

Radical innovations: The role of knowledge acquisition from abroad

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Abstract

This paper explores R&D offshoring's role on radical product innovations. These innovations are important for companies' growth strategy, and we check the extent to which they rely on external sources, which may bring knowledge that differs significantly from that already present internally. The evidence for Spanish firms between 2004 and 2013 shows that R&D offshoring influences significantly the intensity of radical but not of incremental innovations. This influence is apparently smaller when external knowledge comes from universities or research institutions rather than the business sector. The recent financial crisis also exerted a detrimental effect on this influence compared with the previous period of economic growth.

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

1. Introduction

When buying technology from others, firms can choose between firms and institutions that belong to the same country or ones beyond its boundaries. As highlighted by the OECD (2008), the global tendency in the 1960s and 1970s was for firms to develop around 95% of their research projects in their own R&D laboratories. In the 1980s, there was an increasing trend towards the international acquisition of knowledge. Nowadays, around 70% of European enterprises have increased their R&D offshoring strategy during the last decade and approximately 87% see the external acquisition of knowledge as an important step in increasing their innovation capacity.

In this paper, we focus on R&D offshoring and provide evidence regarding its influence on the intensity of radical innovations. As these innovations incorporate a high level of innovativeness, they may depend more on external and diversified sources, which may imply knowledge that differs significantly from that already present in the firm (Laursen & Salter, 2006). We hypothesize that the impact of outsourcing knowledge from foreign countries is greater for radical innovations than in the case of incremental innovations, which are more connected with an imitation strategy that does not require different knowledge from that available internally.

While previous studies have focused their attention on the role of R&D offshoring in the generation of product and/or process innovations (Bertrand & Mol, 2013; Nieto & Rodríguez, 2011), we are interested in the innovative performance that a firm obtains in terms of the share of sales due to product innovations. The innovative activity is completed when it reaches a commercial stage, and, even in such a case, not all innovations lead to the same amount of profitability in terms of sales. That is, the relevant step is not only the decision to innovate; in this paper, we focus on the success of commercializing the firm's inventions once a firm has decided to innovate.

Our final contribution concerns the study of the heterogeneity in the influence of R&D offshoring according to the nature of the agents put in contact as well as to the phase of the economic cycle. With respect to the former, the reasoning lies in the idea that the type of knowledge that can be acquired from foreign universities and research centers, more basic know-how, is different from that provided by the business sector, which is more focused on market profitability. Secondly, we plan to contribute to the literature studying the influence of the last economic recession on the role of R&D offshoring, which has also not been explored in previous studies. The differentiation between small and large firms is also considered.

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

2. Literature review

Among the main reasons for the importance of the acquisition of foreign knowledge, we find the reduction of costs that it implies as well as the access to a well-prepared labor force (Lewin et al., 2009; Youngdahl & 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).

Another relevant advantage of outsourcing is the widening of the scope of a firm's internationalization. It allows access to new markets and new knowledge, increasing the efficiency of the firm's internal capabilities and leading to an improvement in its competitiveness and a positive impact on its innovation capacity (Cassiman & Veugelers, 2006; Grimpe & Kaiser, 2010; Love et al., 2014; OECD, 2008, pp. 20, 91). These theoretical

advantages of knowledge offshoring are expected to be translated into a positive impact on innovation performance.

The European Union Survey (Tübke & 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. Most of the papers providing empirical evidence have reached the conclusion that external knowledge-sourcing strategies have a positive and significant impact on innovation performance (Laursen & Salter, 2006; Mihalache et al., 2012; Nieto & Rodríguez, 2011), while, as pointed out by Dachs et al. (2012, p. 10), studies finding a negative impact are very scarce.

The acquisition of external knowledge connects the firm with a variety of know-how and new knowledge, which are necessary to develop new processes and products. This leads the enterprise to avoid being 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.

Enterprises know that more novel innovations require the exploration of entirely new types of business models and technologies (Ahuja & Lampert, 2001). Moreover, this different knowledge might encourage a different perspective not only from implementing it but also from modifying the external technology into a new and different product.

As enterprises move abroad geographically to acquire new technologies, it is feasible to take advantage of different national innovation systems, which can be associated with differences in culture, market regulations, industry specialization, educational level, and welfare state laws or preferences (Filippetti & 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, especially ones of a more novel nature. As signaled by Castaldi et al. (2015), radical innovation often stems from the connection of previously unrelated technologies.

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 have seemed to support the idea that external knowledge exerts a greater effect on product than on process innovations. The reasoning lies in the fact that the kind of knowledge needed to achieve product innovations tends to be more explicit and easier to codify, so 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.

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 other characteristics, 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 that for France obtained by Bertrand and Mol (2013). With these previous results in mind, we focus our empirical research on the influence of R&D offshoring on product innovation.

3. Hypotheses

Our main concern is to identify the degree to which the acquisition of geographically external knowledge can affect the degree of novelty of the innovations 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 innovations—as well as products that are completely new to the market—radical innovations.¹

A radical 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 & 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 radical innovations, we rely on the *tension theory* (Ahuja & 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) emphasized 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).

¹ By radical innovations we mean those that embed a more novel component than in the case of incremental innovations. As explained in the data section, we use information on new or significantly improved products for the market as a proxy for radical innovation (as compared with new or significantly improved products only for the firm). As signaled by a referee, it is obvious that not everything that is new to the market is a radical or breakthrough innovation. However, this is the only proxy that we can obtain for radical innovations with the information contained in a CIS-type survey, and it has been used by prior studies for measuring breakthrough or radical innovations (Coad et al., 2016; Laursen & Salter, 2006; Tether & Tajar, 2008; Van Beers & Zand, 2014). Thus, we decided to keep the term radical innovations, despite being aware that it could overstate the variables. We thank an anonymous referee for highlighting this point.

There is evidence that international outsourcing, when technological proximity exists, generates breakthrough innovations (Phene et al., 2006). This 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 & Levinthal, 1990). Thus, despite the technological proximity, differences in national innovation systems and in managerial capabilities—human capital, social capital, and cognition²—guarantee the novel recombination of such distant knowledge, which could result in a radical innovation (Phene et al., 2006).

Taking the above evidence into account, we believe that knowledge acquired from foreign enterprises that belong to different national innovation systems may have a stronger degree of novelty, so the likelihood that it will result in the development of a product that is completely new and/or of greater economic value can be higher (Kaplan & Vakili, 2015; Phene et al., 2006). Therefore, we pose the following hypothesis:

Hypothesis 1. *The acquisition of knowledge from abroad is expected to have a greater influence on innovations that incorporate a higher degree of novelty.*

Nevertheless, the influence of the external acquisition of knowledge on innovations that incorporate a high degree of novelty may differ according to the nature of the agent from which the external knowledge is acquired, either an industrial firm or an institutional/scientific agent. Certainly, “the interaction between industry and science is one of the most prominent institutional interfaces for knowledge diffusion” (Robin & 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).

² Beliefs and ways of solving problems that allow decision making in certain directions (see Phene et al., 2006).

This is an important issue, 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. Previous evidence on R&D cooperation has shown that enterprises collaborate more with top foreign universities than with less highly regarded local universities (Laursen et al., 2011). In fact, universities like to partner highly innovative enterprises, meaning that links with universities are not restricted to national boundaries (Monjon & 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 innovations, geographical distance has been losing its relevance to firm–university collaboration (Maietta, 2015).

In addition, evidence exists of an increased probability of outsourcing certain activities focused on knowledge specificities when the enterprise uses more complex knowledge and has a strong connection with universities (Spithoven & Teirlinck, 2015). This kind of relation between firms and public institutions allows enterprises to access a wider pool of knowledge, strengthening their knowledge base (Aschhoff & 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, increasing the likelihood of generating radically new products.

However, 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 more basic know-how with or without industrial application, which can incorporate novel knowledge that could lead to more radical innovation, although this is not necessarily the case, since the knowledge could be far from what the market needs.

Although more related to the topic of cooperation in innovation, Vega-Jurado et al. (2009) considered that agreements with scientific agents in the case of Spanish firms might be more motivated to obtain funds from the Government when developing research projects in government-sponsored programs than to improve their innovative capacities thanks to the integration of complementary knowledge from external sources. Furthermore, Spanish firms' perception is that knowledge acquired from research organizations offers a smaller chance of having real applicability (Nieto & Santamaría, 2007).

These reasons lead us to think that knowledge incorporated from the business sector can generally be more market oriented and, as a consequence, can have a more direct influence on the share of sales due to products that are new to the market. Taking into account all the above arguments, competing hypotheses arise:

Hypothesis 2a. *The influence of the acquisition of external knowledge from an international industrial-based agent is expected to be greater than that of knowledge acquired from an international research-based one.*

Hypothesis 2b. *The influence of the acquisition of external knowledge from an international research-based agent is expected to be greater than that of knowledge acquired from an international industrial-based one.*

Unexplored in previous studies is the way in which the economic crisis in 2008 affected the influence of R&D offshoring on radical innovations. In Spain, 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 coming from the idea of the ease of reallocating internal capabilities from production to R&D (Aghion & 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” (see also 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. 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.

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

We want to provide evidence on whether the acquisition of foreign R&D had a lesser or greater influence on the intensity of radical product 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, with lower access to R&D funding in crisis periods, if internal and external R&D expenses are reduced and the two are complementary (Añón Higón et al., 2014;

Cassiman & Veugelers, 2006), we would expect the return of each euro devoted to the external acquisition of knowledge to 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 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 effects 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 therefore present the following two competing hypotheses:

Hypothesis 3a: *The economic crisis has led to an increase in R&D offshoring's return on radical innovation.*

Hypothesis 3b: *The economic crisis has led to a decrease in R&D offshoring's return on radical innovation.*

Finally, it is sensible to think that the effect of R&D offshoring can differ with respect to the firms' size.³ In this sense, large enterprises have more internal resources, like researchers, and can benefit more from implementing and recombining knowledge from abroad. In addition, large companies are more likely to belong to a company group, so that part of the external knowledge may come from enterprises in the group, with less risk of appropriation, information asymmetry, and opportunism, with a consequently higher impact on the innovative

³ We thank the editor for highlighting this point.

performance of the enterprise (Nieto & Rodríguez, 2011).

Indeed, previous evidence on R&D offshoring has mainly focused on multinational firms and, to a lesser extent, on small and medium-sized enterprises (SMEs). However, on the other hand, SMEs may offshore R&D to increase their partial innovation capabilities. Therefore, we will investigate this concern empirically for the Spanish case.

4. Methodology

We plan to regress firms' innovative performance as a function of the acquisition of foreign technology while controlling by firms' characteristics. This kind of analysis can lead to a sample selection problem. Indeed, 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 also inconsistent parameters (Wooldridge, 2010. p. 805). We therefore use a methodology that allows us to detect and correct sample selection problems making use of the panel structure of the data, following two steps (Wooldridge, 1995):

(i) We perform a yearly probit model of the probability of being an innovative firm as a function of firms' characteristics plus some exclusion restrictions⁴ 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 the inverse Mill's ratios included in the main equation in the second step.

(ii) We regress our measure for the firm's innovative performance with respect to the offshoring of innovation activities plus a set of control variables, our main equation, which is

⁴ The excluded variables are presented in section 5.2. These exclusion restrictions guarantee the identification of the system avoiding problems of collinearity in the last step.

estimated by pooled OLS with bootstrap errors.⁵ Following Wooldridge (2010, 1995), this approach allows us to obtain consistent estimations of the parameters as in the case of the fixed effect estimation in presence of a panel structure of the data.

As we are using time invariant regressors (sectoral dummy variables), we cannot use the fixed effects model. Besides, the random effects model assumes no correlation among the observed characteristics of the firms and the unobserved heterogeneity, which seems not to be plausible in our case.⁶ Having that in mind, the way in which we can correct for the unobserved heterogeneity of firms depends on the observable characteristics (Mundlak, 1978).

Therefore, we follow Wooldridge (2010, 1995) and take the mean values of the exogenous time varying variables and include them into the analysis, jointly with the annual varying variables. We are, thus, correcting for the possible endogeneity among the observable characteristics and the time invariant part of the error term.

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

$$s_{it} = 1(Z_{it}\delta_t + v_{it} > 0), \quad v_{it}|Z_{it} \sim Normal(0,1)$$

where s_{it} is our selection variable, that is, the probability of being an innovative firm, Z_{it} is a vector of explanatory variables with valid exclusion restrictions, δ_t is the vector of their parameters and the error term v_{it} is assumed to be normally distributed. Conditioning on $s_{it} = 1$ our equation of interest will be:

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

⁵ We decided to estimate 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 dependent 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 The exogenous variable could be correlated with managerial abilities which are unobserved.

where y_{it} is our variable proxying for innovation performance, $X_{it}\beta$ will include our key measures of the external acquisition of knowledge and the vector of control variables⁷—without the exclusion restrictions—with their corresponding parameters. The mean values and their vector of parameters are represented by $\bar{X}_i\eta$ which are the correction for the correlation between the explanatory variables and the unobserved heterogeneity. Finally, $\gamma_t\hat{\lambda}_{it}$ is a vector of the inverse Mill's ratios and their coefficients.⁸ All the variables are lagged one period in order to lessen simultaneity problems and to allow for the necessary time from the start of a R&D investment until the generation of profits.

5. Data set, variables and descriptive analysis

5.1 Data set

The data set used is an unbalanced panel taken from the PITEC (*Technological Innovation Panel*), a yearly survey with around 450 variables on the innovation activity carried out by Spanish enterprises. It uses two surveys, the first one—Survey on Technological Innovation of Firms—is the Spanish response to the Community Innovation Survey (CIS) from the Eurostat following the guidelines of the Oslo Manual, while the second one is the Statistics on R&D Activities. Moreover, it offers direct measures of the innovation output as product and process innovations instead of relying only on measures of semi-output like patents or inputs like R&D expenditures.

The PITEC is representative of small and medium size as well as big firms, enterprises with internal R&D expenditures as well as those with external R&D expenditures without having internal R&D, and finally of those small and medium size firms without any

⁷ In this case, X_{it} and Z_{it} can have possibly common elements.

⁸ We interact the inverse Mill's ratios with time dummy variables in order to allow γ to be different across t .

expenditures on innovation. It covers all the business sectors included in the National Classification of Economic Activities (NACE) and the representativeness of the panel is assured thanks to the annual inclusion of firms with similar characteristics to those that disappear from the sample. The response rate is very high due to the fact that it is mandatory for firms.

Our sample covers the period 2004 to 2013, with around 86,000 observations referred to 12,000 enterprises. However, after deleting missing values, taking into account only companies with more than 10 workers, dropped those observations for firms declaring not to have any innovative expenditure while having data for the share of sales due to new products, as well as those outliers with more than 20% of market share in a given sector⁹, we end up with around 7,700 enterprises and around 41,000 observations.

Being part of the EU implies solid laws of intellectual property rights, leading to a high benefit from offshoring strategies.¹⁰ The Spanish case is interesting since it is at the middle of the technological ranking, below the mean of R&D/GDP in the EU—1.22% for Spain in 2014 and 2.08% for the UE15, according to the INE. Most of the productive sector is based on SMEs and the public sector is the main source of knowledge, with the largest share of R&D workers, around 56% in 2014—19% for research centers and 37% for universities. In addition, Spain

⁹ Firms with more than 20% of the market share in a given sector represent around 0.19% of total observations pertaining to a 0.07% of enterprises in the sample. The threshold of 20% of the market share was chosen following previous evidence using also the PITEC survey, such as López-García and Montero (2010). Additionally, in the case of those observations for which internal R&D expenditures are two times the volume of sales, we have replaced such values with a maximum value of 2—representing around 0.6% of total observations. Although the selection of a value of 2 is arbitrary, other smaller values did not imply any change in the results. These additional estimates are available upon request.

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

suffered one of the biggest and most negative impacts of the financial and economic crisis at the end of 2008.

Given that PITEC is a survey in which values are self-reported, one could think of the problem of measurement bias and measurement errors. However, in this kind of surveys where anonymity is a legal concern, there is not a systematic necessity of over- or under-reporting the innovation carried out by the enterprise (Aarstad et al. 2016). In addition, Lucena (2016) shows that the PITEC database does not suffer from common-method-bias.

5.2 Variables

Dependent variables

We focus our empirical research on the influence of R&D offshoring on product innovation and how this has an effect on firms' sales. 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 new to the market. 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 two endogenous variables.

Incremental innovation reflects the share of sales due to product innovations that are only new to the firm, whereas *Radical innovation* considers the share of sales that are due to product innovations that are new to the market (Arvanitis et al., 2015; Barge-Gil, 2013; Grimpe and Kaiser, 2010).¹¹ Moreover, *Innovative enterprise*, which is our selection variable, captures

¹¹ Following previous studies using CIS type survey data we develop the ratio between the percentage of sales over one minus such a percentage of sales taking the logs of the ratio. As the log of the bounds (zero and one) are not defined, we apply a winsorizing process for the extreme values, assigning 0.9999 to 1 and 0.0001 to 0 (see Klomp and Van Leeuwen, 2001; Mohnen et al., 2006; Raymond et al., 2010; Robin and Schubert, 2013). We

whether the firm is innovative (1) or not (0). Table 1 provides a detailed description of our variables (dependent, independent, control variables, and exclusion restrictions) while Table 2 shows the correlation matrix among the variables used in the regression analysis.

[Insert Tables 1 and 2 around here]

Independent variables

For hypothesis 1, we use the variable *Offshoring*, which measures the expenditures on purchased R&D from abroad over total sales.¹² Several studies have found a positive relationship between the purchase of external knowledge and innovation performance—both as dummy variables. However, we analyze the influence of the amount of expenditure devoted to the foreign acquisition of knowledge (a continuous variable) on the intensity of radical product innovations. To test our second hypothesis, we split the offshoring measure into two: the external purchases from foreign research institutes (*Offshoring public*) and purchases from foreign private companies (*Offshoring private*), both over total sales.

Controls

To control for relevant firm characteristics, *Cooperation* has been observed to have an important role on product innovation (Robin and Schubert, 2013), capturing whether the firm acquires external knowledge through other channels. *Internal R&D* captures the effect of the internal capabilities of the enterprise, which have been recognized as an important complement for R&D offshoring (Cassiman and Veugelers, 2006; Spithoven and Teirlinck, 2015).

decided to use this transformation because it is closer to a normal distribution and lies in the set of real numbers varying from $-\infty$ to $+\infty$. As the variable is very skewed, this is a necessary transformation in order to close to a normal distribution.

¹² The offshoring variable, as in the PITEC database, refers to the acquisition of knowledge through licensing and do not include joint ventures.

We also account for the *Size* of the firm, in addition, *Permanent* measures whether the company develops internal R&D efforts continuously, whereas the *Openness* variable counts the number of sources of information that the company has: internal sources, market sources and institutional sources (Laursen and Salter, 2006; Robin and Schubert, 2013). Finally, *Demand Pull* is a variable that proxies for the objectives of product innovations (accessing new markets, gaining market share or having greater quality of products).

Exclusion restrictions

In our first stage for controlling for sample selection, the variable *Group* tries to capture the effect of belonging to a group of enterprises (Raymond et al., 2010; Vega-Jurado et al., 2009). 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.

In line with previous scholars, we also used *Market share* which is an important factor for innovation trying to account for the effect of a more favorable position in the industry due to market concentration (Raymond et al., 2010). Finally, we used obstacles to innovation—*Risk obstacles*, *Cost obstacles*, *Knowledge obstacles* and *Other obstacles*—to account for the perception of the firm about the barriers to innovation (Archibugi et al., 2013; Belderbos et al., 2013). As in previous literature, these exclusion restrictions are assumed to affect the likelihood to innovate while not affecting innovation performance.

5.3 Descriptive analysis

Table 3 provides summary statistics for the variables in the analysis. Around 63% of firms are innovators—have expenditures on innovation—while the average share of sales that a firm declares to obtain as a result of its product innovations is around 11.7% for the case of products new to the firm, and 7.6% for those new to the market. Also, 5% of innovative firms offshore

R&D. Firms tend to perform more offshoring with private organizations (4.16%) instead of research institutions or universities (0.6%). On average, around 41% of the innovative firms conduct internal R&D continuously, while internal R&D expenditures representing around 6% of total sales.

[Insert Table 3 around here]

Interesting differences can be extracted when comparing firms that carry out R&D offshoring with those that do not. Offshoring enterprises double the amount of sales due to radical 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, and cooperate and perform internal R&D continuously more than non-offshored enterprises, tending to be of a bigger size.

6. Regression results

Table 4 shows the results of the first stage of our regressions. The results of the second stage, that is, the estimation of our main equation of interest, are presented in Table 5.¹³

¹³ As stressed in the hypotheses section, in order to consider whether there is a different role of offshoring in large and small enterprises, we split the sample into large enterprises (LEs), those firms with more than 200 workers, and small and medium-sized enterprises (SMEs), with 200 workers and fewer, following the classification in the PITEC survey. The results of the Chow tests at the bottom of columns 2, 4 and 6 in Table 5 stress the significant differences between SMEs and LEs. Thus, we test our first two hypotheses taking into account this difference. However, in the case of our third hypothesis (different impact of offshoring before and during the crisis), we decided to use two dummy variables, one for the pre-crisis period and another one for the crisis, and interact them with the offshoring variable (columns 7 and 8 of Table 5). This procedure allows making a fair comparison between the parameters while avoiding an important reduction in the number of observations in each subsample.

Regarding the latter, time and sectoral dummy variables are included, being jointly significant in most of the specifications.¹⁴ Relative to Heckman's correction, we find strong evidence of the sample selection problem in all the specifications, as concluded from the Wald test on the joint significance of the inverse Mill's ratios (Wooldridge, 1995), indicating the necessity of such correction.

Finally, regarding the Mundlak approach to control for the possible correlation among the exogenous variables and the unobserved heterogeneity, its joint significance points to the need to control for such unobserved heterogeneity.

[Insert Tables 4 and 5 around here]

Columns (1) to (4) in Table 5 display the results of our first hypothesis. The coefficient for the offshoring variable is positive and highly significant for radical innovation, while it is not significant for incremental innovation, giving full statistical support to our first hypothesis: there is a clearer influence of the foreign acquisition of knowledge on the intensity of radical product innovations than on that obtained from incremental ones. This is especially true for LEs. It seems that R&D offshoring activities, far from deterring the firms in a country from innovating, allow them to increase their innovative performance, especially in the case of those innovations incorporating more novelty.

Following the argument given in previous studies, it seems that knowledge acquired from a different national innovation system brings a higher degree of novelty, which, combined with the internal knowledge, may lead to greater benefit.¹⁵

¹⁴ The sectoral dummy variables are at the two-digit level (NACE 1.1). For a detailed list, see the following website (p.11):

[https://icono.fecyt.es/PITEC/Documents/2016/dise%C3%B1oregistro_sindelimitadores2014%20\(2017\).pdf](https://icono.fecyt.es/PITEC/Documents/2016/dise%C3%B1oregistro_sindelimitadores2014%20(2017).pdf)

¹⁵ We acknowledge the possibility of reverse causality, as detailed in section 6.1.

The results in columns (5) and (6) show that the influence of knowledge coming from the foreign business sector is positive and highly significant in the case of LE, whereas the knowledge coming from research centers or universities from abroad is not, giving support to hypothesis 2.a.¹⁶ Again, SMEs do not present any significant impact. 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 with private enterprises.¹⁷

Finally, but no less important, we would like to see how the current economic crisis is affecting the return obtained from the R&D offshoring undertaken by Spanish firms. A descriptive analysis through time shows that Spanish firms have exerted slightly less effort in offshoring strategies during the crisis than before it. Indeed, the share of firms that offshored innovation in 2004 was 5%, 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, we test our predictions on a balanced panel of firms that are present throughout the whole period from 2004 to 2013.¹⁸

¹⁶ We should also be aware that the share of firms that purchase technology from foreign research centers or universities is very small compared with the share purchasing from the business sector (see also Gutiérrez Gracia et al., 2007).

¹⁷ We run the regressions in the case of a balanced panel for hypotheses 1–2, trying to take into account a possible attrition problem (the results are available from the authors on request), and the results barely change. This seems to show that there is no problem of attrition as we would expect since the rate of dropout from the panel is very small. We thank the editor for pointing this out.

¹⁸ The possible major issues reported are: a firm belonging to a sector with high employment turnover; an acquired firm; a change in the unit of reference; a change in or abandonment of activity; a firm remaining from an acquisition process (not part of the acquisition); a firm in liquidation; a merged firm; a firm that has employees ceded by other firms; a consequence of the crisis; and a firm that cedes employees to other firms. The time frame

The results in columns (7) and (8)—for the whole period, dividing the effect of R&D offshoring using an interaction term with a time dummy variable—show that the parameter for the offshoring variable for the period during the crisis is not significant, while it is significant before the crisis for the case of LEs. Indeed, the result of the Chow test on the whole sample with respect to the subsamples before and in the crisis without separating LEs and SMEs, shows that a structural change occurred in 2009. These results give support to our hypothesis 3.b, meaning that the crisis implied a lower return from seeking new knowledge abroad.

With respect to the control variables, Table 5 also shows interesting results. Regarding cooperation with other organizations and internal R&D, the coefficients have a positive impact on the firms' innovative performance. The latter supports the internal capabilities theory: a firm needs internal resources—personal, equipment, and instruments—with a high degree of knowledge to access, understand, and implement new knowledge (Cohen & Levinthal, 1990).

We also find evidence of a positive relationship with firms' size, so larger firms achieve better innovative performance (as in Bertrand & Mol, 2013), probably because they are less constrained by the scarcity of financial, infrastructural, and technological resources.

Developing internal R&D activity continuously (permanent), and having a wide variety of information sources for the external acquisition of knowledge (openness) show the expected positive sign, whereas demand pull (having the objective of accessing new markets, gaining market share, or having greater quality of products when innovating) will affect the innovativeness performance of the enterprise positively.

6.1 Robustness checks

We acknowledge the possibility of reverse causality between offshoring and radical innovation performance, since those firms with better innovation performance would probably

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 & Hussinger, 2015).

tend to acquire more knowledge from abroad. Due to the anonymity laws in Spain, it is impossible to match our data set with external data sets to find truly exogenous instruments for the firm.

In an attempt to control for this, we match our data with sectoral data from the Spanish National Institute of Statistics, leading to an instrument at the sectoral level instead of at the firm level. This instrument is the percentage of purchases of intermediate material from the Internet for each sector (Amiti & Wei, 2005; Görg & Hanley, 2011). We also try to use the growth rate of R&D offshoring at the firm level (Görg & Hanley, 2011). Unfortunately, the results are not satisfactory in the sense of those instruments having very poor predictive power.

Therefore, since the impossibility of obtaining data for good instruments does not allow us to correct for the endogeneity problem, we decide at least to lessen it by using two lags for the case of the offshoring variables used in Table 5. We find that the results (the first robustness part of Table 6) hold and are essentially the same as the main results reported in Table 5, only changing marginally for the case of the offshoring variables. Despite not solving the problem, this points to a low impact due to the reverse causality issue.

[Insert Table 6 around here]

To check the external validity of our results, that is, the extent to which the results can be extrapolated to other economies, we now investigate if our results are sensitive to different definitions of the dependent and our offshoring variables, as previously used in other papers. First, we measure radical innovation as the share of sales due to products that are new to the market without taking logs or performing any winzorizing processes. As shown in the second part of Table 6, most of the main results related to the offshoring of R&D hold, presenting a positive and significant impact of offshoring on radical innovation, as in the German case reported in the study by Grimpe and Kaiser (2010).

Second, we decided to use a dummy variable as a proxy for R&D offshoring (yes/no R&D

offshoring), as mostly performed in previous studies. From the results in the third part of Table 6, we observe that there is no qualitative difference in the influence of offshoring on innovation performance when the dichotomous offshoring variable is used. This is in line with the evidence obtained in the case of Arvanitis et al. (2015) for the Netherlands, Bertrand and Mol (2013) for France, and Cusmano et al. (2009) for Lombardy, although in all these cases the authors did not distinguish between radical and incremental innovation.

Finally, we perform two further sensitivity analysis. First, we test whether our second hypothesis is robust to the business cycle, that is, whether the difference in the influence of the acquisition of external knowledge from an international industrial-based agent versus a research-based one changed as a result of the crisis. Accordingly, we divide the sample according to two time periods: before and during the crisis period for LEs on the one hand, and for SMEs on the other hand (Table 7, columns 1 to 4). The results hold for LEs in the sense that the knowledge acquired from business organizations is more relevant to radical innovations than that from research institutions before the crisis, something that goes in line with our main results.

[Insert Table 7 around here]

Second, we investigate whether the sectoral dimension plays any role when considering the impact of R&D offshoring.¹⁹ Specifically, given that a Chow test rejects only marginally the null that manufacturing and services behave similarly with respect to offshoring, we include a dummy variable for those companies belonging to the service sector and cross it with the offshoring variables (Table 7 columns 5 to 8). The results seem to point to a higher impact of R&D offshoring in the service sector than for manufacturing enterprises in our different hypotheses.

¹⁹ We thank the editor for highlighting this point (results upon request from the authors).

Among other reasons, we could think that developed economies are making a fast transition to deindustrialization giving more weight to service firms. There are also some studies pointing to the fact that service firms are more prone than manufacturing ones to take advantage of innovation processes (Mina et al., 2014). However, further analysis is needed in this case since there is a lack of empirical evidence in the related literature to build a conceptual framework for this latter analysis.

7. Discussion and conclusions

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 (Ahuja & Lampert, 2001), 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). 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. Our research contributes to the literature on innovation offshoring in three different ways.

First, it provides empirical evidence on the influence of knowledge coming from a foreign country on the innovations that incorporate more novelty in the market (known as radical innovations). Second, we consider the success obtained from such innovations (share of sales due to new products) instead of the more common proxy that just considers whether the firm has achieved product innovations or not. Third, it studies the heterogeneity in the return of R&D offshoring depending on the technological differences of the agent from which the knowledge is taken, either a business organization (market oriented) or a research institution (knowledge base oriented).

The evidence provided for Spanish firms from 2004 to 2013 points to R&D offshoring having a significant and positive influence on the benefits of radical product innovations

(measured by sales share) but not on incremental ones. We also find that knowledge from a foreign business organization has a greater influence than that from foreign research-based institutions, which is probably related to the perception by Spanish firms that knowledge acquired from research organizations offers a smaller chance of having real applicability (Nieto & Santamaría, 2007).

Following the heterogeneity of the influence of the R&D offshoring strategy before and within the crisis periods, our findings suggest a greater influence in a no-crisis period. This is interesting, since we observe that the amount of Spanish enterprises engaging in R&D offshoring has decreased over the entire period—a conclusion that also holds for the balanced panel—while the return that they obtain has also decreased.²⁰ This could be due to the complementary relationship between internal and external expenditures on innovation in the Spanish case pointed out by Añón Higón et al. (2014).

Finally, we empirically study the differences between LEs and SMEs on the impact of R&D offshoring in the innovative performance of the firm. Our results points to the fact that LEs are the ones obtaining the most benefit from seeking knowledge from abroad. Following the arguments of Di Gregorio et al. (2008) and Nieto and Rodríguez (2011), LEs are the ones having greater financial, technological, and internal resources so they can be more favored in implementing and recombining the knowledge from abroad while facing less risk of appropriation, information asymmetry, and opportunism, and therefore profiting more from such knowledge.

Several implications for policy makers may be envisaged. First, policy makers should not focus mainly on innovation agreements between national firms and public research institutes;

²⁰ Not only the amount of enterprises but also the amount of money allocated to this strategy has been reduced among those enterprises conducting R&D offshoring throughout the entire period.

at least, they should not be encouraged at all costs. Instead, firms may also be helped to gain access to foreign knowledge to obtain a higher novelty degree of the innovations produced.

Second, our results shed light on the lesser influence of R&D offshoring on the intensity of radical product innovation in periods of financial constraints. As stressed by the OECD (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 good innovation performance.

Therefore, given the complementary relationship between internal and external R&D found in many papers (Añón Higón et al., 2014; Cassiman & Veugelers, 2006), it would be desirable for governments to show greater commitment to maintaining expenditures on innovation even in crisis periods to avoid reducing the return that firms can gain from external R&D strategies.

Limitations and 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 R&D 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 radical innovations. It would be interesting to identify which type of knowledge, with respect to its geographical origin, could be more profitable: 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 R&D 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 influence of the R&D offshoring strategies followed by firms.

In addition, regarding our results for the cases of LEs and SMEs, it would be interesting to analyse empirically which characteristics allow LEs to take more advantage of R&D offshoring than SMEs. Finally, it would be remarkable to study the fact that the service sector is apparently different from the manufacturing one when dealing with the impact of R&D offshoring. We think that more empirical evidence is needed as well as building a theoretical core and some stylized facts for this specific issue.

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Table 1. Definition of the variables included in the empirical analysis

Variables	Definitions
Dependent Variables	
Innovative enterprise	1 if the firm declare to have expenditures (internal or external) in R&D, acquisition of machinery and software, expenditures on the acquisition of external knowledge, expenditures on production/distribution, expenditure on training, and other preparations, 0 otherwise
Incremental innovation	Sales share of new or significantly improved products for the firm
Radical innovation	Sales share of new or significantly improved products for the market
Main Variables	
Offshoring	Expenditure on purchased R&D/Total Sales
Offshoring public	Expenditure on purchased R&D from public institutions/Total Sales
Offshoring private	Expenditure on purchased R&D from private firms/Total Sales
Offshoring Pre crisis	[Expenditure on purchased R&D/Total Sales]*[Dummy variable equal to 1 if time<=2008 and 0 otherwise]
Offshoring Crisis	[Expenditure on purchased R&D/Total Sales]*[Dummy variable equal to 1 if time>2008 and 0 otherwise]
Controls	
Cooperation	1 if the firm reported engagement in collaborative agreements with partners; 0 otherwise
Internal R&D	Ratio between intramural R&D expenditure and turnover
Size	Number of employees
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 has 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 (the firm uses all types 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	
Group	1 if the firm belongs to a group of enterprises; 0 otherwise
Market share	Ratio of the sales of a firm over the total sales of the two-digit industry it belongs to
Risk obstacles	Sum of score of importance that the firm attributed [number between 1 (high) and 4 (not used)] to the uncertain demand for innovative goods or services and to the market dominated by established enterprises as factors that hampered its innovation activities. Rescaled from 0 (unimportant) to 1 (crucial)
Cost obstacles	Sum of the scores of importance that the firm attributed [number between 1 (high) and 4 (not used)] to the following factors that hampered its innovation activities: lack of funds within the enterprise or enterprise group; lack of finance from sources outside the enterprise; innovation costs too high. Rescaled from 0 (unimportant) to 1 (crucial)
Knowledge obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: lack of qualified personnel; lack of information on technology; lack of information on markets; difficulty in finding cooperation partners for innovation. Rescaled from 0 (unimportant) to 1 (crucial)
Other obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: not necessary due to previous innovations; not necessary due to the absence of demand. Rescaled from 0 (unimportant) to 1 (crucial)

Table 2. Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Offshoring	1												

(2) Cooperation	0.14	1												
(3) Internal R&D	0.09	0.15	1											
(4) Size	0.01	0.06	-0.05	1										
(5) Permanent	0.13	0.23	0.22	-0.01	1									
(6) Openness	0.11	0.28	0.13	0.02	0.34	1								
(7) Demand pull	0.06	0.19	0.07	-0.01	0.28	0.34	1							
(8) Group	0.14	0.14	-0.08	0.15	0.04	0.06	0.02	1						
(9) Market share	0.08	0.09	-0.05	0.38	0.04	0.05	0.02	0.22	1					
(10) Risk obstacles	0.01	0.07	0.03	-0.07	0.12	0.22	0.13	-0.08	-0.06	1				
(11) Cost obstacles	-0.02	0.06	0.08	-0.08	0.10	0.19	0.14	-0.15	-0.08	0.44	1			
(12) Knowledge obstacles	-0.01	0.10	0.04	-0.05	0.09	0.23	0.10	-0.10	-0.06	0.55	0.50	1		
(13) Other obstacles	-0.07	-0.12	-0.08	0.00	-0.23	-0.11	-0.15	-0.02	-0.01	0.14	0.02	0.14	1	

Table 3. Descriptive statistics of the variables in the analysis

VARIABLES	Whole Sample				No R&D Offshoring				R&D Offshoring			
	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max
Dependent Variables												
Innovative enterprise	0.63	0.48	0	1	0.61	0.49	0	1	16.67	26.20	0	100
Incremental innovation	11.69	25.54	0	100	11.45	25.48	0	100	16.67	26.20	0	100
Radical innovation	7.58	20.04	0	100	7.27	19.78	0	100	14.05	24.02	0	100
Main Variables												
Offshoring	0.05	0.21	0	1								
Offshoring public	0.01	0.08	0	1					0.13	0.34	0	1
Offshoring private	0.04	0.20	0	1					0.93	0.25	0	1
Offshoring pre crisis	0.02	0.15	0	1					0.31	0.46	0	1
Offshoring crisis	0.02	0.15	0	1					0.35	0.48	0	1
Controls												
Cooperation	0.37	0.48	0	1	0.36	0.48	0	1	0.64	0.48	0	1
Internal R&D	0.06	0.22	0	2	0.05	0.21	0	2	0.16	0.41	0	2
Size	347	1,552	10	41,509	344	1,570	10	41,509	409	1,099	10	21,905
Permanent	0.41	0.49	0	1	0.39	0.49	0	1	0.80	0.40	0	1
Openness	3.81	3.26	0	8	3.69	3.25	0	8	6.32	2.25	0	8
Demand pull	0.65	0.48	0	1	0.64	0.48	0	1	0.76	0.42	0	1
Exclusion Restrictions												
Group	0.43	0.49	0	1	0.41	0.49	0	1	0.70	0.46	0	1
Market share	0.01	0.02	0	0.20	0.00	0.02	0	0.20	0.01	0.03	0	0.20
Risk obstacles	0.46	0.33	0	1	0.46	0.33	0	1	0.52	0.29	0	1
Cost obstacles	0.54	0.34	0	1	0.54	0.34	0	1	0.58	0.29	0	1
Knowledge obstacles	0.37	0.27	0	1	0.36	0.27	0	1	0.39	0.23	0	1
Other obstacles	0.27	0.27	0	1	0.27	0.28	0	1	0.15	0.22	0	1

Table 4. Marginal effects of the first stage (Sample selection).

(2005) (2006) (2007) (2008) (2009) (2010) (2011) (2012) (2013)

VARIABLES	Innovative enterprise	Innovative enterprise	Innovative enterprise	Innovative enterprise	Innovative enterprise	Innovative enterprise	Innovative enterprise	Innovative enterprise	Innovative enterprise
Group	0.059*** (0.013)	0.045*** (0.012)	0.062*** (0.013)	0.074*** (0.013)	0.065*** (0.013)	0.067*** (0.014)	0.063*** (0.014)	0.056*** (0.015)	0.077*** (0.015)
Market share	1.010*** (0.333)	1.027*** (0.345)	1.183*** (0.408)	2.444*** (0.422)	2.060*** (0.467)	3.995*** (0.632)	3.262*** (0.569)	2.088*** (0.482)	1.824*** (0.517)
Risk obstacles	0.198*** (0.025)	0.123*** (0.021)	0.104*** (0.023)	0.154*** (0.024)	0.129*** (0.024)	0.136*** (0.025)	0.166*** (0.026)	0.161*** (0.026)	0.201*** (0.028)
Cost obstacles	0.117*** (0.024)	0.141*** (0.020)	0.178*** (0.023)	0.187*** (0.024)	0.174*** (0.024)	0.112*** (0.024)	0.087*** (0.025)	0.088*** (0.025)	0.104*** (0.025)
Knowledge obstacles	0.085*** (0.032)	0.143*** (0.027)	0.149*** (0.030)	0.161*** (0.031)	0.141*** (0.031)	0.208*** (0.032)	0.203*** (0.033)	0.208*** (0.034)	0.188*** (0.036)
Other obstacles	-0.440*** (0.022)	-0.441*** (0.019)	-0.469*** (0.021)	-0.482*** (0.022)	-0.491*** (0.022)	-0.539*** (0.023)	-0.505*** (0.024)	-0.567*** (0.025)	-0.554*** (0.026)
Size (in logs)	-0.001 (0.005)	0.003 (0.005)	0.010** (0.005)	0.023*** (0.005)	0.031*** (0.005)	0.029*** (0.006)	0.046*** (0.006)	0.054*** (0.006)	0.056*** (0.006)
Observations	7,720	9,112	8,629	8,307	8,167	7,727	7,517	7,207	6,868

Standard errors in parentheses. Sectoral dummy variables included. *** p<0.01, ** p<0.05, * p<0.1

Table 5. Influence of R&D offshoring on incremental and radical product innovation.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7) (8)	
	LEs	SMEs	LEs	SMEs	LEs	SMEs	Balanced Panel	
	Incremental innovation	Incremental innovation	Radical innovation	Radical innovation	Radical innovation	Radical innovation	LEs Radical innovation	SMEs Radical innovation
Offshoring $t-1$ (in logs)	0.035 (0.026)	-0.008 (0.020)	0.059** (0.024)	0.015 (0.019)				
Offshoring public $t-1$ (in logs)					0.093 (0.163)	0.037 (0.098)		
Offshoring private $t-1$ (in logs)					0.071** (0.036)	0.030 (0.030)		
Offshoring Pre crisis $t-1$ (in logs)							0.067*** (0.025)	0.047 (0.034)
Offshoring Crisis $t-1$ (in logs)							0.014 (0.039)	-0.002 (0.033)
Cooperation $t-1$	0.358*** (0.137)	0.108 (0.094)	0.108 (0.120)	0.250*** (0.078)	0.111 (0.118)	0.250*** (0.078)	0.065 (0.118)	0.205* (0.105)
Internal R&D $t-1$	-0.828 (0.669)	0.003 (0.186)	2.303** (1.078)	1.284*** (0.189)	2.299** (1.114)	1.277*** (0.188)	1.731 (1.264)	1.363*** (0.348)
Size $t-1$ (in logs)	0.157 (0.207)	0.495*** (0.150)	0.338* (0.199)	-0.024 (0.127)	0.336* (0.182)	-0.024 (0.127)	-0.048 (0.314)	0.029 (0.184)
Permanent $t-1$	0.417** (0.185)	0.132 (0.092)	0.392** (0.157)	0.396*** (0.084)	0.394** (0.157)	0.396*** (0.084)	0.471*** (0.170)	0.209* (0.119)
Openness $t-1$	0.014 (0.031)	0.035** (0.018)	0.031 (0.025)	0.059*** (0.015)	0.032 (0.028)	0.059*** (0.015)	0.042 (0.043)	0.045** (0.019)
Demand pull $t-1$	0.512*** (0.156)	0.217** (0.098)	0.282** (0.128)	0.333*** (0.076)	0.283** (0.131)	0.333*** (0.076)	0.267** (0.134)	0.350*** (0.100)
Constant	-5.031*** (1.156)	-7.242*** (0.656)	-11.895*** (1.009)	-7.199*** (0.553)	-11.081*** (1.708)	-6.764*** (1.094)	-13.050*** (1.520)	-7.593*** (0.754)
Observations	10,537	30,417	10,537	30,417	10,537	30,417	7,018	15,577
R-squared	0.071	0.036	0.125	0.101	0.125	0.101	0.169	0.134
Test F lambda	69.03***	102.4***	36.95***	122***	42.43***	122.2***	62.77***	59.36***
Wald Test Mean values (Mundlak)	79.77***	162.8***	201.9***	548.4***	195.9***	547***	268.2***	521***
Wald Test Sectoral dummy variables	394.6***	228.8***	264.8***	683***	406.3***	679.3***	55.95***	598.4***
Wald Test Time dummy variables	13.69*	13.97*	3.047	74.57***	3.535	74.64***	29.23***	22.48***
Chow Test		2.529***		3.030***		2.983***		

Bootstrap errors in parentheses. Means fixed effect, time and sectoral dummy variables included. Dependent variables correspond to the log-transform: $\log[y/(1-y)]$. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6. Robustness checks

Robustness check 1. Two lags of the offshoring variables								
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7) (8) Balanced Panel	
	LEs Incremental innovation	SMEs Incremental innovation	LEs Radical innovation	SMEs Radical innovation	LEs Radical innovation	SMEs Radical innovation	LEs Radical innovation	SMEs Radical innovation
Offshoring t_{-2} (in logs)	0.022 (0.027)	-0.019 (0.023)	0.063** (0.027)	0.036* (0.021)				
Offshoring public t_{-2} (in logs)					-0.120 (0.160)	0.059 (0.102)		
Offshoring private t_{-2} (in logs)					0.089** (0.040)	0.047 (0.031)		
Offshoring Pre crisis t_{-2} (in logs)							0.045** (0.020)	0.029 (0.033)
Offshoring Crisis t_{-2} (in logs)							0.000 (0.046)	0.011 (0.037)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mill Ratios	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Means fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time and Sectoral dummy variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,968	24,869	8,968	24,869	8,968	24,869	6,296	13,671
Robustness check 2. Changing the dependent variable (no winzoring transformation)								
Offshoring t_{-1} (in logs)	0.085 (0.146)	0.006 (0.114)	0.200* (0.121)	0.161 (0.115)				
Offshoring public t_{-1} (in logs)					-0.012 (0.636)	0.499 (0.544)		
Offshoring private t_{-1} (in logs)					0.295 (0.192)	0.283 (0.179)		
Offshoring Pre crisis t_{-1} (in logs)							0.461** (0.228)	0.346 (0.214)
Offshoring Crisis t_{-1} (in logs)							0.116 (0.199)	0.155 (0.186)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mill Ratios	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Means fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time and Sectoral dummy variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,537	30,417	10,537	30,417	10,537	30,417	7,018	15,577
Robustness check 3. Offshoring as a dummy variable								
Offshoring t_{-1}	0.097 (0.139)	-0.048 (0.120)	0.322** (0.133)	0.029 (0.117)				
Offshoring public t_{-1}					-0.168 (0.273)	-0.018 (0.391)		
Offshoring private t_{-1}					0.321** (0.142)	0.053 (0.092)		
Offshoring Pre crisis t_{-1}							0.416* (0.231)	0.108 (0.194)
Offshoring Crisis t_{-1}							0.147 (0.203)	-0.052 (0.194)
Controls	Yes			Yes	Yes	Yes	Yes	Yes
Mill Ratios	Yes			Yes	Yes	Yes	Yes	Yes
Means fixed effects	Yes			Yes	Yes	Yes	Yes	Yes
Time and Sectoral dummy variables	Yes			Yes	Yes	Yes	Yes	Yes
Observations	10,537	30,417	10,537	30,417	10,537	30,417	7,018	15,577

Bootstrap errors in parentheses. Control variables, means fixed effects, time and sectoral dummy variables included. Dependent variables in parts 1 and 3 of the table correspond to the log-transform: $\log[y/(1-y)]$; in part 2 correspond to the sales share of new or significantly improved products (for the firm and for the market) without logs or winzoring process (from 0 to 100). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7. Further analyses

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	LE		SME		Incremental innovation	Radical innovation	Radical innovation	Radical innovation
	Pre-crisis Radical innovation	Crisis Radical innovation	Pre-crisis Radical innovation	Crisis Radical innovation				
Offshoring $t-1$ (in logs)					0.019 (0.019)	0.004 (0.016)		
Offshoring public $t-1$ (in logs)	0.295 (0.294)	-0.192 (0.249)	0.205 (0.137)	-0.159 (0.117)			-0.021 (0.090)	
Offshoring private $t-1$ (in logs)	0.066* (0.038)	0.056 (0.056)	0.036 (0.042)	0.026 (0.042)			0.005 (0.024)	
Offshoring Pre crisis $t-1$ (in logs)								0.047 (0.029)
Offshoring Crisis $t-1$ (in logs)								-0.007 (0.025)
Services (dummy variable)					-1.293*** (0.443)	1.112*** (0.398)	3.692** (1.700)	0.480 (0.663)
Offshoring $t-1$ (in logs)*Services (dummy variable)					-0.029 (0.038)	0.131*** (0.033)		
Offshoring public $t-1$ (in logs)*Services (dummy variable)							0.264 (0.178)	
Offshoring private $t-1$ (in logs)*Services (dummy variable)							0.180*** (0.049)	
Offshoring Pre crisis $t-1$ (in logs)*Services (dummy variable)								0.109* (0.057)
Offshoring Crisis $t-1$ (in logs)*Services (dummy variable)								0.131** (0.057)
Cooperation $t-1$	0.003 (0.184)	0.283 (0.196)	0.172 (0.112)	0.355*** (0.124)	0.189*** (0.073)	0.213*** (0.073)	0.214*** (0.073)	0.165** (0.083)
Internal R&D $t-1$	3.338* (1.981)	1.575 (1.283)	1.311*** (0.249)	1.214*** (0.265)	-0.004 (0.162)	1.418*** (0.188)	1.415*** (0.188)	1.568*** (0.320)
Size $t-1$ (in logs)	0.667** (0.279)	0.318 (0.288)	-0.129 (0.160)	0.223 (0.198)	0.345*** (0.105)	0.180* (0.103)	0.180* (0.103)	0.171 (0.167)
Permanent $t-1$	0.319** (0.162)	0.378* (0.227)	0.462*** (0.102)	0.276** (0.128)	0.192** (0.083)	0.403*** (0.070)	0.404*** (0.070)	0.275*** (0.099)
Openness $t-1$	0.029 (0.033)	0.033 (0.035)	0.063*** (0.020)	0.058*** (0.021)	0.034** (0.016)	0.051*** (0.013)	0.051*** (0.013)	0.041*** (0.015)
Demand pull $t-1$	0.286* (0.156)	0.386** (0.182)	0.535*** (0.106)	0.017 (0.112)	0.295*** (0.085)	0.318*** (0.067)	0.318*** (0.067)	0.332*** (0.082)
Constant	-9.917*** (3.033)	-13.445*** (2.447)	-5.646*** (1.483)	-7.961*** (1.357)	-5.960*** (0.450)	-8.887*** (0.424)	-9.080*** (0.944)	-9.527*** (0.579)
Observations	5,050	5,487	15,800	14,617	40,954	40,954	40,954	22,595
R-squared	0.137	0.132	0.105	0.102	0.040	0.102	0.102	0.137
Test F lambda	125.5***	29.63***	59.11***	35.07***	145.9***	89.75***	89.67***	81.66***
Wald Test Mean values (Mundlak)	122.6***	69.18***	394.6***	285.1***	211***	790***	789.9***	665.3***
Wald Test Sectoral dummy variables	758.6***	293***	406.4***	338.1***	373.5***	584.1***	585.2***	628.6***
Wald Test Time dummy variables	0.0220	2.810	11.99***	41.72***	19.86**	56.43***	56.57***	21.64***
Chow Test		1.427***		1.119				

Bootstrap errors in parentheses. Means fixed effects, time and sectoral dummy variables included. Dependent variables correspond to the log-transform: $\log[y/(1-y)]$. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Large enterprises (LEs) are those firms with more than 200 workers, while small and medium enterprises (SMEs) are those firms with less or equal to 200 workers as determined in the PITEC.

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