(6)	21.85***	8.89	23.10***	22.09***	22.48***	21.96***
Constant	-4.016***	-6.494***	-7.397***	-7.275***	-7.275***	-7.402***
	(0.386)	(0.354)	(0.319)	(0.317)	(0.293)	(0.319)
Wald chi2	2748.06	1459.81	4047.83	4335.85	5590.25	4077.02
Prob > chi2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	31,467	31,467	31,467	30,967	30,967	31,467
R-squared	0.074	0.037	0.099	0.099	0.099	0.099

Bootstrap errors in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Table 4. Two stage process (IV). Robustness check

VARIABLES	(1) Offshoring $_{t-1}$	(2) New market
Offshoring (Predicted)		0.120**
		(0.060)
Cost $_{t-2}$	-0.121***	
	(0.041)	
Risk $_{t-2}$	0.020	
	(0.047)	
FACneed $_{t-2}$	-0.221***	
	(0.058)	
Market share $_{t-2}$	0.044	
	(0.442)	
Group $_{t-2}$	0.274***	
	(0.026)	
Appropriation $_{t-2}$	0.136***	
	(0.026)	
Patent $_{t-2}$	0.170***	
	(0.030)	
Internal R&D $_{t-1}$	0.356***	1.168***
	(0.045)	(0.131)
Size $_{t-1}$	0.183***	-0.693***
	(0.048)	(0.087)
Size^2 $_{t-1}$	-0.009**	0.070***
	(0.005)	(0.009)
Permanent $_{t-1}$	0.035	0.282***
	(0.045)	(0.086)
Foreign $_{t-1}$	0.125	-0.007
	(0.084)	(0.177)
Openness $_{t-1}$	0.040***	0.102***
	(0.006)	(0.011)
Demand pull $_{t-1}$	0.009	0.328***
	(0.040)	(0.075)
Wald-Test industry dummies chi2(48)	579.27***	631.40***
Wald-Test Time dummies chi2(7)	2.69	114.34***
Constant	-2.888***	-7.875***
	(0.143)	(0.249)
Wald chi2(70)	2359.42	5393.55
Prob > chi2	(0.000)	(0.000)
Observations	28,977	37,992
Pseudo R-squared	*0.138*	0.097

Bootstrap errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix

Table A1. Correlation matrix of explanatories variables used in the second stage

VARIABLES	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Offshoring	1.000													
2.Offgroup	0.550	1.000												
3.Offnogroup	0.859	0.115	1.000											
4.Offpublic	0.357	0.044	0.415	1.000										
5.Offprivate	0.965	0.570	0.808	0.180	1.000									
6.Offpre08	0.438	0.279	0.355	0.159	0.428	1.000								
7.Offcri08	0.445	0.283	0.371	0.159	0.438	-0.037	1.000							
8.Internal R&D	0.079	-0.014	0.106	0.067	0.073	0.037	0.059	1.000						
9.Size	0.119	0.138	0.066	0.038	0.122	0.082	0.081	-0.179	1.000					
10.Size^2	0.111	0.131	0.061	0.036	0.113	0.076	0.075	-0.162	0.980	1.000				
11.Permanent	0.092	0.005	0.114	0.060	0.084	0.064	0.063	0.188	0.001	-0.006	1.000			
12.Foreign	0.157	0.270	0.023	0.005	0.166	0.107	0.105	-0.086	0.280	0.265	-0.003	1.000		
13.Openness	0.088	0.009	0.105	0.054	0.082	0.054	0.068	0.104	0.055	0.051	0.255	-0.020	1.000	
14.Demand pull	0.038	0.001	0.048	0.019	0.037	0.008	0.045	0.039	-0.025	-0.024	0.203	-0.008	0.252	1.000