Radical Innovations: The Role of Knowledge Acquisition from Abroad

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Abstract
This paper explores R&D offshoring’s role in radical product innovations. These innovations are important for companies’ growth strategies, and we check the extent to which companies 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 from the business sector. The recent financial crisis also exerted a detrimental effect on this influence, as 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, the purchasing firms can choose from among 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

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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 with regard to 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 and 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 and Mol 2013; Nieto and 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 further contribution concerns the study of the heterogeneity in the influence of R&D offshoring according to the nature of the agents, 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. Second, we contribute to the literature that studies 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 Sect. 2 provides a literature review, while the Sect. 3 exposes the main hypotheses of the paper. Section 4 sketches the empirical model, before Sect. 5 presents the data. The main results are provided in Sect. 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 is the reduction of costs that it implies, as well as the access to a well-prepared labor force (Lewin et al. 2009; Youngdahl and Ramaswamy 2008). People—scientists, researchers, or engineers—are not perfectly mobile, and talent is an intangible good that is embedded in individuals, not easy to imitate, and part of the knowledge base of an enterprise (Lewin et al. 2009).
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, increases the efficiency of the firm’s internal capabilities, and leads to an improvement in its competitiveness and a positive impact on its innovation capacity (Cassiman and Veugelers 2006; Grimpe and Kaiser 2010; Love et al. 2014; OECD 2008, pp. 20, 91). These theoretical advantages of knowledge offshoring are expected to be translated into a positive impact on innovation performance.

The European Union Survey (Tübke and Van Bavel 2007) reported that the most important reason for offshoring R&D is the access to specialized R&D knowledge; cost reduction is the least important. Most of the papers that provide empirical evidence have reached the conclusion that external knowledge-sourcing strategies have a positive and significant impact on innovation performance (Laursen and Salter 2006; Mihalache et al. 2012; Nieto and Rodríguez 2011); as pointed out by Dachs et al. (2012, p. 10), studies that find a negative impact are scarce.

The acquisition of external knowledge connects the firm with an array 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—and provides it with an opportunity set that, combined with the internal R&D process, leads to new knowledge.

Enterprises find that more novel innovations often require the exploration of entirely new types of business models and technologies (Ahuja and 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 and Archibugi 2011; Phene et al. 2006). This could lead not only to an improvement in the adaption of existing products but also to the creation of new ones—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.

With respect to 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 that is 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 often the case in process innovations—the host firm will need skills that are 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; this is a similar result to that for France, as shown 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 that are achieved by a firm. Indeed, the new products that are 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 and Li 2012). This completely new product can generate a new platform or business domain that could imply new benefits and expansion into new markets (O’Connor et al. 2008).

To connect R&D offshoring and radical innovations, we rely on the tension theory (Ahuja and Lampert 2001; Weisberg 1998), which emphasizes the importance of a wide search or combinations of different sources to implement and recombine dissimilar and distant knowledge to achieve a revolutionary innovation. A search in a small segment of innovative sources has a negative influence on enterprises’ performance and promotes 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).

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

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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 and Salter 2006; Tether and Tajar 2008; Van Beers and 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.
from sources that are close to their knowledge base or close to their research fields (Cohen and Levinthal 1990). In addition, despite the technological proximity, international differences in national innovation systems and in managerial capabilities—human capital, social capital, and cognition—help induce 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 that is 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 and 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 and Schubert 2013). Universities play an important role in innovation: They provide scientific research, produce knowledge with industrial applications, and provide human capital (Schartinger et al. 2002).

This is an important issue, since, as suggested by Cohen and Levinthal (1990), the type of knowledge that comes 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 with highly innovative enterprises, which means that links with universities are not restricted to national boundaries (Monjon and Waelsbroeck 2003).

Also, 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. This implies 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 for 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 and Teirlinck 2015). This kind of relation between firms and public institutions...
allows enterprises to access a wider pool of knowledge, which strengthens their knowledge base (Aschhoff and Schmidt 2008). At the same time, this increased knowledge base could enable access to a higher degree of understanding and implementing of foreign technologies that come from different partners, which increases the likelihood of generating radically new products.

However, it is widely accepted that the type of knowledge that is 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 and Santamaría 2007).

These reasons lead us to think that knowledge that is 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 that is 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; or

**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); this reasoning comes from the idea of the ease of reallocating internal capabilities from production to R&D (Aghion and Saint-Paul 1998; Schumpeter 1939).

Alternatively, the procyclical approach points out that financial constraints might prohibit firms from maintaining or increasing their R&D budget (Stiglitz 1993) and that firms postpone innovation to periods of expansion to maximize the
returns (Barlevy 2004). Previous evidence has shown that the procyclical argument tends to prevail over the countercyclical one relative to innovation (Paunov 2012), even though there are countries (such as Sweden) in which the response to the recent economic crisis was countercyclical (Makkonen 2013).

For the case of Spain, Makkonen (2013) found that, “according to government science and technology budgets, Spain was one of the European countries most affected by the crisis” (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 in 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 and Veugelers 2006), we would expect the return of each euro that is 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 would try to choose those with higher chances of success. In such a case, the return that is 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 that shows 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 led to an increase in R&D offshoring’s return on radical innovation; or

**Hypothesis 3b** The economic crisis 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. 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 performance of the enterprise (Nieto and 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 regress firms’ innovative performance as a function of the acquisition of foreign technology, while controlling for firms’ characteristics. This kind of analysis can lead to a sample selection problem. Indeed, we are testing our hypotheses only for innovative firms—those that have positive expenditures on innovation; this is a possible source of sample selection that was posited 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 for sample selection problems with the use of the panel structure of the data, following two steps (Wooldridge 1995):

1. We perform a yearly probit model of the probability of being an innovative firm as a function of firms’ characteristics plus some exclusion restrictions 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.
2. 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 estimated by pooled OLS with bootstrap errors. Following Wooldridge (1995, 2010), this approach allows us to obtain consistent estima-

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3 We thank the editor for highlighting this point.
4 The excluded variables are presented in Sect. 5.2. These exclusion restrictions guarantee the identification of the system and avoid problems of collinearity in the last step.
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 non-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).
tions 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 (1995, 2010) 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:

\[
s_{it} = 1 \left( Z_{it} \delta + v_{it} > 0 \right), \quad v_{it} | Z_{it} \sim \text{Normal}(0, 1)
\]

where \(s_{it}\) is our selection variable: the probability of being an innovative firm; \(Z_{it}\) is a vector of explanatory variables with valid exclusion restrictions; \(\delta\) 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:

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

where \(y_{it}\) is our variable that proxies for innovation performance; and \(X_{it} \beta\) will include our key measures of the external acquisition of knowledge and the vector of control variables\(^7\)—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 of the RHS 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.

\(^6\) The exogenous variable could be correlated with managerial abilities, which are unobserved.

\(^7\) 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 \(\gamma\) to be different across \(t\).
5 Data Set, Variables and Descriptive Analysis

5.1 Data Set

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

The PITEC is representative of: small and medium-size as well as large firms; enterprises with internal R&D expenditures, as well as those with external R&D expenditures without having internal R&D; and finally those small and medium-size firms without any expenditures on innovation. It covers all of the business sectors that are included in the National Classification of Economic Activities (NACE); 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 for 12,000 enterprises. However, after deleting missing values, taking into account only companies with more than 10 workers, dropping those observations for firms that declare that they do not 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 sector, we arrive at around 7700 enterprises and around 41,000 observations.

Being part of the EU implies solid laws of intellectual property rights, which leads to a substantial benefit from offshoring strategies. The Spanish case is interesting since it is at the middle of the EU 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

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9 Firms with more than 20% of the market share in a given sector represent around 0.19% of total observations and 0.07% of the enterprises in the sample. The threshold of 20% of the market share was chosen following previous evidence that is also based on the PITEC survey, such as López-García and Montero (2010). Additionally, in the case of those observations for which internal R&D expenditures are more than 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 Van 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 survey, where anonymity is a legal concern, there is not a systematic propensity for over- or under-reporting the innovation that is 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

5.2.1 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 equivalent 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 2 years: either products that are new only to the firm or products that are 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 that are due to product innovations that are new only to the firm; 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). Moreover, Innovative enterprise, which is our selection variable, captures 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.

5.2.2 Independent Variables

For hypothesis 1, we use the variable Offshoring, which measures the expenditures on purchased R&D from abroad over total sales. 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

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11 Following previous studies that use CIS-type survey data, we develop the ratio between the percentage of sales over one minus the percentage of sales, and take 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 decided to use this transformation because it is closer to a normal distribution and lies in the set of real numbers that vary from -∞ to +∞. As the variable is very skewed, this is a necessary transformation in order to get close to a normal distribution.

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

5.2.3 Controls

To control for relevant firm characteristics, Cooperation has been observed to have an important role on product innovation (Robin and Schubert 2013); it captures 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).

We also account for the Size of the firm: measured by the number of employees. 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.

5.2.4 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, accompanied 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 may be an important factor in encouraging innovation; the effect of a more favorable position
|          | (1) Offshoring | (2) Cooperation | (3) Internal R&D | (4) Size | (5) Permanent | (6) Openness | (7) Demand pull | (8) Group | (9) Market share | (10) Risk obstacles | (11) Cost obstacles | (12) Knowledge obstacles | (13) Other obstacles |
|----------|----------------|-----------------|------------------|----------|--------------|--------------|-----------------|----------|-----------------|-----------------------|-------------------|-----------------------|---------------------|
| (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                   |
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 the 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 occur 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.

Interesting differences can be extracted when we compare firms that carry out R&D offshoring with those that do not. Offshoring enterprises double the amount of sales that are 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 do non-offshored enterprises; also, offshoring enterprises tend to be larger.

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 With regard to the latter: Time and sectoral dummy variables are included and are jointly significant in most of the specifications.14 With respect to Heckman’s correction, we find strong evidence of the sample selection problem

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. 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 a fair comparison between the parameters while avoiding an important reduction in the number of observations in each subsample.

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%B1o_registro_sindelimiteadores2014%20(2017).pdf
| 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   | 14.05  | 24.02  | 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     | 0.01   | 0.08   | 0   | 1     | 0.13   | 0.34   | 0   | 1     |
| Offshoring public                  | 0.04   | 0.20   | 0   | 1     | 0.02   | 0.15   | 0   | 1     | 0.31   | 0.46   | 0   | 1     |
| Offshoring private                 | 0.02   | 0.15   | 0   | 1     | 0.02   | 0.15   | 0   | 1     | 0.35   | 0.48   | 0   | 1     |
| Offshoring pre crisis              |        |        |     |       |        |        |     |       |        |        |     |       |
| Offshoring crisis                  |        |        |     |       |        |        |     |       |        |        |     |       |
| 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    | 1552   | 10  | 41,509| 344    | 1570   | 10  | 41,509| 409    | 1099   | 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     |
all the specifications, as concluded from the Wald test on the joint significance of the inverse Mill’s ratios (Wooldridge 1995), which indicate the necessity of such correction.

Finally, with regard to 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.

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; this gives 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 appears that R&D offshoring activities—instead of deterring the offshoring firms from innovating—allow them to increase their innovative performance, especially for those innovations that incorporate more novelty.

Consistent with previous studies, knowledge that is acquired from a different national innovation system brings a higher degree of novelty, which, combined with the internal knowledge, may lead to greater benefit.  

The results in columns (5) and (6) show that the influence of knowledge that comes from the foreign business sector is positive and highly significant in the case of LE, whereas the knowledge that comes from research centers or universities from abroad is not; this gives support to hypothesis 2.a. 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.  

Finally, but no less important, we examine how the current economic crisis is affecting the return that is 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

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15 We acknowledge the possibility of reverse causality, as detailed in Sect. 6.1.
16 We should also be aware that the share of firms that purchase technology from foreign research centers or universities is very small as compared with the share that purchase from the business sector (see also Gutiérrez Gracia et al. 2007).
17 We also run the regressions for a balanced panel for hypotheses 1–2, thereby trying to take into account a possible attrition problem; and the results barely change (the results are available from the authors on request). 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.
Table 4  Marginal effects of the first stage (sample selection)

| Variables                  | (2005)         | (2006)         | (2007)         | (2008)         | (2009)         | (2010)         | (2011)         | (2012)         | (2013)         |
|----------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| **Group**                  | 0.059***       | 0.045***       | 0.062***       | 0.074***       | 0.065***       | 0.067***       | 0.063***       | 0.056***       | 0.077***       |
|                           | (0.013)        | (0.012)        | (0.013)        | (0.013)        | (0.013)        | (0.014)        | (0.015)        | (0.015)        |                |
| **Market share**           | 1.010***       | 1.027***       | 1.183***       | 2.444***       | 2.060***       | 3.995***       | 3.262***       | 2.088***       | 1.824***       |
|                           | (0.333)        | (0.345)        | (0.408)        | (0.422)        | (0.467)        | (0.632)        | (0.569)        | (0.482)        | (0.517)        |
| **Risk obstacles**         | 0.198***       | 0.123***       | 0.104***       | 0.154***       | 0.129***       | 0.136***       | 0.166***       | 0.161***       | 0.201***       |
|                           | (0.025)        | (0.021)        | (0.023)        | (0.024)        | (0.024)        | (0.025)        | (0.026)        | (0.026)        | (0.028)        |
| **Cost obstacles**         | 0.117***       | 0.141***       | 0.178***       | 0.187***       | 0.174***       | 0.112***       | 0.087***       | 0.088***       | 0.104***       |
|                           | (0.024)        | (0.020)        | (0.023)        | (0.024)        | (0.024)        | (0.025)        | (0.025)        | (0.025)        |                |
| **Knowledge obstacles**    | 0.085***       | 0.143***       | 0.149***       | 0.161***       | 0.141***       | 0.208***       | 0.203***       | 0.208***       | 0.188***       |
|                           | (0.032)        | (0.027)        | (0.030)        | (0.031)        | (0.031)        | (0.032)        | (0.033)        | (0.034)        | (0.036)        |
| **Other obstacles**        | -0.440***      | -0.441***      | -0.469***      | -0.482***      | -0.491***      | -0.539***      | -0.505***      | -0.567***      | -0.554***      |
|                           | (0.022)        | (0.019)        | (0.021)        | (0.022)        | (0.022)        | (0.023)        | (0.024)        | (0.025)        | (0.026)        |
| **Size (in logs)**         | -0.001         | 0.003          | 0.010***       | 0.023***       | 0.031***       | 0.029***       | 0.046***       | 0.054***       | 0.056***       |
|                           | (0.005)        | (0.005)        | (0.005)        | (0.005)        | (0.005)        | (0.006)        | (0.006)        | (0.006)        |                |
| **Observations**           | 7720           | 9112           | 8629           | 8307           | 8167           | 7727           | 7517           | 7207           | 6868           |

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      | LEs       | SMEs      |
|                               | Incremental innovation | Innovation | Radical innovation | Innovation | Radical innovation | Innovation | Radical innovation | Innovation |
| Offshoring\(_{t-1}\) (in logs) | 0.035     | −0.008    | 0.059**   | 0.015     |           |           |           |           |
|                               | (0.026)   | (0.020)   | (0.024)   | (0.019)   |           |           |           |           |
| Offshoring public\(_{t-1}\) (in logs) |           |           |           |           | 0.093     | 0.037     |           |           |
|                               |           |           |           |           | (0.163)   | (0.098)   |           |           |
| Offshoring private\(_{t-1}\) (in logs) |           |           |           |           | 0.071**   | 0.030     |           |           |
|                               |           |           |           |           | (0.036)   | (0.030)   |           |           |
| Offshoring pre crisis\(_{t-1}\) (in logs) |           |           |           |           |           |           | 0.067*** | 0.047     |
|                               |           |           |           |           |           |           | (0.025)   | (0.034)   |
| Offshoring Crisis\(_{t-1}\) (in logs) |           |           |           |           |           |           | 0.014     | −0.002    |
|                               |           |           |           |           |           |           | (0.039)   | (0.033)   |
| Cooperation\(_{t-1}\)         | 0.358***  | 0.108     | 0.108     | 0.250***  | 0.111     | 0.250***  | 0.065     | 0.205*    |
|                               | (0.137)   | (0.094)   | (0.120)   | (0.078)   | (0.118)   | (0.078)   | (0.118)   | (0.105)   |
| Internal R&D\(_{t-1}\)        | −0.828    | 0.003     | 2.303**   | 1.284***  | 2.299**   | 1.277***  | 1.731     | 1.363***  |
|                               | (0.669)   | (0.186)   | (1.078)   | (0.189)   | (1.114)   | (0.188)   | (1.264)   | (0.348)   |
| Size\(_{t-1}\) (in logs)      | 0.157     | 0.495***  | 0.338*    | −0.024    | 0.336*    | −0.024    | −0.048    | 0.029     |
|                               | (0.207)   | (0.150)   | (0.199)   | (0.127)   | (0.182)   | (0.127)   | (0.314)   | (0.184)   |
| Permanent\(_{t-1}\)           | 0.417**   | 0.132     | 0.392**   | 0.396***  | 0.394**   | 0.396***  | 0.471***  | 0.209*    |
|                               | (0.185)   | (0.092)   | (0.157)   | (0.084)   | (0.157)   | (0.084)   | (0.170)   | (0.119)   |
Table 5 (continued)

| Variables          | (1)       | (2)       | (3)       | (4)       | (5)       | (6)       | (7)       | (8)       |
|--------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                    | LEs       | SMEs      | LEs       | SMEs      | LEs       | SMEs      | LEs       | SMEs      |
|                    | Incremental innovation | Incremental innovation | Radical innovation | Radical innovation | Radical innovation | Radical innovation | Radical innovation | Radical innovation |
| Openness$_{t-1}$  | 0.014     | 0.035**   | 0.031     | 0.059***  | 0.032     | 0.059***  | 0.042     | 0.045**   |
|                    | (0.031)   | (0.018)   | (0.025)   | (0.015)   | (0.028)   | (0.015)   | (0.043)   | (0.019)   |
| Demand pull$_{t-1}$ | 0.512*** | 0.217**   | 0.282**   | 0.333***  | 0.283**   | 0.333***  | 0.267**   | 0.350***   |
|                    | (0.156)   | (0.098)   | (0.128)   | (0.076)   | (0.131)   | (0.076)   | (0.134)   | (0.100)   |
| Constant           | −5.031*** | −7.242*** | −11.895*** | −7.199*** | −11.081*** | −6.764*** | −13.050*** | −7.593*** |
|                    | (1.156)   | (0.656)   | (1.009)   | (0.553)   | (1.708)   | (1.094)   | (1.520)   | (0.754)   |
| Observations       | 10.537    | 30.417    | 10.537    | 30.417    | 10.537    | 30.417    | 7018      | 15.177    |
| 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***  | 59.48***  |
| 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. Large enterprises (LEs) are those firms with more than 200 workers, while small and medium-sized enterprises (SMEs) are those firms with less or equal to 200 workers as determined in the PITEC.
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.

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 support to our hypothesis 3.b: The crisis implied a lower return from seeking new knowledge abroad.

With respect to the control variables, Table 5 also shows interesting results: With regard to cooperation with other organizations and internal R&D, the coefficients show 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 and Levinthal 1990).

We also find evidence of a positive relationship with firms’ size, so larger firms achieve better innovative performance (as in Bertrand and 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 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; we thereby can develop 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 and Wei

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18 The major issues reported include: 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 for the pre-crisis period is 2004–2008, while the crisis period is 2009–2013. The reasoning comes from the fact that the crisis started to show its impact in 2009 (Hud and Hussinger 2015).
We also try to use the growth rate of R&D offshoring at the firm level (Görg and 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 that are reported in Table 5; they change only marginally for the case of the offshoring variables. Despite not solving the problem, this points to a likely low impact of the potential reverse causality.

To check the external validity of our results—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 variable and the offshoring variables, as previously used in other papers:

First, we measure radical innovation as the share of sales that are due to products that are new to the market, without taking logs or performing any winsorizing processes. As shown in the second part of Table 6, most of the main results that are related to the offshoring of R&D hold; this presents a positive and significant impact of offshoring on radical innovation, as in the German case that is reported by Grimpe and Kaiser (2010).

Second, we use a dummy variable as a proxy for R&D offshoring (yes/no R&D offshoring), as is mostly done 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 of these cases the authors did not distinguish between radical and incremental innovation.

Finally, we perform two further sensitivity analyses: First, we test whether our second hypothesis is robust to the business cycle: 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 offshoring effect according to two time periods using an interaction term with a time dummy variable: before and during the crisis period for LEs and for SMEs (Table 7, columns 1 and 2). The results hold for LEs in the sense that the knowledge that is acquired from business organizations is more relevant to radical innovations than that from research institutions before the crisis; this is in line with our main results.

Second, we investigate whether the sectoral dimension plays any role when considering the impact of R&D offshoring. Specifically, given that a Chow test rejects only marginally the null hypothesis that manufacturing and services behave similarly, we include a dummy variable for those companies that belong to the service sector and cross it with the offshoring variables (Table 7 columns 3 to 6). The results

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19 We thank the editor for highlighting this point (results upon request from the authors).
Table 6 Robustness checks

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|
|           | LEs Incremental innovation | SMEs Incremental innovation | LEs Radical innovation | SMEs Radical innovation | LEs Radical innovation | SMEs Radical innovation | LEs Radical innovation | SMEs Radical innovation |
| Balanced Panel | | | | | | | | |
| Robustness check 1: Two lags of the offshoring variables | | | | | | | | |
| Offshoring \( t-2 \) (in logs) | 0.022 | −0.019 | 0.063** | 0.036* | | | | |
| | (0.027) | (0.023) | (0.027) | (0.021) | | | | |
| Offshoring public \( t-2 \) (in logs) | | | | | −0.120 | 0.059 | | |
| | | | | | (0.160) | (0.102) | | |
| Offshoring private \( t-2 \) (in logs) | | | | | 0.089** | 0.047 | | |
| | | | | | (0.040) | (0.031) | | |
| Offshoring pre crisis \( t-2 \) (in logs) | | | | | | | 0.045** | 0.029 |
| | | | | | | | (0.020) | (0.033) |
| Offshoring crisis \( t-2 \) (in logs) | | | | | | | 0.000 | 0.011 |
| | | | | | | | (0.046) | (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 |
| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|
| LEs       |     |     |     |     |     |     |     |     |
| SMEs      |     |     |     |     |     |     |     |     |
| Incremental innovation |     |     |     |     |     |     |     |     |
| Radical innovation |     |     |     |     |     |     |     |     |
| Time and sectoral dummy variables | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 8968 | 24,869 | 8968 | 24,869 | 8968 | 24,869 | 6296 | 13,671 |
| Robustness check 2: Changing the dependent variable (no winsorizing transformation) |     |     |     |     |     |     |     |     |
| Offshoring\(_{t-1}\) (in logs) | 0.085 | 0.006 | 0.200* | 0.161 |     |     |     |     |
|  | (0.146) | (0.114) | (0.121) | (0.115) |     |     |     |     |
| Offshoring pre crisis\(_{t-1}\) (in logs) | −0.012 | 0.499 |     |     |     |     |     |     |
|  | (0.636) | (0.544) |     |     |     |     |     |     |
| Offshoring private\(_{t-1}\) (in logs) | 0.295 | 0.283 |     |     |     |     |     |     |
|  | (0.192) | (0.179) |     |     |     |     |     |     |
| Offshoring public\(_{t-1}\) (in logs) |     |     |     |     |     |     |     |     |
|  |     |     |     |     |     |     |     |     |

**Note:** The table continues with additional columns for Robustness check 2: Changing the dependent variable (no winsorizing transformation).
### Table 6 (continued)

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|
| LEs       |     |     |     |     |     |     |     |     |
| SMEs      |     |     |     |     |     |     |     |     |
| Incremental innovation |     |     |     |     |     |     |     |     |
| Radical innovation |     |     |     |     |     |     |     |     |
| LEs       |     |     |     |     |     |     |     |     |
| SMEs      |     |     |     |     |     |     |     |     |
| Incremental innovation |     |     |     |     |     |     |     |     |
| Radical innovation |     |     |     |     |     |     |     |     |
| Offshoring crisis<sub>-1</sub> (in logs) | | 0.116 | 0.155 | | | | | |
| Offshoring crisis<sub>-1</sub> (in logs) | | (0.199) | (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 | 7018 | 15,577 |
| Robustness check 3: Offshoring as a dummy variable | | | | | | | | |
| Offshoring<sub>-1</sub> public | 0.097 | −0.048 | 0.322** | 0.029 | | | | |
| Offshoring<sub>-1</sub> public | (0.139) | (0.120) | (0.133) | (0.117) | | | | |
| Offshoring<sub>-1</sub> private | −0.168 | −0.018 | | | | | | |
| Offshoring<sub>-1</sub> private | (0.273) | (0.391) | | | | | | |
| Offshoring<sub>-1</sub> private | 0.321** | 0.053 | | | | | | |
| Offshoring<sub>-1</sub> private | (0.142) | (0.092) | | | | | |
| Variables | (1)      | (2)      | (3)      | (4)      | (5)      | (6)      | (7)      | (8)      |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Offshoring pre crisis, t−1 | 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 crisis, t−1 | 0.416*   | 0.108    | (0.231)  | (0.194)  | 0.147    | −0.052   | (0.203)  | (0.194)  |
| Controls | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      |
| Mill ratios | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      |
| Means fixed effects | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      |
| Time and sectoral dummy variables | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      | Yes      |
| Observations | 10,537  | 30,417  | 10,537  | 30,417  | 10,537  | 30,417  | 7018  | 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 winsorizing process (from 0 to 100). ***\(p<0.01\); **\(p<0.05\); *\(p<0.1\). Large enterprises (LEs) are those firms with more than 200 workers, while small and medium-sized enterprises (SMEs) are those firms with less or equal to 200 workers as determined in the PITEC.
| Variables                                      | (1) LEs | (2) SMEs | (3) | (4) | (5) | (6) Balanced panel |
|------------------------------------------------|---------|----------|-----|-----|-----|-------------------|
| Radical innovation                            |         |          |     |     |     |                   |
| Radical innovation (in logs)                   | 0.314   | 0.162    |     |     |     |                   |
|                                               | (0.192) | (0.119)  |     |     |     |                   |
| Incremental innovation                         |         |          |     |     |     |                   |
| Incremental innovation (in logs)               | −0.423  | −0.166   |     |     |     |                   |
|                                               | (0.329) | (0.127)  |     |     |     |                   |
| Radical innovation                            |         |          |     |     |     |                   |
| Radical innovation (in logs)                   | 0.091*  | 0.034    |     |     |     |                   |
|                                               | (0.046) | (0.032)  |     |     |     |                   |
| Radical innovation                            |         |          |     |     |     |                   |
| Radical innovation (in logs)                   | 0.052   | 0.032    |     |     |     |                   |
|                                               | (0.060) | (0.046)  |     |     |     |                   |
| Services (dummy variable)                      |         |          |     |     |     |                   |
| Services (dummy variable) (in logs)            | −1.293*** | 1.112*** | 3.692*** | 0.480 * |       |
|                                               | (0.443) | (0.398)  | (1.700) | (0.663) |       |
| Offshoring (_t−1 in logs)*services (dummy variable) | −0.029 | 0.131*** |     |     |     |                   |
|                                               | (0.038) | (0.033)  |     |     |     |                   |
Table 7 (continued)

| Variables                               | (1) LEs | (2) SMEs | (3) Radical innovation | (4) Incremental innovation | (5) Radical innovation | (6) Balanced panel |
|-----------------------------------------|---------|----------|-------------------------|---------------------------|------------------------|-------------------|
| Offshoring public_{t-1} (in logs) * services (dummy variable) | 0.140   | 0.256*** | 0.189***                | 0.213***                 | 0.214***               | 0.165***          |
|                                         | (0.127) | (0.080)  | (0.073)                 | (0.073)                  | (0.073)                | (0.083)           |
| Offshoring private_{t-1} (in logs) * services (dummy variable) | 2.240** | 1.291*** | -0.004                  | 1.418***                 | 1.415***               | 1.568***          |
|                                         | (1.007) | (0.198)  | (0.162)                 | (0.188)                  | (0.188)                | (0.320)           |
| Offshoring Pre crisis_{t-1} (in logs) * services (dummy variable) | 0.323*  | -0.010   | 0.345***                | 0.180*                   | 0.180*                 | 0.171             |
|                                         | (0.191) | (0.130)  | (0.105)                 | (0.103)                  | (0.103)                | (0.167)           |
| Offshoring crisis_{t-1} (in logs) * services (dummy variable) | 0.476***| 0.484*** | 0.192***                | 0.403***                 | 0.404***               | 0.275***          |
|                                         | (0.160) | (0.080)  | (0.083)                 | (0.070)                  | (0.070)                | (0.099)           |
| Cooperation_{t-1}                        | 0.044*  | 0.069*** | 0.034**                 | 0.051***                 | 0.051***               | 0.041***          |
|                                         | (0.023) | (0.016)  | (0.016)                 | (0.013)                  | (0.013)                | (0.015)           |
| Permanent_{t-1}                          | 0.304** | 0.375*** | 0.295***                | 0.318***                 | 0.318***               | 0.332***          |
Table 7 (continued)

| Variables                        | (1) LEs | (2) SMEs | (3) | (4) | (5) | (6) Balanced panel |
|----------------------------------|---------|----------|-----|-----|-----|-------------------|
|                                  | Radical innovation | Radical innovation | Incremental innovation | Radical innovation | Radical innovation | Radical innovation |
| Constant                         | 0.118   | 0.084    | 0.085 | 0.067 | 0.067 | 0.082             |
|                                  | (2.040) | (1.285)  | (0.450) | (0.424) | (0.944) | (0.579)           |
| Observations                     | 10,411  | 30,052   | 40,954 | 40,954 | 40,954 | 22,595           |
| R-squared                        | 0.133   | 0.106    | 0.040 | 0.102 | 0.102 | 0.137             |
| Test F lambda                    | 44.62***| 78.28*** | 145.9*** | 89.75*** | 89.67*** | 81.66***         |
| Wald test mean values (Mundlak)  | 208.2***| 661.5*** | 211*** | 790*** | 789.9*** | 665.3***         |
| Wald test sectoral dummy variables| 203.5***| 1064***  | 373.5*** | 584.1*** | 585.2*** | 628.6***         |
| Wald test time dummy variables   | 7.210   | 67.29*** | 19.86** | 56.43*** | 56.57*** | 21.64***         |

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-sized enterprises (SMEs) are those firms with less or equal to 200 workers as determined in the PITEC.
point to a higher impact of R&D offshoring in the service sector than for manufacturing enterprises.

Among other reasons, we could think that developed economies are making a fast transition to deindustrialization and giving more weight to service firms. There are also some studies that point 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 and Lampert 2001), such as knowledge 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 that comes from a foreign country on the innovations that incorporate more novelty in the market (known as radical innovations). Second, we consider the success that follows 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, we study the heterogeneity in the returns to R&D offshoring depending on the technological differences of the agent from which the knowledge is obtained: either a business organization (market oriented) or a research institution (knowledge-base oriented).

The evidence provided for Spanish firms from 2004 to 2013 indicates that R&D offshoring has a significant and positive influence on 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 and 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 that engage 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. This could be due to the complementary relationship between internal and external expenditures on innovation in the Spanish case, as pointed out by Añón Higón et al. (2014).

Finally, we empirically study the differences between LEs and SMEs with respect to the impact of R&D offshoring on the innovative performance of the firm. Our results indicate that LEs obtain the most benefit from seeking knowledge from abroad. Following the arguments of Di Gregorio et al. (2008) and Nieto and Rodríguez (2011), LEs have greater financial, technological, and internal resources, so they are more able to implement and recombine the knowledge from abroad, while they face less risk of appropriation, information asymmetry, and opportunism, and therefore profit more from such knowledge.

Several implications for policy makers follow: First, policy makers should focus less on innovation agreements between national firms and public research institutions; at least, these agreements should not be encouraged at all costs. Instead, firms should also be helped to gain access to foreign knowledge.

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 that was devoted to R&D, which resulted in a decrease in the funds that were 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 that has been found in many papers (Añón Higón et al. 2014; Cassiman and 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.

8 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: We argued for the existence of differences in the knowledge that comes 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 an absence of different categories of R&D offshoring in the data—such as R&D, design, and marketing, among others—that might 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

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20 Not only the number of enterprises but also the amount of money that is allocated to this strategy has been reduced among those enterprises that conducted R&D offshoring throughout the entire period.
whether location in one region or another could imply a different influence of the R&D offshoring strategies that are followed by firms.

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

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