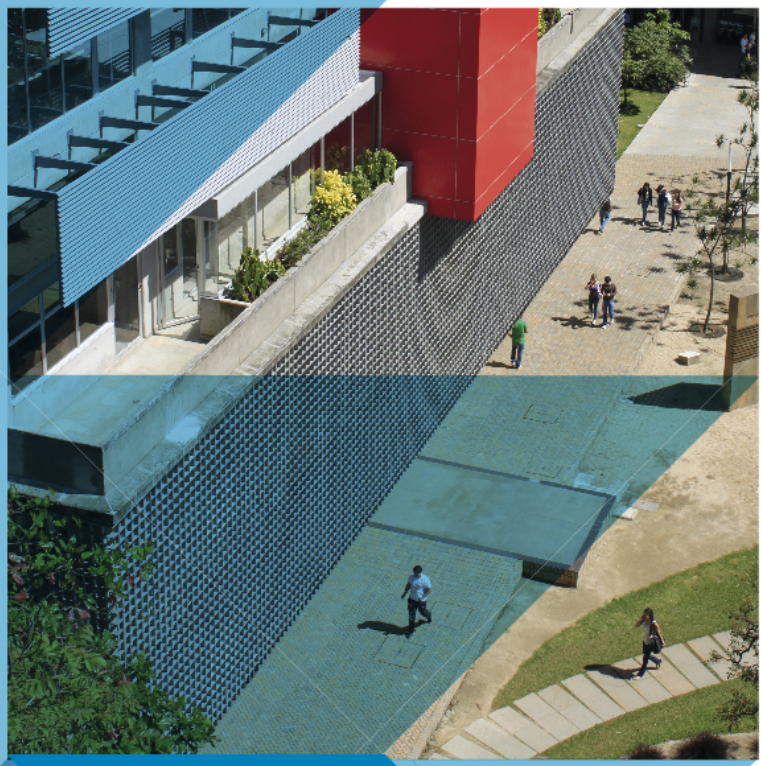

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Determinants of internal versus external R&D offshoring: Evidence from Spanish firms

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Abstract

This paper analyzes the determinants of R&D offshoring of Spanish firms using information from the Panel of Technological Innovation. We find that being an exporter, continuous R&D engagement, applying for patents, being a subsidiary, and firm size are factors that positively affect the decision to offshore R&D. In addition, we obtain that the factors that influence this decision for firms that belong to a business group differ depending on whether the firm purchases R&D services within the group or through the market: the lack of information is an obstacle relatively less important for internal R&D offshoring than for external R&D offshoring, while a higher degree of importance assigned to institutional and market sources of information for innovation as compared to internal sources increases the probability of R&D offshoring through the market.

JEL Classification: L24, O32.

Key words: R&D offshoring, firms' strategies, obstacles to innovation, independent firms, subsidiaries.

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1. Introduction

As Jensen (2009) points out, over the last decade, the offshoring of manufactures has taken a back seat to that of services, since demand has grown substantially for more advanced services in technical and administrative areas. Aspects such as the liberalization of trade, economic and regulatory reforms, and technological advances in communication, digitalization, and the new commercialization of certain goods are behind this change.

An important proportion of these exchanges of knowledge-intensive services corresponds to R&D offshoring. For instance, the National Science Foundation (NSF) (2010) reports that, in the United States**,** there has been a rise of R&D imports of around 23% p.a. during the last decade. In parallel, the empirical literature about the determinants of R&D offshoring at the firm level has also grown.[1]

For this analysis, it is important to remember that the concept of R&D offshoring includes international outsourcing of R&D services, as well as R&D purchases consisting of technology transactions within a group (internal or captive offshoring). More specifically, within this concept of offshoring, we can also consider the purchases of R&D services that firms located in Spain make from other firms in their same group, but which are located abroad.

Why could we expect a different behavior between independent single firms and companies in business groups? Previous empirical literature gathers evidence about a different propensity to offshore R&D services between these two groups of firms. In their analysis of a sample of French manufacturing firms from 1993 to 2001, Jabbour and Zuniga (2009) show that

[1] Some recent examples are the analyses made by Jabbour and Zuniga (2009), García-Vega and Huergo (2011), Martínez-Noya et al. (2012) and Holl and Rama (2014).

individual firms appear to be more active in international R&D outsourcing than firms that belong to business groups.

Holl and Rama (2014) compare the technology sourcing via R&D outsourcing, R&D outsourceoffshoring, domestic cooperation for innovation and international cooperation forinnovation, distinguishing between foreign subsidiaries and national firms. Their results for a sample of Spanish firms suggest not only that these choices are interdependent, but also that the behavior of foreign subsidiaries is different. In comparison with national subsidiaries, foreign subsidiaries show less propensity towards national R&D outsourcing, as well as towards R&D offshoring.

In addition, there is also evidence of a different effect from these two governance modes - captive R&D offshoring and offshore R&D outsourcing on firms' performance. García-Vega and Huergo (2013) find that subsidiaries of foreign multinational firms which acquire R&D services through the group are more innovative than the average innovative Spanish firm.

Also for Spanish companies, Nieto and Rodríguez (2011, 2013) obtain that, although both models of offshoring are positively related to innovation results and productivity, the impact of captive offshoring on innovation outperforms the impact of offshore outsourcing. In addition, they find that offshoring also has a positive and indirect impact on productivity through innovation, and that this indirect effect is greater in captive offshoring than in international outsourcing. All of this leads us to expect a different behavior from foreign subsidiaries in relation to domestic independent firms.

In this paper, we explore the determinants of R&D offshoring for innovative Spanish firms using information from the Technological Innovation Panel (Panel de Innovación Tecnológi-

ca, henceforth referred to using its Spanish acronym PITEC). The paper aims to contribute to this literature by analyzing whether the choice of the governance mode for R&D offshoring is driven by different determinants in the case of firms belonging to business groups in comparison with individual independent firms.

Our results confirm previous empirical literature about the determinants of R&D offshoring: being an exporting firm, continuous R&D engagement, applying for patents, being a subsidiary, and firm size increase the probability of offshoring. In addition, we find that the factors that influence the decision to offshore R&D for firms that belong to a business group differ depending on whether the firm purchases the R&D services within the group or through the market: a lack of financing negatively affects firms that offshore R&D exclusively within the group, while a lack of information reduces the probability of undertaking R&D offshoring only with suppliers outside the group.

2. R&D offshoring strategies: firms' motives and determinants

The reasons why companies decide to carry out outsourcing or offshoring activities have been frequently analyzed in economic literature. They are basically associated with a reduction of costs and risks, with an increase in organizational flexibility, which allows a quicker adaptation to changing market needs, or with the generation of competitive advantages, freeing internal resources that can be engaged in core business activities.

However, these activities also entail disadvantages. In this regard, transaction cost theory, agency theory and the resource-based view are the approaches most used in the literature to explain why companies decide to outsource part of their production.

According to Coase (1937) and Williamson (1975, 1979, and 1981), the decision to internalize certain transactions or make them through the market depends on their costs, which may be associated with search costs, selection costs, bargaining costs and coordinating work. The higher these transaction costs are, the greater the propensity of firms to perform activities internally is, while they will outsource more insofar as transaction costs decrease.

From the agency theory perspective, the principal will try to establish the contract that best guarantees the optimal effort of the agent. This obviously implies agency costs associated with monitoring and evaluation, as opportunism is an important risk factor in an outsourcing contract (Aubert et al., 1998).

Consistent with the resource-based view, a need for access to complementary resources or capabilities that are not available within the companywill be behind the outsourcing decision (Peteraf, 1993; Argyres, 1996). In the particular case of R&D outsourcing, firms would benefit from the investments, innovations and specialized professional skills of external suppliers (Anagnostou and Carthy, 2004).

To these arguments, we have to add the factors that influence the international dimension of offshoring. Regardless of thegovernance mode (through the group or through the market), one of the reasons to offshore may be the reduction of costs, especially labour costs, if tasks are outsourced in countries where wages are lower. Other reasons may be the intent to follow a growth strategy, competitive pressure or access to qualified personnel (Lewin and Peeters, 2006).

As for the specific case of R&D offshoring, according to Martínez-Noya et al. (2012), the determinants of international R&D outsourcing would be related to both the international ex-

perience of the company and its skills and technological resources. The firm's experience in international markets would reduce the costs of search and selection of suitable foreign suppliers. In addition, we could expect that, by selling to a larger market, exporters decrease their financial constraints, making international outsourcing relatively less costly for them (García-Vega and Huergo, 2011). The studies by Jabbour and Zuniga (2009), García-Vega and Huergo (2011), and Holl and Rama (2014) gather clear evidence of the positive relation between the exporting character of firms and international R&D outsourcing.

Furthermore, although greater internal capabilities can make international outsourcing less necessary, because of the complexity of the innovation process, firms could find it more efficient to outsource non-core parts of this process in foreign countries where they have leading or cheaper suppliers.This strategy would help companies to reduce their operating costs, achieving a greater focus on their core competencies (Anagnostou and Carthy, 2004). In addition, internal resources and capabilities can increase firms' absorptive capacities of foreign knowledge, stimulating the complementarity between internal and external R&D (Cassiman and Veugelers 2006; Goyal et al. 2008).

One of these internal resources is qualified employment. Representatives of the theory of human capital (Hamermesh, 1980, 1993; Kremer, 1993; Dunne and Schmitz, 1995) highlight the complementarity between physical and human capital, the advantages derived from grouping qualified workers with other qualified workers, and the improved capacity to amortize fixed costs associated with hiring qualified workers. For this reason, it seems logical to think that firms' employment in internal R&D activities would be complementary to R&D offshoring.

In the same line, it is also expected that obstacles to innovation have a negative effect on the decision to invest in technological activities and, therefore, on the decision to offshore R&D (Garcia and Huergo, 2011). According to Chaney (2013), when faced with fixed costs associated with exporting and liquidity restrictions, for some firms it would be profitable to export, but they decide not to because of thedoubts that they have that liquidity is not enough. Something similar may occur with the offshoring of R&D services if the search for foreign suppliers generates sunk costs that increase in a context of financial constraints or lack of information.

To summarize, according to previous literature, the more international experience and technological resources and capabilities the firm possesses, the more likely it will outsource R&D services internationally compared to other sourcing strategies.

However, we might think that the intensity of these relationships may differ between individual firms and companies that belong to business groups. In the latter case, companies not only have the option of performing international R&D outsourcing, but also internal captive offshoring, i.e., outsourcing part of the production process in companies from the same group located abroad. In addition, firms in groups and especially multinationals can benefit from the resources and capabilities of the group and tend to perceive obstacles to innovation as significantly less relevant than independent firms (Iammarino et al., 2009). Therefore, we propose the following hypothesis:

Hypothesis 1: When companies decide to offshore R&D services, a lack of financing is an obstacle relatively more important for independent firms than for firms belonging to business groups.

Moreover, in the case of firms in groups, we can wonder what leads the selection of the governance model, or why they sometimes choose a combination of both channels (internal and external). A first explanation is related to technology leakage. External R&D offshoring implies higher risks in situations of imperfect contracts, hold-up problems, and cultural differences (e.g., Baccara, 2007, Lai et al., 2009, Ornelas and Turner, 2008), making firms more sensitive to a lack of information.In this context, companies can be prone to offshoring through the group, avoiding exposure to subcontractors, especially in countries with poor intellectual property rights (García-Vega and Huergo, 2011). On the basis of this argument, the following hypothesis is put forward:

Hypothesis 2:In the case of firms belonging to business groups, a lack of information is an obstacle relatively more important for external R&D offshoring than for internal R&D offshoring.

For the same reason, we can expect that the selection of the offshoring channel depends on the relevance that companies allocate to internal sources of information in order to innovate as compared to institutional and market sources of information. This leads to formulating the following hypothesis:

Hypothesis 3: Firms belonging to business groups that find institutional and market sources of information for innovation very relevant compared to internal sources of information are more likely to offshore R&D services through the market.

3. Database

Our empirical analysis is done with the information provided in the Panel of Innovation Technology (PITEC), from 2004 to 2010. The PITEC is a statistical database created in the

format of panel data and the result of the joint effort by the Spanish Foundation for Science and Technology (FECYT), the National Institute of Statistics (INE), and the Cotec Foundation along with assessment by a group of academic experts. Its goal is to facilitate the monitoring of technological innovation activities by Spanish firms[2].

The panel is selected on the basis of two national surveys carried out by the INE in the innovation sector: "Survey on Technological Innovation of Firms" (the Spanish version of the Community Innovation Survey) and "Statistics on R&D Activities". The PITEC was started in the year 2003 with two representative samples: a sample of firms with 200 or more workers (with an estimated representation of 73%) and a sample of companies with internal R&D expenditures. In 2004, the panel was expanded to include a sample of firms with fewer than 200 employees and external expenditures on R&D but no internal R&D, and a representative subsample of firms with fewer than 200 workers and no innovation expenditures.

Although the PITEC includes a sample of firms that do not undertake technological activities, given the objective of this study, we focus the analysis on the sample of innovative firms, that is, firms that have positive innovation expenditures during the period. There are, on average, around 7,500 companies with innovation expenditures in the PITEC each year. Overall, our final sample consists of an unbalanced panel of 31,425 observations, 12,659 of which correspond to companies that belong to a business group.

In the PITEC, companies answer questions related to the R&D done within the firm (internal R&D) or outside the firm through a contract or an agreement (external R&D). They also spe-

[2]The PITEC is publicly available to researchers at: http://icono.fecyt.es/PITEC/Paginas/por_que.aspx. The files accessible on this site correspond to the files maintained by INE, except for the "anonymization" of a series of variables so thatcorresponding firms cannot be identified. López (2011) shows that the expected biases due to this anonymization are small through the comparison of regressions that use original and harmonized data alternatively.

cify whether the purchase of services takes place in Spain or abroad, and whether the suppliers are firms from the same group, firms outside the group, public institutions, universities, etc. With this in mind, we will use the term R&D offshoring for purchases of R&D services abroad, regardless of the provider's location.

Most firms in our sample do not offshore R&D; only around 7% are R&D offshorers. This percentage is constant throughout the time period. As we mentioned in the introduction, it is important to differentiate between the following two cases: when suppliers are firms from the same business group, and when purchases are made from the market; in other words, when suppliers are firms outside the group, public research centers, universities, etc.

In Table 1, we see the number of observations that correspond to firms from the PITEC that offshore R&D and whether or not these firms belong to a group, specifying whether the suppliers of R&D services are firms from the group or other firms and institutions. It is obvious that independent firms can only acquire R&D services outside the group. On the other hand, note that even in multinational firms, the majority of offshoring consists of suppliers outside the group and in only a small percentage of cases (9.2%) do firms combine suppliers of both types.

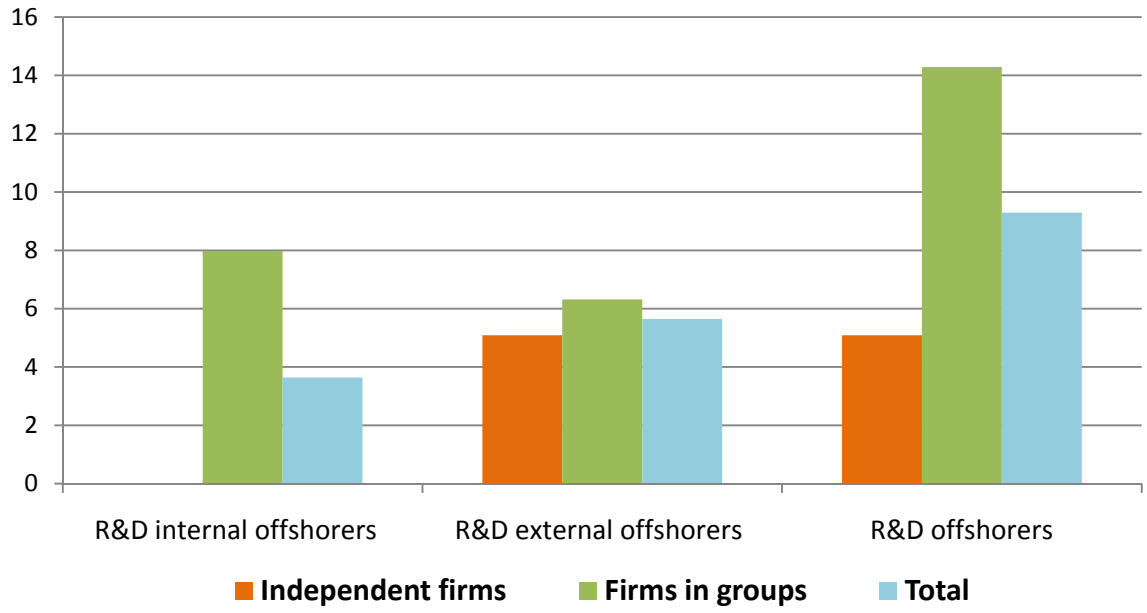
Table 1. R&D offshoring in the PITEC
(Number of observations in the sample)

	R&D offshoring			
	Internal offshoring	**External offshoring**	**Internal and external offshoring[a)]**	**Total**
Independent firms	0	1,053	0	1,053
	(0.0)	(100.0)	(0.0)	
Firms in groups	955	1,405	199	2,160
	(44.2)	(65.0)	(9.2)	
Total	955	2.458	199	3,214
	(29.7)	(76.5)	(6.2)	

Note: Percentages over the total of each row are shown in parentheses. a) This column is included in the previous ones.

As for the intensity of R&D offshoring (defined as the percentage of R&D purchases from foreign providers over the total amount of R&D purchases), in Figure 1 we can see that, regardless of whether the firm has a group, offshorers tend to combine foreign purchases with purchases in Spain. Nevertheless, the percentage of imports is higher in firms that belong to a group.

Figure 1. R&D offshoring intensity
(Percentage of R&D imports of the total amount of R&D purchases)



Note: Percentage calculated for offshorers with corresponding purchases.

Moreover, it is worth mentioning that the intensity of external R&D outsourcing is also higher in firms in groups, which would at first seem to contradict the findings put forward by Jabbour and Zuniga (2009) for a sample of French firms from 1993 to 2001, according to which individual firms were the most active in international R&D outsourcing. This is one of the issues which will be more deeply analyzed in this paper.

4. Empirical model and variables

To analyze the determinants of R&D offshoring, we estimate two different types of specifications. First, we turn our attention to the factors that affect this activity for the whole sample of innovative firms. The analysis refers to the extensive margin (the decision to offshore) as well as to the intensive margin (the magnitude of the purchases of R&D services).[3] This study is done through the estimation of a Heckman or generalized Tobit model, where two equations are estimated simultaneously for maximum likelihood. The first equation refers to the firm's decision to buy R&D services abroad (selection equation), while the second refers to the intensity with which purchases are made (intensity equation).

More formally, the model is the following: the intensity of R&D offshoring of firm *i* in the year *t* is described by using the latent variable oss_{it}^{*} :

$$oss_{it}^{*} = z_{it}'\beta + e_{it},$$

where z_{it} is a vector of determinants for R&D offshoring intensity that is measured as the percentage that purchases of R&D services abroad represent in the total amount of R&D service purchases.

However, this intensity is only observed if the firm decides to import R&D services. The selection equation is expressed by the following equation:

$$doss_{it} \begin{cases} = 1 & \text{if } \pi oss_{it}^{*} = F(X_{it}^{'}b + u_{it}) > 0 \\ = 0 & \text{otherwise} \end{cases},$$

[3] As Markusen (2005) suggests, although liberalization allows the trade volume of already-existing products to expand (intensive margin), the increase in service offshoring is also related to the expansion of trade in the extensive margin, since new tasks can be commercialized because of innovation in communication and technology.

where $doss_{it}$ represents the decision of firm *i* in the year *t* to buy R&D services abroad as a binary variable that takes the value of 1 when the firm does R&D offshoring and 0 otherwise, πoss^{*} is a latent variable that can be interpreted as expected benefits of that decision, *X* is the vector of explanatory variables and *u* is the error term.

Conditioned on whether the firm imports R&D services, we can observe the intensity of this activity:

$$oss_{it} = \begin{cases} oss_{it}^{*} = z_{it}'\beta + e_{it} & \text{if} \quad doss_{it} = 1 \\ 0 & \text{if} \quad doss_{it} = 0 \end{cases},$$

where we assume that the error terms *u* and *e* follow a bivariate normal distribution with mean zero, $\sigma_U = 1$ and σ_e, and coefficient of correlation rho. Notice that in this case we do not distinguish between internal and external R&D offshoring.

Secondly, we focus on the subsample of firms that belong to business groups and that therefore can purchase R&D services through two different (non-exclusive) channels: from other companies in the group or from the market (firms or institutions outside the group). As observed when analyzing the distribution of R&D offshorers, only a small percentage of firms that belong to a business group undertake both internal and external R&D offshoring, while the majority choose a single channel when they make purchases of foreign R&D.

As a way to further explore the behavior of firms that belong to a group, a bivariate Probit or Biprobit model is estimated. This allows us to gain a better understanding of the elements that lead firms to choose different channels at the moment of offshoring R&D. Just as Greene (2003) suggests, the bivariate Probit model is an extension of the multi-equational models of classical regression, in which a system of equations where errors are correlated is

considered. According to Zellner and Huang (1962), taking into account the correlation between the perturbations, one may obtain more efficient estimations than if each equation is estimated separately.

For the specific case of internal and external R&D offshoring, the specification of the biprobit model is the following:

$$doss_{it}^{I} = \begin{cases} 1 & \text{if } \pi oss_{it}^{I*} = w_{it}' b_1 + \mu_{1it} > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$doss_{it}^{E} = \begin{cases} 1 & \text{if } \pi oss_{it}^{E*} = w_{it}' b_2 + \mu_{2it} > 0 \\ 0 & \text{otherwise} \end{cases}$$

where $doss_{it}^{I}$ and $doss_{it}^{E}$ represent the decisions by firm *i* in year *t* to undertake internal or external R&D offshoring, respectively, with both variables as a binary that takes the value 1 when the firm does R&D offshoring and 0 otherwise. The vector *w* corresponds to the explanatory variables related to the characteristics of the country of origin and to the specific characteristics of the firm. The error terms of these equations follow a normal distribution with $E[\mu_{1it}] = E[\mu_{2it}] = 0$, $Var[\mu_{1it}] = Var[\mu_{2it}] = 1$ and $Cov[\mu_{1it}, \mu_{2it}] = \rho_{IE}$.

In both models, the choice of independent variables follows previous literature on the determinants of R&D strategies described in Section 2. In particular, we classify the main explanatory variables in two groups according to whether they are related to the firm's international experience or to its technological resources and capabilities. The main statistics that describe these variables can be found in Table 2.

The indicator of international experience most used in this context is the exporting character of the firm. In this line, we use a dummy variable that indicates whether the firm exports in

the current year. In order to avoid problems of simultaneity, this variable is included in the estimations lagged one period. As can be seen in Table 2, the difference of means test shows that international experience is higher among firms that belong to business groups.

Table 2. Descriptive statistics of main variables

Variables	All Firms	Firms in groups	Independent Firms	Difference of means test	
				t-test	*p-value*
R&D offshoring (in logarithms)	0.76	1.36	0.37	-32.8	0.000
R&D offshorer[d]	0.07	0.11	0.034	-33.8	0.000
R&D offshorer from the market (external offshorer)[d]	0.05	0.74	0.036	-18.8	0.000
R&D offshorer within the group (internal offshorer)[d]	0.02	0.50	0.00	-38.9	0.000
R&D offshoring from the market (in logarithms)	0.56	0.84	0.37	-19.1	0.000
R&D offshoring within the group (in logarithms)	0.25	0.63	0.00	-31.3	0.000
International experience					
Exporter (t-1)[d]	0.59	0.65	0.53	-23.4	0.000
Technological resources and capabilities					
R&D employment (number of employees)	18.71	12.65	22.60	44.6	0.000
Continuous R&D engagement[d]	0.78	0.82	0.74	-17.9	0.000
Patent applicant[d]	0.17	0.19	0.15	-9.5	0.000
Obstacles to innovation:					
- Lack of financing	1.84	1.67	1.94	33.4	0.000
- Lack of information	1.24	1.17	1.28	14.9	0.000
Size (in logarithms)	4.12	5.04	3.51	-120.0	0.000
Size squared (in logarithms)	19.33	27.76	13.89	-110.0	0.000
Medium and high-technology manufacturing[d]	0.33	0.35	0.32	-6.7	0.000
Medium and high-technology services[d]	0.14	0.10	0.16	16.6	0.000
Sources of information for innovation:					
- Institutional sources[d]	0.18	0.17	0.19	3.2	0.0015
- Market sources[d]	0.54	0.54	0.54	0.6	0.554
- Internal sources[d]	0.41	0.42	0.41	-2.2	0.025
Foreign subsidiary[d]	0.08	0.20	0.00	-80.6	0.000

Notes: d= dummy variable. (t-1) indicates that the variable is lagged one period.*t-test* denotes the difference of meanstest between independent firms and firms in groups. The contrast corresponds to the Wilcoxon rank-sum test (Mann-Whitney) for discrete variables.

To measure a firm's technological resources and capabilities, we use a wide range of indicators. Firstly, we take into account the firm's *R&D employment*. The information in the PITEC allows us to distinguish what part of a firm's total employment corresponds to R&D re-

searchers. The term researcher refers specifically to professionals who work on the creation of new concepts, products or processes, methods and systems, and on the management of their respective projects.

Secondly, in the database, firms declare whether they have performed *continuous R&D activities* and whether they have been *patent applicants* in the last three years. With this information, we have created two dummy variables that take the value 1 if, respectively, the firm engages in R&D continuously or if it has applied for patents in the current year or in the previous two years.

Thirdly, the PITEC allows us to consider the lack of financing and the lack of information as factors that hinder innovation. The lack of financing is associated with the lack of a firm's own funds, the lack of external financing, and innovation costs. In the survey, firms value each of these factors on a scale of 0-3 (irrelevant, low importance, medium importance, or high importance), the average of the factors serving as an indicator of lack of financing. As for lack of information, two aspects are taken into consideration: a lack of information about technology and a lack of information about markets. The way to quantify them is the same as in the previous case.

Fourthly, in the survey, firms declare the importance of institutional, internal, and market sources in order to innovate. From these sources, they gain information for new innovative projects or to complete ongoing innovative projects. Institutional sources concern universities or other higher education centers, from public research bodies or from technology centers. Sources from the market refer to whether the information was obtained from suppliers of equipment, material, components or software, from clients, competitors or other firms from the same branch of activity, or by consultants, commercial laboratories or private R&D

institutions. And internal sources refer to whether the information comes from the same firm or from the business group. In the PITEC, firms indicate whether these sources of information have high, medium, or low importance, or no importance at all. Based on the answers, we assign for each of the three types of sources a dummy variable which takes the value 1 if the evaluation given by the firm for that source type is high, and zero otherwise.

Finally, we also consider the firm that belongs to a *sector of medium-high technology* according to the NACE-2009 classification, and firm *size* (measured as the logarithm of the number of workers).

Several authors have analyzed the relation between firm size and technological inputs. As for offshoring strategy, traditionally we might think that large firms find providers abroad more easily, especially with regard to manufacturing activities. However, given the technological developments of the last few decades, searching costs have decreased, benefiting both large and small companies.

Chen and Sen (2012) propose that the effect of scale economies can drive both integrated and disintegrated downstream firms to offshore intermediate goods. In a context of economies of scale in upstream production, a disintegrated downstream firm would tend to purchase intermediate goods from a pure offshore provider rather than its vertically integrated rival. And a vertically integrated firm would also outsource offshore because of the incentive to exploit scale economies.

From the empirical point of view, the evidence about the link between firm size and R&D offshoring is not conclusive. For example, Chang and Robin (2006) confirm that firm size is a key variable for explaining R&D intensity and technology imports in Taiwanese manufactur-

ing firms, following the pattern of an inverted U. For Japanese firms, Hideo and Sadao (2011) find that a larger company tends to generate more patents from a research project but not more valuable patents, concluding that the main source of such a scale economy is not internal knowledge inflow but the "appropriation advantage" of a large firm.

Notice that, in general, in our sample, our indicators of firms' technological resources and capabilities show a greater average for firms in business groups. The remarkable exceptions are *R&D employment* and *public sources of information*, which are statistically higher in independent domestic companies.

Lastly, given the specific objective of this paper, in the estimates for the whole sample, we identify foreign subsidiaries through a dummy variable which takes the value 1 if the firm is a private *subsidiary* with at least 50% participation of foreign capital.

5. Results

As we have explained before, to analyze the determinants of R&D offshoring, we estimate two different types of specifications. Firstly, we estimate a generalized Tobit model for the intensity of this activity. Secondly, we use a Biprobit model to focus on the subsample of firms that belong to business groups and that therefore can purchase R&D services through two different channels: from other companies in the group (internal offshoring) or from the market (external offshoring).

The results for the generalized Tobit model are reported in Table 3.As for the decision to undertake R&D offshoring (selection equation), being an exporter, continuous R&D engagement, R&D employment, applying for patents, and institutional and market sources of information have a positive impact.

Table 3. Determinants of R&D offshoring (generalized Tobit model). All firms

	Propensity to offshore R&D $\Pr(doss)=1$	Intensity of R&D offshoring
International experience		
Exporter (t-1)	0.028***	0.051
	(0.003)	(0.095)
Technical resources & capabilities		
R&D employment	0.001***	0.013***
	(0.000)	(0.002)
Continuous R&D engagement	0.023***	
	(0.003)	
Patent applicant	0.039***	0.218***
	(0.004)	(0.083)
Obstacles to innovation:		
- Lack of finance	-0.002	-0.036
	(0.002)	(0.049)
- Lack of information	-0.004**	-0.170***
	(0.002)	(0.055)
Size	0.052***	0.506***
	(0.004)	(0.136)
Size squared	-0.003***	0.014
	(0.000)	(0.013)
Medium & high-tech manufact.	0.016***	0.384***
	(0.003)	(0.085)
Medium & high-tech services	-0.008**	0.368***
	(0.004)	(0.140)
Sources of information for innovation:		
- Institutional sources	0.014***	0.043
	(0.003)	(0.087)
- Market sources	0.015***	0.007
	(0.004)	(0.117)
- Internal sources	-0.005	0.114
	(0.004)	(0.109)
Foreign subsidiary	0.062***	0.651***
	(0.006)	(0.100)
Selection term rho		0.737***
		(0.051)
No. obs. not censured/censured	29,117/2,308	
No. observations	31,425	

Notes: Marginal effects are reported at sample means for probability of offshoring and for the expected value of R&D offshoring intensity conditional on offshoring R&D. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parenthesis. (t-1) denotes that the variable is lagged one period. * significant at 10%; ** significant at 5%; *** significant at 1%.

In addition, the effect of size shows a non-linear association with the probability of offshoring. A lack of finance does not seem to affect this decision, while a lack of information decreases the probability of importing R&D services. In particular, when a firm is an exporter, the probability of undertaking R&D offshoring rises by 2.8 percentage points, and a lack of information reduces the probability of offshoring by approximately 0.4 percentage points.

These results are coherent with previous evidence, globally confirming that the more international experience and the more technological resources and capabilities the firm possesses, the more likely it will offshore R&D services.

As for intensity of R&D offshoring, the exporting character of the firm is not a significant determinant. However, most of the variables that represent firm technical capabilities keep a positive effect. In addition, in line with the descriptives of Table 1 and Figure 1, being a subsidiary increases both the probability of offshoring and its intensity.

It is noteworthy that firms in medium and high-tech manufacturing sectors have a higher propensity to offshore R&D, while the effect is the opposite for companies in medium and high-tech services activities. However, regardless of whether they are services or manufacturing firms, belonging to a sector of medium-high technology has a positive impact on offshoring intensity.Notice also that the correlation term is statistically different from zero, which indicates that it is necessary to make this correction when estimating the intensity determinants.[4]

[4]When firms from the manufacturing and service sectors are analyzed separately (see Table A1 of the Annex), we see that the trends for all firms are maintained, although the magnitude of the effects differs between both firm groups and the correlation term rho is only statistically significant for manufacturing firms.

This selection model is also estimated by distinguishing between individual independent firms and those companies that belong to a business group (Table 4). Irrespective of belonging to a business group, exporter character, continuous R&D engagement, R&D employment and applying for patents keep their positive impact on the probability of undertaking R&D offshoring. Institutional and market sources of information also increase offshoring probability in all cases, as the marginal effects are substantially higher for firms that belong to a group.

However, a lack of information decreases the probability of importing R&D services exclusively for firms in business groups, while a lack of finance only negatively affects this decision in independent firms. In particular, a lack of information reduces the probability of offshoring by approximately 1.1 percentage points for companies in business groups and a lack of financing decreases the probability of undertaking R&D offshoring by approximately 0.4 percentage points in the case of individual firms. This last result gives support to our hypothesis 1, pointing out that a lack of funding is an obstacle relatively more important for the offshoring decision in the case of independent firms in comparison to firms that belong to business groups.

As for the intensity of R&D offshoring, belonging to a high or medium-tech manufacturing sector and institutional sources of information have a positive impact in the case of companies that belong to business groups. On the contrary, internal sources of information positively affect the intensity of R&D offshoring just for individual independent firms, while a lack of financing is not relevant regardless of the type of firm.

Table 4. Determinants of R&D offshoring by type of firm (generalized Tobit model)

	Firms in groups		Independent firms	
	Propensity Pr(*doss*) = 1	Intensity of R&D offshoring	Propensity Pr(*doss*) = 1	Intensity of R&D offshoring
International experience				
Exporter (t-1)	0.042***	0.058	0.021***	0.068
	(0.006)	(0.129)	(0.003)	(0.133)
Technical resources & capabilities				
R&D employment	0.002***	0.021***	0.001***	0.004
	(0.000)	(0.003)	(0.000)	(0.003)
Continuous R&D engagement	0.040***		0.015***	
	(0.006)		(0.003)	
Patent applicant	0.063***	0.110	0.023***	0.375***
	(0.007)	(0.105)	(0.004)	(0.126)
Obstacles to innovation:				
- Lack of finance	0.003	-0.051	-0.004***	-0.002
	(0.003)	(0.064)	(0.002)	(0.075)
- Lack of information	-0.011***	-0.140*	0.0001	-0.210***
	(0.004)	(0.073)	(0.002)	(0.080)
Size	0.104***	0.744***	0.031***	-0.496*
	(0.011)	(0.210)	(0.005)	(0.263)
Size squared	-0.006***	-0.006	-0.002***	0.116***
	(0.001)	(0.018)	(0.001)	(0.032)
Medium & high-tech manufact.	0.032***	0.500***	0.005	0.058
	(0.006)	(0.107)	(0.003)	(0.136)
Medium & high-tech services	-0.031***	0.484**	0.002	0.317*
	(0.009)	(0.218)	(0.004)	(0.169)
Sources of information for innovation:				
- Institutional sources	0.028***	0.037	0.006*	0.101
	(0.007)	(0.113)	(0.003)	(0.130)
- Market sources	0.029***	-0.040	0.009**	0.012
	(0.008)	(0.151)	(0.004)	(0.176)
- Internal sources	-0.014*	0.068	0.001	0.391**
	(0.008)	(0.141)	(0.004)	(0.161)
Foreign subsidiary	0.064***	0.525***		
	(0.008)	(0.108)		
Selection term rho		0.706***		-0.007
		(0.069)		(0.099)
No. obs. not censured/censured	11,119/1,540		17,998/768	
No. observations	12,659		18,766	

Notes: Marginal effects are reported at sample means for the probability of offshoring and for the expected value of the R&D offshoring intensity conditional on offshoring R&D. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parenthesis. (t-1) denotes that the variable is lagged one period. * significant at 10%; ** significant at 5%; *** significant at 1%.

It is also important to observe that, although the size variable affects offshoring intensity in both groups of firms, the sign of the impact differs according to whether a firm belongs to a group or not.

Until now, we have analysed the determinants of firms' decisions on R&D offshoring without distinguishing between internal and external R&D offshoring. However, in the case of firms that belong to business groups, the decisions to offshore R&D services through the group or through the market could be correlated. Therefore, we also undertake an estimation of the determinants of these two decisions through a bivariate Probit model.

Notice that this model is estimated only for companies in groups, which are the ones for which the choice of governance mode is relevant. It is also noteworthy that, as in the univariate Probit model, the estimated coefficients in the bivariate Probit model do not directly quantify the increase in the probability given a marginal change in an independent variable**.** Instead, it is necessary to calculate the partial derivatives or marginal effects, which are presented in Table 5.

The coefficient ρ_{IE} is significant, indicating that for firms that belong to business group, the decisions to do R&D offshoring within the group or through the market are correlated. At the same time, we can observe that the results for most variables show tendencies and magnitudes similar to the ones in Table 4 for firms in groups. Regardless of the governance mode, being an exporting firm, R&D employment, applying for patents and belonging to a high or medium-tech manufacturing sector positively affect R&D offshoring. Firm size also keeps its non-linear impact.

Table5. Determinants of internal and external R&D offshoring (Biprobit model). Only firms in business groups

	Propensity to offshore R&D	
	Internally $\Pr(doss^{I})=1$	**Externally** $\Pr(doss^{E})=1$
International experience		
Exporter (t-1)	0.023***	0.022***
	(0.003)	(0.005)
Technical resources & capabilities		
R&D employment	0.001***	0.002***
	(0.0001)	(0.0001)
Continuous R&D engagement	0.006*	0.036***
	(0.004)	(0.006)
Patent applicant	0.010***	0.057***
	(0.004)	(0.006)
Obstacles to innovation:		
- Lack of finance	-0.002	0.006**
	(0.002)	(0.003)
- Lack of information	-0.003	-0.007**
	(0.002)	(0.003)
Size	0.034***	0.078***
	(0.006)	(0.009)
Size squared	-0.002***	-0.005***
	(0.001)	(0.001)
Medium & high-tech manufacturing	0.011***	0.022***
	(0.003)	(0.005)
Medium & high-tech services	0.005	-0.030***
	(0.006)	(0.007)
Sources of information for innovation:		
- Institutional sources	-0.0004	0.024***
	(0.003)	(0.006)
- Market sources	-0.002	0.030***
	(0.005)	(0.007)
- Internal sources	-0.007	-0.018***
	(0.005)	(0.006)
Foreign subsidiary	0.078***	-0.002
	(0.007)	(0.006)
ρ_{IE}	0.348***	
	(0.030)	
No. observations	12,659	

Notes: Marginal effects are reported at sample means for the probability of observing each outcome. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parenthesis. (t-1) denotes that the variable is lagged one period. * significant at 10%; ** significant at 5%; *** significant at 1%.

However, there are some remarkable differences regarding obstacles to innovation and sources of information for innovation. A lack of financing seems to stimulate the choice of the market channel in the offshoring decision, while a lack of information shows the opposite impact, as it is a less relevant obstacle for internal R&D offshoring than it is for external R&D offshoring.

Similarly, we find that a high relevance of institutional and market sources of information increases the probability of offshoring R&D services through the market, whereas a high importance of internal sources of information reduces this probability. These latter two results provide evidence for our hypotheses 2 and 3.[5]

6. Conclusions

Although the literature on determinants of service offshoring has grown substantially in the last few years, there is still relatively very little information on this subject that looks at individual firm data. This paper aims to gain a deeper understanding of this process, taking advantage of the information on Spanish firms that offshore R&D services, which is available in the Technological Innovation Panel (PITEC) constructed by the Spanish Statistical Institute.

The analysis is limited to firms with innovation expenditure, which is an average of 7,500 a year. According to this data, approximately 7% of innovative firms offshore R&D, with R&D offshoring intensity (percentage of purchases of foreign R&D services over total R&D pur-

[5]Again, if we distinguish between manufacturing and service firms (Table A2 of the Annex), the main trends hold for both groups. Notice, however, that the obstacles to innovation have no effect on the choice of governance mode for services firms.

chases) around 5% and 14.3%, respectively, in individual firms and in firms that belong to business groups.

The analysis of determinants of the decision to offshore R&D in this paper provides evidence that is generally in accordance with the previous empirical literature: irrespective of belonging to a business group, exporting character, continuous R&D engagement, R&D employment and applying for patents show a positive impact on the probability of undertaking R&D offshoring. However, a lack of financing is an obstacle relatively more important for independent firms than for firms that belong to business groups. These latter firms, especially if they are subsidiaries of multinationals, can benefit from the resources and capabilities of the group and therefore would perceive obstacles to innovation as significantly less relevant than independent firms.

In order to clarify the factors that influence the decision to offshore R&D for firms that belong to a business group, the estimation of a multiple decision model is also used, where four options are considered: not undertaking R&D offshoring, offshoring R&D only within the group, offshoring R&D only through the market (international R&D outsourcing), and offshoring R&D through both channels. The results confirm the positive effect that exporting character of firms and R&D employment have on all types of R&D offshoring. Furthermore, we find that some variables have a different effect depending on the strategy followed by the firm: a lack of information is an obstacle relatively more important for external R&D offshoring than for internal R&D offshoring. In particular, if the firms find institutional and market sources of information for innovation very relevant as compared to internal sources of information, they will be more prone to offshore R&D services through the market.

These results suggest that public policies which reduce financial constraints for R&D projects could be a suitable instrument if the government wants to stimulate the insertion of independent firms in international markets through R&D offshoring. In addition, a clear, efficient and guiding public information system, which includes aspects such as available technology, market development and market characteristics, would favor the external offshoring of R&D services by firms that belong to business groups.

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Annex

Table A1. Determinants of R&D offshoring by sector of activity (generalized Tobit model). Marginal effects

	Manufacturing firms		Services firms	
	$\Pr(doss)=1$	Intensity	$\Pr(doss)=1$	Intensity
International experience				
Exporter (t-1)	0.020***	-0.079	0.029***	0.160
	(0.004)	(0.152)	(0.005)	(0.159)
Technical resources & capabilities				
R&D employment	0.002***	0.023***	0.001***	0.007**
	(0.000)	(0.004)	(0.000)	(0.003)
Continuous R&D engagement	0.028***		0.011**	
	(0.004)		(0.005)	
Patent applicant	0.038***	0.024	0.028***	0.850***
	(0.005)	(0.107)	(0.007)	(0.178)
Obstacles to innovation:				
- Lack of financing	-0.0001	-0.059	-0.006**	0.020
	(0.002)	(0.063)	(0.003)	(0.103)
- Lack of information	-0.005**	-0.098	0.000	-0.398***
	(0.002)	(0.072)	(0.003)	(0.114)
Size	0.059***	0.904***	0.044***	0.785***
	(0.007)	(0.226)	(0.006)	(0.223)
Size squared	-0.002***	-0.009	-0.004***	-0.032
	(0.001)	(0.020)	(0.001)	(0.023)
Medium & high-tech sectors	0.011***	0.437***	0.004	0.194
	(0.003)	(0.104)	(0.005)	(0.183)
Sources of information for innovation				
- Institutional sources	0.016***	0.128	0.005	0.020
	(0.005)	(0.118)	(0.005)	(0.174)
- Market sources	0.016***	0.139	0.011*	-0.311
	(0.005)	(0.159)	(0.006)	(0.239)
- Internal sources	-0.002	-0.053	0.002	0.719***
	(0.005)	(0.149)	(0.006)	(0.217)
Subsidiary	0.051***	0.566***	0.086***	1.024***
	(0.007)	(0.116)	(0.016)	(0.247)
Rho		0.705***		-0.749
		(0.069)		(0.113)
No. obs. not censured/censured	15,590/1,365		8,451/501	
No. observations	16,955		8,952	

Notes: Marginal effects are reported at sample means for the probability of offshoring and for the expected value of R&D offshoring intensity conditional on offshoring R&D. For dummy variables,the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parenthesis. (t-1) denotes that the variable is lagged one period. * significant at 10%; ** significant at 5%; *** significant at 1%.

TableA2. Determinants of internal and external R&D offshoring (Biprobit model). Marginal effects. Only firms in business groups

	Manufacturing firms		Services firms	
	Internal	**External**	**Internal**	**External**
	$\Pr(doss^I)=1$	$\Pr(doss^E)=1$	$\Pr(doss^I)=1$	$\Pr(doss^E)=1$
International experience				
Exporter (t-1)	0.014***	0.017**	0.021***	0.007
	(0.005)	(0.008)	(0.005)	(0.008)
Technical resources & capabilities				
R&D employment	0.0004**	0.003***	0.0003***	0.001***
	(0.0002)	(0.0003)	(0.0001)	(0.0002)
Continuous R&D engagement	0.012**	0.027***	-0.003	0.025***
	(0.005)	(0.009)	(0.006)	(0.009)
Patent applicant	0.012**	0.049***	0.002	0.040***
	(0.005)	(0.008)	(0.006)	(0.013)
Obstacles to innovation:				
- Lack of finance	-0.004	0.009**	-0.001	0.001
	(0.003)	(0.004)	(0.002)	(0.005)
- Lack of information	-0.003	-0.012***	-0.002	0.0002
	(0.003)	(0.004)	(0.003)	(0.005)
Size	0.043***	0.103***	0.015**	0.046***
	(0.012)	(0.017)	(0.006)	(0.011)
Size squared	-0.002**	-0.005***	-0.001**	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
Medium & high-tech sectors	0.008*	0.014**	0.002	0.006
	(0.004)	(0.006)	(0.004)	(0.008)
Sources of information for innovation:				
- Institutional sources	-0.004	0.028***	0.008	0.002
	(0.005)	(0.009)	(0.005)	(0.009)
- Market sources	-0.004	0.030***	0.005	0.029***
	(0.007)	(0.009)	(0.006)	(0.010)
- Internal sources	0.010	-0.011	0.005	-0.020**
	(0.007)	(0.009)	(0.006)	(0.010)
Foreign subsidiary	0.077***	-0.018***	0.078***	0.028**
	(0.008)	(0.007)	(0.014)	(0.014)
ρ_{IE}	0.295***		0.510***	
	(0.039)		(0.061)	
No. observations	7,072		3,039	

Notes: Marginal effects are reported at sample means for the probability of observing each outcome. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parenthesis. (t-1) denotes that the variable is lagged one period. * significant at 10%; ** significant at 5%; *** significant at 1%.