Determinants of International R&D Outsourcing: The Role of Trade

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Abstract

This paper investigates the determinants of international R&D outsourcing, in particular the role of trade. We construct a monopolistic competition model with heterogeneous firms where outsourcing increases a firm's fixed transaction as well as its productivity. Financial constraints affect the decision to outsource R&D more to non-exporters than to exporters. In contrast, exporters are more sensitive to a lack of information because they have higher losses when there is technology leakage. We test these predictions using a panel database of Spanish companies. The results highlight the relevance of information in competitive markets, and the role of trade to induce companies to engage in other globalization strategies.

JEL Classification: F2, L24, O3.

Keywords: R&D outsourcing, foreign locations, exporters, financial constraints, technology leakage.

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+ The authors are grateful for detailed comments from Christian Volpe, Luis Miguel de Castro, Lourdes Moreno, and the audiences at X Jornadas de Economía Internacional (Madrid), the ETSG 2007 Conference (Athens), the ESF/COST Workshop on "Science and Technology Research in a Knowledge-based Economy" (Leuven), the XXXII Simposio del Análisis Económico (Granada), and Workshop on "International Economics" (Zaragoza). All errors are ours. This research has been partially funded by the CICYT project SEJ2004-02525/ECON. Elena Huergo also acknowledges financial support from the CDTI (Centro para el Desarrollo Tecnológico Industrial).
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1. Introduction

In highly competitive industries, innovation is essential for the survival of the firms. Companies have incentives to buy technological services from commercial providers, customers, universities or even competitors located around the world (Baumol, 2001). For example, in the pharmaceutical industry, a large part of the clinical tests are done by external companies in Israel, Taiwan or South Korea; Boeing subcontracts the design of some components from companies located all around the world; manufacturers of semiconductors work closely with suppliers from other countries to jointly develop new products (The Economist Intelligent Unit, 2007).

Despite the growing importance of international R&D outsourcing, little is known about its determinants. In this paper, we study the determinants to international R&D outsourcing, in particular we analyse how trade can affect the decision to outsource R&D internationally. We develop a theoretical model and provide empirical evidence.

Some previous studies have empirically analysed the complementarities between international R&D outsourcing and internal R&D (e.g., Arvanitis and Hollenstein, 2006, and Braga and Willmore, 1991, Veugelers and Cassiman, 1999). An important message from this literature is that international R&D outsourcing does not seem to substitute domestic R&D, since firms need absorptive capacities to outsource R&D[1]. These papers, however, do not look at the role of trade, which is our main research question. Specifically, we analyse to what extent trade favours international R&D outsourcing, and whether some of the determinants to outsource R&D abroad differ between exporters and non-exporters. We focus on the factors that firms report as the most important ones for their decision to outsource R&D: intellectual property loss, and financial constrains (The Economist Intelligent Unit, 2007, Lewin and Couto, 2006, *R&D magazine*, 2007). We have three main sets of theoretical and empirical findings. First, we find that international R&D outsourcing is more likely for exporters than for non-exporters. Second, we show that financial constraints affect only non-exporters. Third, we find that exporters are more sensitive than non-exporters to a lack of information that helps to monitor technological leakage.

[1] Absorptive capacities typically refer to internal R&D investments or other firm characteristics that enable companies to use external technologies (Cohen and Levithal, 1990). Also the literature that analyses international outsourcing of intermediate goods has emphasized potential complementarities between outsourcing and R&D (Glass and Saggi, 2001, Marjit and Mukherjee, forthcoming).

In order to explain the link between trade and international R&D outsourcing, we propose a model of monopolistic competition with heterogeneous firms. In the model, companies can outsource internationally, domestically, or not at all. Outsourcing increases the firms' productivity and fixed transaction costs. We assume that there is a cash-in-advance constraint at the beginning of the period, which deters the possibility to outsource unless a bank finances the transaction costs. Under borrowing constraints, the bank extends finance to a firm if the company can offer its operating profits to the creditor.

The model predicts that exporters tend to outsource more abroad than non-exporters for the following reasons: First, there is a scale effect associated with exports. As exporters are selling to a larger market, technological international outsourcing is relatively less costly for exporters. Secondly, exporters have higher operating profits than non-exporters. By trading, a firm decreases its financial constraints, which allows the purchase of technology abroad. However, a company becomes reluctant to outsource R&D internationally when there is technology leakage. As in Lai *et al* (2005), we formalize this concept by assuming that a firm experiences a reduction in its demand when there are hold-up problems. This leads to exporters facing larger potential losses than non-exporters under technology leakage. The model predicts that an exporter becomes more dependent on information than a non-exporter if technology leakage can be partly monitored with information about the technology or about the market characteristics.

We provide empirical evidence by using data on approximately 7000 Spanish companies for the years 2004 and 2005. We find that being an exporter increases the probability of outsourcing R&D abroad by more than one half. We show that financial constraints are obstacles to outsourcing internationally for non-exporters, but that this is not the case for exporters. By contrast, only exporters find that the lack of information on markets or on technology is an obstacle to outsourcing abroad. This result is consistent with the existence of hold-up problems associated with R&D outsourcing as shown by Baccara (2007) and Lai *et al.* (2005).

Our paper is related to the existence literature as follows. Our model builds on recent contributions by Antràs and Helpman (2004) and Helpman *et al.* (2004). In both models, the firm decides whether to outsource intermediate goods depending on the firm's productivity, among other reasons. In our paper, we also emphasize the importance of firm selection with regard to R&D outsourcing. Our paper is also part of the literature of financial market frictions and firms' decisions (Cooley and Quadrini, 2001). For example, Manova (2006) shows that credit constraints determine trade patterns. In Chaney (2005) and Manova (2006) heterogeneous companies face credit constraints to finance their costs of trade. But unlike these papers, we study how financial constraints can affect the decision to outsource R&D.

This paper is also related to the growing literature on international outsourcing (e.g., Feenstra and Hanson, 1999, Grossman and Helpman, 2002), but we analyse outsourcing of technological services instead of manufactured goods. Our paper is also related to the literature that analyses international diffusion of knowledge among countries (e.g., Eaton and Kortum, 1996, or Keller, 2004, among others). Our contribution is that we analyse a specific channel of international knowledge transfers - the acquisition of technological services among firms.

The structure of the paper is as follows. In Section 2, we present a theoretical model for the determinants of R&D outsourcing. In this section, we first specify the basic model in which firms cannot export. Then, we extend the model into an open economy framework. We study the determinants of R&D outsourcing with financial constraints. Finally, we consider the case of leakage of technology. Section 3 describes the data, sets out the empirical methodology, and presents the empirical results of the estimations. Section 4 concludes.

2. The model

Our model builds on the Antràs and Helpman (2004) and Helpman *et al.* (2004) models of monopolistic competition with heterogenous firms. We analyse an industry with a measure *M* of active firms. We assume that the economy has two sectors: one is characterized by a numeraire good, and the other by differentiated products. The preferences of a representative consumer are given by the following utility function:

$$U = x_0 + Q, \tag{1}$$

where x_0 is the consumption of the numeraire good, and Q is an index of consumption of the differentiated products. As in Dixit and Stiglitz (1977), Q reflects the consumer's taste for varieties, which can be written as:

$$Q = \left(\int_0^M q_j^{\alpha} dj \right)^{1/\alpha} \text{ and } 0 < \alpha < 1,$$

where q_j is the quantity of variety j of the differentiated product demanded by the consumer. The elasticity of substitution among varieties is $\sigma = 1/(1-\alpha)$. In this set up, the aggregate demand for any of the varieties of the differentiated product is given by

$$y(p_j) = \frac{p_j^{1/(\alpha-1)}}{P} E\ , \tag{2}$$

where E is the aggregate expenditure or the market size, p_j is the price of the good, and $P = \int_0^M p_z^{\alpha/(\alpha-1)} dz$ is the weighted aggregate price index.

As in Melitz (2003), we assume that firms are heterogeneous. Companies have different levels of productivity, denoted by $\varphi > 1$, associated with traditional inputs (labor, physical capital, materials…), and internal R&D resources that provide absorptive capacities. We consider that a firm's efficiency is drawn from a Pareto distribution with support $\varphi \in [1, \infty)$, and shape ψ. More productive firms have lower marginal costs than their less productive counterparts.

After knowing their efficiency level, firms can outsource part of their innovative activities either to companies in their country or to firms in another country. In both cases, their marginal cost decreases. The cost of producing one unit of output is equal to $1/(\varphi\, c_i)$, with $c_i \geq 1$, for $i = 0, D, F$. The constant c_i is a multiplicative increase of productivity due to outsourcing domestically if $i = D$, or to outsourcing abroad if $i = F$, respectively. If firms do not outsource (in this case $i = 0$), there is no productivity increase (and thus $c_0 = 1$). This multiplicative form ensures that more productive firms benefit relatively more from outsourcing than less productive companies. Our justification for this specification is that firms with higher efficiency have higher absorptive capacity than less efficient firms. The firm's productivity increases if the firm outsources, which in the model implies that $c_F = \zeta c_D > c_0 = 1$, with $\zeta > 0$. The parameter ζ is a way of modelling the degree to which the productivity increase is different if the firm outsources abroad instead of domestically. What is the interpretation of ζ? If $\zeta > 1$, outsourcing abroad is more productive than domestic outsourcing. For some industries it is a question of the complexity of technology. For example, aerospace companies buy some pieces from very specialized foreign providers. In this line, Hagedoorn (1993), Brusoni *et al.* (2001), and Cesaroni (2004) show that technology sources in some fields provided by suppliers from other countries are the best option for the firm to keep up to date. The reason is that international outsourcing offers the possibility to buy the best available technology. The size of ζ might also depend on the firms' focus on the market. Market proximity can be especially important for international companies that face competition. For example, manufactures of food and industrial ingredients buy research studies on dietary habits from external companies located in foreign countries. In this way, the company can better meet the requirements of their overseas customers.

We model the cost of outsourcing as a transaction fixed cost denoted by f_i, for $i = D, F$ (e.g., Feenstra *et al*., 2004). If the firm does not outsource, it bears a fixed cost f_0. R&D outsourcing requires close collaboration between the research teams. Therefore, international outsourcing implies higher communication, coordination, and organizational costs than domestic outsourcing. In the model, this assumption implies that $f_F > f_D > f_0 \geq 0$, as in Antràs and Helpman (2004).

Each firm faces a cash-in-advance constraint: at the beginning of every period, it requires a bank to finance the outsourcing investment and the fixed cost. Both the bank and the borrower are risk-neutral. We assume that only one-period debt contracts are signed with the bank (Cooley and Quadrini, 2001). As in Melitz (2003), we assume that a constant exogenous shock can force companies to exit the market[2]. If the firm defaults, the bank liquidates the company, and the firm immediately exits the industry. The bank perfectly observes a firm's characteristics. It makes a take-it-or-leave-it offer to the firm, and issues funds at an interest rate r. As in Cooley and Quadrini (2001), the bank chooses the interest rate such that the expected repayment from the loan is equal to the repayment of a riskless loan, as in the following equation:

$$(1+r_0)\, f_i = (1+r)\, f_i\, \lambda + (1-\lambda)C, \qquad \text{with } (1+r_0)\, f_i > C, \text{ for } i = 0, D, F. \tag{3}$$

The left-hand side of equation (3) gives the return of the loan at the riskless interest rate r_0. The right-hand side of the equation says that with probability λ, the firm can repay its debts, and with probability $1-\lambda$, it goes bankrupt. In the case of bankruptcy, the bank gets the collateral denoted by C.

A firm's objective consists of maximizing profits subject to the constraints given by equations (2) and (3),

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[2] For the purpose of our model, we do not need that the probability of bankruptcy depends on firm's characteristics. The model still predicts that large and more productive firms are less financially constrained than small and less productive companies.

where profits are given by[3]

$$B(\varphi,c_i) = p\ y(p) - \left[\frac{y(p)}{\varphi\ c_i} + \lambda(1+r)\ f_i + (1-\lambda)C \right], \text{ for } i = 0, D, F\ .$$

On the right-hand side, the first term reflects the firm's income, and other three terms are the variable costs, and the return of the loan at the riskless interest rate as expressed in equation (3). This leads to the standard pricing rule $p(\varphi,c_i) = 1/(\alpha\ \varphi\ c_i)$. We call $\Pi(\varphi,c_i)$ the maximum profit of a firm of type φ that chooses outsourcing of type i after applying this pricing rule.

We assume that the company with the lowest level of efficiency that decides not to outsource obtains zero profit, i.e., $\Pi(1,c_0) = 0$ (Zero Profit Condition). To make the analysis interesting, we consider that $\zeta > 1$; this rules out the trivial case where firms always prefer not to outsource R&D abroad. We show in Appendix 1 that, under the previous assumptions, there exist two unique efficiency thresholds. The first threshold refers to the efficiency such that companies are indifferent with respect to either outsourcing domestically or not outsourcing, and the second one to outsourcing either domestically or abroad. They are denoted by φ_D and φ_F, respectively, and they are calculated as the efficiency levels for which maximum profits of the decisions are equalized: $\Pi(\varphi_D, c_0) = \Pi(\varphi_D, c_D)$, and $\Pi(\varphi_F, c_D) = \Pi(\varphi_F, c_F)$. We obtain a partition of firms similar to the one in Antràs and Helpman (2004), in the component-intensive sector, where only highly efficient firms outsource abroad. As it can be seen in Figure 1, if a firm's efficiency is $\varphi \geq \varphi_F$, the company prefers to outsource internationally; if $\varphi \in [\varphi_D, \varphi_F)$, the firm outsources in the domestic market; and finally, if $\varphi < \varphi_D$, the company chooses not to outsource[4].

INSERT FIGURE 1

Both thresholds, specified in Appendix 1, depend negatively on market size E. This reflects the simple idea that in larger markets fixed transaction costs are a lower proportion of the firm's income than in smaller markets. Moreover, the thresholds depend negatively on the aggregate price in the industry and the number of

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[3] In what follows, we omit the sub-index *j* to simplify the expressions.

[4] In this simplified model without financial constraints, all firms that choose the same type of outsourcing have to pay the same interest rate independently of their efficiency. However, the implications of the model do not change if either the probability of bankruptcy or the collateral depends on the company's efficiency. In that case, the interest rate would depend negatively on the firm's efficiency.

companies in the market. We also show in Appendix 1 that φ_F decreases with ζ. In other words, if foreign outsourcing is more productive than domestic outsourcing, there are more companies that decide to outsource abroad.

2.1 Open economy model

We now assume that there are two identical countries that trade the varieties of *Y*. Trade for *continuous* exporters involves only one type of cost: there is a variable per unit cost of the good that is transported[5]. This variable cost takes the form of an iceberg cost, so that for one unit of a good to arrive at the final destination, $\tau > 1$ units of the good need to be shipped. While a firm's prices in the domestic market are the same as before, $p(\varphi, c_i) = 1/(\alpha c_i \varphi)$, exporters set prices in the foreign market taking into account the transport cost, as in the following expression $p_x(\varphi, c_i) = \tau/(\alpha c_i \varphi)$.

Under these assumptions, we want to answer the following question: Is the probability of outsourcing higher for exporters than for non-exporters? In our framework, this is equivalent to determining whether the efficiency threshold to outsource is lower for exporters than for non-exporters.

The total maximum profits of a non-exporter with efficiency φ that chooses outsourcing of type *i* are equal to the maximum profits in the domestic market. They are given by $\Pi_{nx}(\varphi, c_i) = \frac{(\varphi\ c_i)^{\rho} E\ (1-\alpha)}{P(\phi)} - (1+r_0) f_i$, where $\rho = \alpha/(1-\alpha) > 0$, and $P(\phi)$ is the weighted aggregate price index in the domestic economy with trade. This price is a function of $\phi = (\varphi_{D,x}, \varphi_{D,nx}, \varphi_{F,x}, \varphi_{F,nx})$, which is the efficiency threshold to outsource domestically for exporters and non-exporters (denoted by $\varphi_{D,x}$ and $\varphi_{D,nx}$, respectively), and the efficiency threshold to outsource abroad for exporters and non-exporters (denoted by $\varphi_{F,x}$ and $\varphi_{F,nx}$, respectively). Since both countries are identical, the aggregate price indices are equal in the domestic and in the foreign market.

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[5] We also assume that there is a sunk cost to start exporting. In the empirical analysis, we study the decision to outsource for continuous exporters. For this reason, we assume in the model that exporters have already paid the sunk cost of entry into the foreign market. The sunk trade cost implies that only some firms can export, and that there exists a unique efficiency threshold such that firms with efficiency lower than the threshold do not export, while firms with efficiency higher than the threshold decide to export (Melitz, 2003).

The maximum profit of an exporter with efficiency φ that chooses outsourcing of type *i* is equal to the sum of the profits in the domestic and in the foreign market, as expressed in the following equation; on the right-hand side, the first term is the income minus the variable cost to sell in the domestic market, the second term reflects the income minus the variable cost to sell in the foreign market, and the third term is the return of the loan at the riskless interest rate:

$$\Pi_x(\varphi, c_i) = \frac{(\varphi\, c_i)^{\rho} E\ (1-\alpha)}{P(\phi)} + \frac{(\varphi\, c_i)^{\rho} E\ (\tau-\alpha)\tau^{1/(\alpha-1)}}{P(\phi)} - (1+r_0)\, f_i\,.$$

We can express the maximum profit of an exporter in terms of the profits of a firm (with the same characteristics) that does not export as:

$$\Pi_x(\varphi, c_i) = \Pi_{nx}(\varphi, c_i) + \frac{(\varphi\, c_i)^{\rho} E\ (\tau-\alpha)\tau^{1/(\alpha-1)}}{P(\phi)}\,.$$

We show in Appendix 1 that if $\zeta > 1$, some firms outsource R&D abroad, and that if $\zeta \leq 1$, firms do not outsource R&D abroad. Furthermore, if $\zeta > 1$, the threshold efficiency levels for outsourcing are larger for non-exporters than for exporters, i.e., $\varphi_{i,x} < \varphi_{i,nx}$ for $i = D, F$. The difference between the minimum thresholds to outsource depends on the differences between the profits of exporters and non-exporters. It implies that, before making the decision to outsource, exporters need to be less efficient than firms with similar characteristics that operate only in the domestic market (although, ex post exporters become more efficient due to outsourcing). The probability of outsourcing internationally is equal to the probability of having efficiency that is higher than the efficiency threshold. This result leads to the following proposition.

Proposition 1: *If $\zeta > 1$, the probability of outsourcing R&D abroad is higher for exporters than for non-exporters.*

Exporters have on average higher revenues than non-exporters before outsourcing, consequently fixed transaction costs associated with outsourcing become relatively lower in terms of the total revenue. We consider the general case in which transaction costs of international R&D outsourcing are the same for exporters than for non-exporters. If we assume a more specific framework where transaction costs are lower for exporters than non-exporters, the results of the model would be reinforced.

2.2 Open economy model with financial constraints

There is much evidence showing that financial constraints have important implications for firm decisions (e.g., Clementi and Hopenhayn, 2006). These constraints can influence a firm's purchase of technology. Moreover, there are some empirical studies that find that continuous exporters tend to be financially healthier than non-exporters (Greenaway *et al.*, 2007). In this section, we introduce financial constraints in the model, distinguishing their effect for exporters and non-exporters.

We assume that banks only extend finance to the firm if the company can offer its operating profits $\Pi_k^0(\varphi, c_i)$ to the creditor, i.e., $(1+r) f_i \leq \Pi_k^0(\varphi, c_i)$, with $k = nx$ for non-exporters, and $k = x$ for exporters (e.g., Manova, 2006), for $i = D, F$. A company obtains financial credit if its efficiency level is as large as the threshold $\overline{\varphi}_{i,k}$. This threshold is calculated by solving for the efficiency level such that operating profits are equal to the repayment of the loan plus the interest, for both exporters and non-exporters, respectively,

$$\Pi_k^0(\overline{\varphi}_{i,k}, c_i) = \frac{(1+r_0) f_i - (1-\lambda)C}{\lambda}, \text{ for } i = D, F. \quad (4)$$

We show in Appendix 1 that operating profits are larger for exporters than for non-exporters. Therefore, the efficiency threshold to obtain financial resources to outsource is lower for exporters than for non-exporters, i.e., $\overline{\varphi}_{i,x} < \overline{\varphi}_{i,nx}$, for $i = D, F$. As it can be seen in Figure 2, and as we show in Appendix 1, the impact of financial constraints on the decision to outsource is more important for non-exporters than for exporters. The reason is that the increase in the efficiency threshold needed to outsource when there are financial constraints (compared with the situation without financial frictions) is larger for non-exporters than for exporters: $\overline{\varphi}_{i,x} - \varphi_{i,x} < \overline{\varphi}_{i,nx} - \varphi_{i,nx}$, or, equivalently, $(\overline{\varphi}_{i,nx} - \varphi_{i,nx}) - (\overline{\varphi}_{i,x} - \varphi_{i,x}) > 0$, for $i = D, F$. Furthermore, this differential increases as financial constraints increase. It implies that the decrease in the probability of outsourcing is higher for non-exporters than for exporters. These results can be expressed as the following proposition.

Proposition 2: *The negative effect of financial constraints on the probability of outsourcing R&D abroad is higher for non-exporters than for exporters.*

Trade increases operating profits. Our model shows that this fact leads to a decrease in the financial constraints of continuous exporters. Having lower financial constraints, exporters can buy technology more easily than non-exporters.

INSERT FIGURE 2

2.3 Open economy model with technology leakage

A key characteristic of R&D outsourcing, and, particularly, outsourcing abroad, is that it induces some risks in a situation of imperfect contracts, hold-up problems, and cultural differences (Ornelas and Turner, 2008, Lai *et al*., 2005, Baccara, 2007). Companies can be reluctant to outsource because they can be exposed to subcontractors, especially in countries with poor intellectual property rights. The next step of our analysis is to look at the impact of technology leakage in an open economy framework. In order to simplify the model, we assume that there are no financial constraints in the economy. As in Lai *et al.* (2005), we consider that firms experience a reduction in their demand when there is technology leakage. That is,

$$y(p_j,\delta)=\begin{cases}\dfrac{p_j^{\,1/(\alpha-1)}}{P}E & \text{if there is no leakage}\\[2ex] \dfrac{\delta p_j^{\,1/(\alpha-1)}}{P}E & \text{if there is leakage}\end{cases},\ \text{where } \delta\in(0,1).$$

The variable δ reflects the importance of technology leakage. We assume that it depends on the capacity to monitor a subcontractor. Furthermore, we consider that companies can monitor better if they have some knowledge of the technological characteristics of the innovation or the market. These assumptions guarantee that, from the point of view of the company, information reduces the potential hold-up problem. In this very simple framework, the pricing rule does not change with respect to the base case. Prices in the domestic market are equal to $p(\varphi,c_i)=1/(\alpha c_i\varphi)$, and in the foreign market exporters set prices equal to $p_x(\varphi,c_i)=\tau/(\alpha c_i\varphi)$. It implies that maximum profits, in case of outsourcing, are given by $\Pi_{nx}(\varphi,c_i,\delta)=\dfrac{\delta(\varphi\, c_i)^{\rho}E\,(1-\alpha)}{P(\phi)}-(1+r_0)f_i$, and $\Pi_x(\varphi,c_i,\delta)=\Pi_{nx}(\varphi,c_i,\delta)+\dfrac{\delta(\varphi\, c_i)^{\rho}E\,(\tau-\alpha)\tau^{1/(\alpha-1)}}{P(\phi)}$, for $i=D,F$, for non-exporters and exporters, respectively. Under the previous simplified assumptions, the negative effect of leakage on profits is more severe for exporters than for non-exporters since $\dfrac{\partial\Pi_x(\varphi,c_i,\delta)}{\partial\delta}-\dfrac{\partial\Pi_{nx}(\varphi,c_i,\delta)}{\partial\delta}>0$. If there is more leakage (δ decreases), the reduction in profits is higher for exporters than for non-exporters. If profits decrease, the minimum efficiency threshold needed to outsource increases. This effect is more relevant for exporters than for exporters. Thus, information that helps to monitor subcontractors is relatively more valuable for exporters than for non-exporters. We summarize this result in the following proposition.

Proposition 3: *When companies decide to outsource internationally, the lack of information is an obstacle that is relatively more important for exporters than for non-exporters.*

In summary, our model relates trade to international R&D outsourcing. It predicts that:

(i) When a firm exports, it becomes more likely to outsource (Proposition 1).

(ii) Trade has two indirect effects on the decision to outsource technology abroad.

- Trade makes exporters less financially constrained than non-exporters. This effect facilitates international R&D outsourcing for exporters. The theory predicts that financial constraints decrease the probability of outsourcing internationally mostly for non-exporters (Proposition 2).
- In contrast, the model shows that exporters have larger losses than non-exporters in case of technology leakage. When there is a lack of information that helps to monitor subcontractors, exporters are more exposed to the potential danger of international outsourcing than non-exporters. This effect tends to decrease international R&D outsourcing for exporters. As a result, the model predicts a negative relationship between a lack of information and international R&D outsourcing for exporters, and a weaker relationship for non-exporters (Proposition 3).

In the next section, we investigate these predictions empirically.

3. The empirical evidence

3.1. The data and the main variables

The data set that we use comes from a survey of innovating Spanish firms (*Panel de Innovación Tecnológica*, *PITEC*). It is a panel database constructed from two ongoing statistics: the Technological innovation survey, and the Statistics about R&D activities, carried out in a coordinated way since 2002 by the

Spanish National Institute of Statistics[6]. In the survey, each company provides information on some of its economic data, such as sales or number of employees. The firm also answers several questions about its innovating activities. Although 2003 is the first year of the panel, in this paper, we only use the years 2004 and 2005 for reasons of comparability[7]. In order to avoid endogeneity problems, some variables related to exporting activity are included with a one-period lag. The empirical analysis is conducted for the year 2005, for which we have information from 7,205 innovating firms, that is, firms that perform R&D internally and/or buy R&D services from other companies or institutions. We consider that a firm is outsourcing R&D if the R&D provider is outside of the company. In the survey, there are 2,759 firms that outsource R&D, 447 of which are located abroad.

The main interest of our analysis consists of testing the predictions developed in the previous section: to what extent exports increase international R&D outsourcing (proposition 1), and whether exporters and non-exporters are influenced differently by financial constraints (proposition 2), and by information problems (proposition 3) at the moment of international R&D outsourcing. Our data provides detailed information on these variables at the firm level. Each firm indicates its purchases of *R&D services* from other companies or institutions at foreign locations. This variable is our measure of *R&D outsourcing*, and it is defined in the survey as:

> *"Acquisitions of R&D services outside the firm from foreign providers through contracts, informal agreements, etc… Funds to finance other companies, research associations ,etc… that do not directly imply purchases of R&D services are excluded".*

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[6] The database is constructed on the basis of the annual Spanish responses to the Community Innovation Survey (CIS). This survey is specifically designed to analyze R&D and other innovating activities following the recommendations of the OSLO Manual on performing innovation surveys (see OECD and Eurostat, 1997). The survey is targeted to industrial companies whose main economic activity corresponds to sections C, D, and E of NACE 93, except non-industrial companies because of the imprecision of methodological marking in the international context by other branches of activity. The questions we quote bellow are the English version from the CIS questionnaire. These questions are the exact equivalent of the Spanish questionnaire.

[7] Initially, the panel was assembled with two samples of firms surveyed on the basis of a census: firms with 200 or more employees and firms with internal R&D expenditures in 2003. In 2004, the panel was enlarged with two new sets of firms employing fewer than 200 employees: firms with external R&D expenditure but without internal R&D expenditure, and non-innovative firms. The data after 2005 are not available yet.

Note that this variable also excludes the acquisition of software, royalties, or investments in foreign R&D capacity[8].

Companies report their exports. We define a dummy variable for *being an exporter*, and a variable for *export intensity*, constructed as the ratio of exports over total employment.

Companies answer questions about the factors that prevent them to innovate. We construct a variable that measures a firm's financial constraints with the information that is specified in the following question in the database. The companies are asked:

> *"During the three years 2003 to 2005, how important were the following factors for hampering your innovation activities? Lack of funds within your enterprise or group, lack of finance from sources outside your enterprise, and innovation costs too high."*

For each of the factors, a company can answer that the importance of the factor was high, intermediate, or low, or that the factor was not relevant. We assign a number that varies from zero (not experienced) to three (high importance) for each answer. Then, we calculate the average importance of the cost factors. This is our variable *lack of finance.* We expect that financial constraints affect non-exporters but not exporters, or at least that the latter are influenced to a lesser extent.

We construct a variable that quantifies the value of the information for the company. In the survey, the companies are asked:

> *"During the three years 2003 to 2005, how important were the following factors for hampering your innovation activities? Lack of information on technology, and lack of information on markets"*

Again, for each of the factors, companies can answer that the importance of the factor was high, intermediate or low, or that the factor was not experienced. We calculate the variable *lack of information* in the same way as the variable *lack of finance*. This variable is our measure of the capacity of a firm to monitor its subcontractors. We consider that information is a relevant asset for the firm because it helps to avoid technology leakage. Therefore, access to knowledge stimulates international R&D outsourcing. We expect that the variable *lack of information* is negatively correlated with international R&D outsourcing for exporters, and that it has less influence for non-exporters than for exporters.

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[8] *R&D services* are defined in the survey as: *"Creative work to increase the volume of knowledge and to create new or improved products and processes (including the development of software)"*.

3.2. Descriptive analysis

During 2005, around half of the continuous innovating firms were actively engaged in external R&D expenditures[9]. However, only a small percentage of those companies (9.4%) bought R&D abroad (see Figure 3). The database distinguishes the firms' R&D providers. These can be firms belonging to the same company, other companies, public administrations, universities, non-profit institutions, and other international organizations. We consider R&D outsourcing if the provider is outside the enterprise group. As it can be seen in Figure 4, among firms that buy technology abroad, nearly 70% outsource. The definitions of the other variables are documented in Appendix 2.

INSERT FIGURES 3 AND 4

Proposition 1 states that the probability of outsourcing R&D abroad is higher for exporters than for non-exporters. This is a relationship that is strongly supported by the data. Our first empirical observation is depicted in Figure 5. There, we show that there are almost twice as many exporters as non-exporters that outsource abroad.

INSERT FIGURE 5

In Table 1, we show some descriptive statistics of the variables of our empirical specification. The frequencies of the qualitative variables are quite similar between the sample of innovating firms and the sub-sample of innovating firms that outsource R&D, with the exception of the variables related with exports. The exporting intensity is higher for companies with international R&D outsourcing than for companies with national outsourcing or for firms with only internal R&D expenditures. Again, this pattern illustrates that international outsourcing and export activity are strongly positively related.

INSERT TABLE 1

Figure 6 displays our second empirical observation. We compare the importance of the *lack of finance* for the firm by exporting status. Among the companies that do not outsource internationally, non-exporters are more concerned about their lack of financial resources than exporters. However, this obstacle is less relevant for non-exporters than for exporters once firms outsource abroad. This pattern is consistent with our Proposition 2. This

[9] We call a firm with positive innovation expenditures both in 2004 and 2005 a "continuous innovator"

feature suggests that non-exporters have to face fewer financial constraints than exporters in order to outsource abroad.

We depict our third empirical observation in Figure 7. We compare the importance of the *lack of information* for the firm by its exporting status. For companies that do not outsource internationally, we can see that exporters are more influenced by the *lack of information* than non-exporters. Once companies outsource internationally, exporters are less concerned about the *lack of information* than non-exporters. We interpret this variation as reflecting that exporters need to accumulate more information than non-exporters in order to outsource, which is consistent with Proposition 3.

INSERT FIGURES 6 AND 7

In summary, the descriptive analysis supports the propositions. In the next section, we test our predictions econometrically by controlling for potential covariates.

3.3. The empirical specification

We now turn to examining the determinants of international R&D outsourcing at the firm level. We simultaneously estimate two equations by maximum likelihood. The first one describes a firm's decision to contract technological activities abroad (selection equation). The second equation refers to the intensity of the R&D expenditure abroad. The selection equation is given by:

$$rd = \begin{cases} 1 & \text{if} \quad \varphi - \varphi_F = w'\alpha + \varepsilon > 0 \\ 0 & \text{if} \quad \varphi - \varphi_F = w'\alpha + \varepsilon \leq 0. \end{cases} \tag{5}$$

The intensity equation, conditional on the firm reporting international R&D outsourcing, is expressed as in the following specification:

$$r = \begin{cases} r^* = z'\beta + e & \text{if} \quad rd = 1 \\ 0 & \text{if} \quad rd = 0. \end{cases} \tag{6}$$

In equation (5), rd is the observed binary endogenous variable equal to one if a given firm reports international R&D outsourcing, and zero for non-R&D reporters. The vector w reflects factors that influence this decision. In equation (6), the variable *r* stands for international R&D outsourcing expenditures, and the vector z represents its determinants. We denote the error terms as e and ε, and we assume that they are distributed as a normal bivariate with zero mean, variances $\sigma_\varepsilon^2 = 1$ and σ_e^2, and correlation coefficient $\rho_{e\varepsilon}$.

Vectors w and z include, among others, the variables *lack of finance* and *lack of information,* and the indicators of the exporting activity. Notice that R&D outsourcing abroad can stimulate exports, given that outsourcing can allow access to a wider technological network and the accommodation of the firm's products to the specificities of foreign markets. This can generate a potential endogeneity problem. In order to avoid this problem, we include the indicators of the exporting activity lagged one period. We also incorporate each of the *lack of finance* and *lack of information* variables multiplied by the *being an exporter* dummy variable (*interacted variables*) in the regression. We denote these variables as *lack of finance: exporters*, *lack of finance: non-exporters*, *lack of information: exporters*, and *lack of information: non-exporters*, respectively.

In the theoretical model, each firm has an ex ante efficiency φ associated with the productivity of traditional inputs and R&D resources. Recall that we assume that firms with ex ante higher efficiency have also higher absorptive capacity. Therefore, we include in the regressions a group of variables that reflect internal capabilities such as economies of scale coming from specialization, and firms' specific advantages. We include the variables: *R&D employment*, a binary variable for companies with *continuous R&D engagement*, and firm *size*. Under the existence of economies of scale, we expect that firm *size* affects outsourcing positively[10]. Additionally, we include two dummy variables denoting whether the firm is part of a *multinational*, and whether it has applied for *patents*. An important result in the literature refers to the fact that multinationals produce with intensive technological techniques (e.g., Girma and Görg, 2004). Being a multinational can imply having management and organization advantages or superior knowledge capital. The same effect happens if the company has applied for a patent. We also include two dummies reflecting whether the firm belongs to a *high-tech manufacturing industry*, or to the *high-tech services sector*. Finally, we include a set of *geographical dummies*. The reason for including these variables is that firms can learn from the outsourcing strategy implemented by geographically close companies, given the importance of agglomeration effects to induce spillovers. The list of high-tech activities and the definition of the geographical variables can be found in Appendix 2.

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[10] For example, Chang and Robin (2006) show that firm *size* is a key variable for explaining technology imports in Taiwanese firms.

In addition, if a firm's ex ante efficiency is higher than a certain threshold φ_F, the firm finds outsourcing abroad profitable. In the model, this threshold depends on *the lack of finance*, the *lack of information*, *export activity*, and relative gains in productivity between the different types of outsourcing (the parameter ζ), among other factors. Following these considerations, we also include in our specification variables that could make foreign outsourcing more productive than domestic outsourcing. We consider that market focused companies can obtain more productivity gains if they outsource abroad than less market focused firms. Companies report the importance of *institutional sources of information*, *internal sources of information*, and *market sources of information* in order to innovate. These variables can measure how market-focused the companies are[11]. We consider that companies that obtain information from universities, other public research centres or internal sources are less market-focused than companies that prefer market sources of information. Therefore, we expect that these two groups of firms obtain fewer gains from outsourcing than companies that obtain many innovations from the market.

We have estimated both equations with the same set of explanatory variables ($z = w$), with two exceptions. We expect the *continuous R&D engagement* to be relevant for the outsourcing decision, but we assume that it has no effect on outsourcing intensity. The model predicts that the decision to outsource abroad instead of domestically depends on both costs differentials and the decision to maintain regular internal R&D activities (through being more productive). However, we consider that the intensity of outsourcing abroad mostly depends on costs differentials. The other exception refers to the export activity that in the selection equation is introduced through the dummy variable *being an exporter*, while in the intensity equation it is introduced in terms of *export intensity*. We expect that among continuous exporters, those with a higher presence in international markets have more operating profits, and therefore more incentives to outsource more abroad.

3.4. The results

[11] See the detailed construction of the variables in Appendix 2.

In order to get a first approximation of the determinants of international R&D outsourcing, we estimate the probability of outsourcing from domestic and/or from foreign locations through a probit model without *interacted variables*[12]. The results are presented in Table 2.

INSERT TABLE 2

In these preliminary estimations, we cannot detect any impact of *lack of finance* or *lack of information* on the determinants to outsource. We find that firms' internal R&D capabilities, proxied by *continuous R&D engagement* and *R&D employment*, increase the probability of outsourcing R&D. The rest of the explanatory variables show the expected effects: *export* activity, being a *multinational*, the *patents* application, and the maintenance of *technological cooperation* increase the propensity to buy R&D.

Next, we turn to the analysis of international R&D outsourcing. We estimate equations (6) and (7) using a Generalized Tobit model without including the *interacted variables*. The first column of Table 3 exhibits the coefficients of the probit model for the decision to outsource R&D internationally. The second one corresponds to the intensity, taking the selection term into account. The correlation term $\rho_{e\varepsilon}$ is statistically different from zero, pointing out the need to estimate a selection model for the observed intensity.

INSERT TABLE 3

Being an *exporter* increases the probability of outsourcing R&D abroad by 5 percentage points. The estimated coefficients in column (2) show that export intensity yields a significant effect in the outsourcing expenditures. To place this result in perspective, the probability to outsource abroad of an average company with external R&D expenditures is 9.4%, which implies that exporting increases the probability to outsource internationally by more than one half. This result is consistent with our Proposition 1, and our first empirical observation, supporting the hypothesis of complementarities between both types of internationalisation strategies.

Our theory predicts that financial constraints and information are major determinants for international R&D outsourcing. The estimations show that *lack of information* reduces the probability of outsourcing by approximately 2 percentage points, but it has a negligible influence on the quantity outsourced abroad. By contrast, we find that the

[12] The *interacted variables* are the variables *lack of finance* and *lack of information* multiplied by the dummy variable *being an exporter* .

lack of finance has a negative impact on the quantity that is outsourced abroad, while having no influence on the outsourcing decision.

Conditional on reporting external R&D expenditures, most variables have the expected positive impact on the propensity to contract R&D abroad. Larger firms are more likely to outsource than smaller companies, although the relationship is non-linear. Firms that consider *market sources of information* as crucial are keener to outsource internationally. However, companies that find *institutional sources of information* important give priority to domestic locations. This is what we would expect if they were less market-focused.

The previous estimations have the limitation that we cannot distinguish whether the impacts of financial constraints and information problems differ between exporters and non-exporters. We address this issue by including the *interacted variables* in the specification. The results of the estimations are reported in Table 4. We find strong confirmation for our Proposition 3. In columns (1) and (2), we show that for exporters a *lack of information* on technology or on markets decreases the probability of outsourcing R&D abroad by approximately 3 percentage points, while for non-exporters the impact of this variable is negligible.

We also find some support for Proposition 2. The *lack of finance* variable has a negative effect on the outsourcing expenditure only for non-exporters but it has no effect on the decision to outsource, either for exporters or for non-exporters. Plausibly, smaller firms tend to be more financially constrained than large companies[13] . Therefore, firm *size* can be negatively correlated with *lack of finance*. This simultaneity can induce a bias in the estimated coefficient for non-exporters. To avoid this simultaneity problem, columns (3) and (4) present the regressions excluding the variable *size* in the estimations. The results are statistically significant: *lack of finance* affects the decision to outsource R&D abroad but only for non-exporters, as Proposition 2 states. Financial constraints lead to a decrease in international R&D outsourcing by non-exporters of almost 2 percentage points, and it has no effect on exporters. This finding suggests that exporters outsource abroad more than non-exporters due to lower financial constraints, in line with our Proposition 2, and not only because they have advantages in finding suppliers abroad.

INSERT TABLE 4

[13] For example Carpenter and Petersen (2002) show that the growth of most small firms is constrained by internal finance.

These results are consistent with our theoretical model and with the empirical observations. However, international outsourcing can stimulate exporting activity. We have addressed this potential endogeneity problem using the lags of the *being an exporter* and *export intensity* variables in the estimations. As a robustness test, we now examine the determinants of international R&D outsourcing only for exporters[14]. As Table 5 shows the magnitudes of the estimated coefficients increase compared to those calculated in Table 4. The evidence suggests that financial constraints do not prevent exporters from outsourcing; however, exporters seem more sensitive to the lack of information than non-exporters.

INSERT TABLE 5

4. Conclusions

In this paper, we study the determinants of international R&D outsourcing by analysing the role of trade, financial constraints, and information. We develop a model of monopolistic competition with heterogeneous firms. The model shows that the probability of outsourcing R&D abroad is higher for exporters than for non-exporters. Furthermore, financial constraints decrease the probability of outsourcing internationally. This effect is more important for non-exporters than for exporters. The reason is that, as firms become more global, they can obtain more revenue. By contrast, exporters have major losses if there is technology leakage. It makes them more sensitive to obtaining information that helps to monitor their outsourced R&D.

The empirical results are consistent with the predictions of the model. The probability to outsource abroad of an average company with external R&D expenditures is 9.4%. Being an exporter increases this probability by around 5.5 percentage points. Financial constraints reduce the probability of outsourcing abroad for non-exporters, by 2 percentage points. For exporters, we find no relationship between outsourcing abroad and financial constraints. The lack of information on technology or on markets reduces the probability of outsourcing abroad only for exporters, by approximately 3 percentage points. Our empirical results also reflect that more R&D-intensive companies tend to buy more R&D abroad.

International R&D outsourcing is becoming a rapidly growing source of technological flows that can decrease productivity differences across countries. The type of public policies to promote international

[14] The same model has been estimated for the sub-sample of non-exporters. The results are less robust due to the small number of non-exporters that outsource in foreign locations. They are available from the authors upon request.

acquisitions of R&D, and therefore to enhance the country's technological advantage, can differ depending on the internationalization of the firm. Stronger intellectual property rights can induce exporters to outsource R&D internationally because it can reduce the hold-up problem. However, innovative non-exporters can require soft loans, grants, or investments from specialized financial organizations, which in turns should make them less financially constraint.

An aspect that remains to be studied is the consequences of international R&D outsourcing for the domestic industry. Relative to public policy, we consider this to be an important issue to be analysed in future research.

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Appendix 1: Proofs

Proof of the existence of φ_D *and* φ_F *in autarky without financial constraints.*

We want to show that in the closed economy without financial constraints, there exist two unique efficiency levels denoted as φ_D, and φ_F, such that $\Pi(\varphi_D, c_0) = \Pi(\varphi_D, c_D)$, and $\Pi(\varphi_F, c_D) = \Pi(\varphi_F, c_F)$. Furthermore,

$$\text{for } \begin{cases} \varphi > \varphi_F, & \text{then } \ \Pi(\varphi,1) < \Pi(\varphi,c_D) < \Pi(\varphi,c_F) \\ \varphi_D < \varphi < \varphi_F, & \text{then } \ \Pi(\varphi,c_F) < \Pi(\varphi,c_D), \text{ and } \Pi(\varphi,1) < \Pi(\varphi,c_D) \\ \varphi < \varphi_D, & \text{then } \ \Pi(\varphi,c_F) < \Pi(\varphi,c_0), \text{ and } \Pi(\varphi,c_D) < \Pi(\varphi,c_0) \end{cases}$$

If there are two unique efficiency thresholds such that $\varphi_D < \varphi_F$, the price index can be expressed as

$$\int_0^M p_z^{\alpha/(\alpha-1)} dz = M \left[\int_1^{\varphi_D} \left(\frac{1}{\alpha \varphi c_0} \right)^{\frac{\alpha}{(\alpha-1)}} \mu(\varphi) d\varphi + \int_{\varphi_D}^{\varphi_F} \left(\frac{1}{\alpha \varphi c_D} \right)^{\frac{\alpha}{(\alpha-1)}} \mu(\varphi) d\varphi + \int_{\varphi_F}^{\infty} \left(\frac{1}{\alpha \varphi c_F} \right)^{\frac{\alpha}{(\alpha-1)}} \mu(\varphi) d\varphi \right]$$

where $\mu(\varphi) = \psi / \varphi^{\psi+1}$, since we consider that a firm's efficiency is drawn from a Pareto distribution with support $\varphi \in [1, \infty)$ and shape ψ. After some arithmetic calculations, we obtain that $\int_0^M p_z^{\alpha/(\alpha-1)} dz = \dfrac{M \ \alpha^\rho \ \psi}{\psi - \rho} \xi$, where $\rho = \alpha/(1-\alpha) > 0$ and $\xi = (c_D^\rho - c_0^\rho) {\varphi_D}^{\rho-\psi} + (c_F^\rho - c_D^\rho) {\varphi_F}^{\rho-\psi} + 1$. Additionally, we have assumed that $\psi > \rho$ to ensure that the integral converges.

The profits of a firm with efficiency φ are equal to:

$$\Pi(\varphi, c_i) = p(\varphi, c_i) y(\varphi, c_i) - \frac{y(\varphi, c_i)}{\varphi \ c_i} - (1+r_0) f_i = \frac{E \ (1-\alpha)(\psi-\rho)}{M \ \psi} \frac{(\varphi \ c_i)^\rho}{\xi} - (1+r_0) f_i, \text{ for } i = 0, D, F.$$

Now, if there exists a unique φ_D such that $\Pi(\varphi_D, c_0) = \Pi(\varphi_D, c_D)$, it would imply that

$\dfrac{E \ (1-\alpha)(\psi-\rho)}{M \ \psi} \dfrac{(\varphi_D \ c_0)^\rho}{\xi} - (1+r_0) f_0 = \dfrac{E \ (1-\alpha)(\psi-\rho)}{M \ \psi} \dfrac{(\varphi_D \ c_D)^\rho}{\xi} - (1+r_0) f_D$, which is equivalent to:

$$(1+r_0)(f_D - f_0) = \frac{E \ (1-\alpha)(\psi-\rho)}{M \ \psi} \frac{{\varphi_D}^\rho (c_D^\rho - c_0^\rho)}{\xi}. \tag{A.1}$$

And, if there exists a unique φ_F such that $\Pi(\varphi_F, c_D) = \Pi(\varphi_F, c_F)$, it would imply that:

$\dfrac{E \ (1-\alpha)(\psi-\rho)}{M \ \psi} \dfrac{(\varphi_F \ c_D)^\rho}{\xi} - (1+r_0) f_D = \dfrac{E \ (1-\alpha)(\psi-\rho)}{M \ \psi} \dfrac{(\varphi_F \ c_F)^\rho}{\xi} - (1+r_0) f_F$, which is equivalent to:

$$(1+r_0)(f_F - f_D) = \frac{E \ (1-\alpha)(\psi-\rho)}{M \ \psi} \frac{{\varphi_F}^\rho (c_F^\rho - c_D^\rho)}{\xi}. \tag{A.2}$$

Dividing equation (A.2) by (A.1), we obtain that

$${\varphi_D}^\rho = \frac{(c_F^\rho - c_D^\rho)}{(c_D^\rho - c_0^\rho)} \frac{(f_D - f_0)}{(f_F - f_D)} {\varphi_F}^\rho. \tag{A.3}$$

Equation (A.3) implies that for any φ_D, there exists a unique φ_F. The partitioning of firms by outsourcing type ($\varphi_F > \varphi_D$) will occur if the relative transaction costs are higher than the relative increase in productivity due to outsourcing, i.e., $\dfrac{c_F^\rho - c_D^\rho}{c_D^\rho - c_0^\rho} < \dfrac{f_F - f_D}{f_D - f_0}$. Furthermore, in the equilibrium some firms do not outsource (that is the case when $\varphi_D > 1$), as we observe in the data, if the relative transaction cost between outsourcing domestically and not outsourcing is high: $(f_D / f_0) > c_D^{\rho}$. The reason is as follows: the zero profit condition, i.e., $\Pi(1, c_0 = 1) = 0$, implies that $\frac{E}{M}\frac{(1-\alpha)(\psi-\rho)}{\psi}\frac{1}{\xi} = (1+r_0) f_0 \Leftrightarrow$

$$\Leftrightarrow \frac{E}{M}\frac{(1-\alpha)(\psi-\rho)}{\psi(1+r_0) f_0} - 1 = (c_D^{\rho} - c_0^{\rho})\varphi_D{}^{\rho-\psi} + (c_F^{\rho} - c_D^{\rho})\varphi_F{}^{\rho-\psi} . \tag{A.4}$$

Furthermore, we know that $\Pi(1, c_D) = \frac{E}{M}\frac{(1-\alpha)(\psi-\rho)}{\psi}\frac{c_D^{\rho}}{\xi} - (1+r_0) f_D$. Substituting the zero profit condition in the previous equation, we obtain that $\Pi(1, c_D) = (1+r_0) f_0 c_D^{\rho} - (1+r_0) f_D$, which implies that if $(f_D / f_0) > c_D^{\rho}$, then $\Pi(1, c_D) < 0$. This is enough to show that $\varphi_D > 1$. Note that if $c_F \le c_D$ and $f_F > f_D$, firms would not have incentives to outsource abroad. In this case, firms would only outsource domestically.

Substituting equation (A.3) into (A.4), and after some arithmetic calculations, we find that there is a unique threshold efficiency value φ_F given by

$$\varphi_F{}^{\rho-\psi} = \left[\frac{E}{M}\frac{(1-\alpha)(\psi-\rho)}{\psi(1+r_0) f_0} - 1\right] \frac{(f_F - f_D)^{1-\psi/\rho}}{(c_F^{\rho} - c_D^{\rho})^{1-\psi/\rho}[(f_D - f_0)^{1-\psi/\rho}(c_D^{\rho} - c_0^{\rho})^{\psi/\rho} + (c_F^{\rho} - c_D^{\rho})^{\psi/\rho}(f_F - f_D)^{1-\psi/\rho}]}$$

which ends the proof.

Note that if the market size increases (E), the number of firms (M) decreases, or the riskless interest rate (r_0**)** decreases, the threshold values φ_F, and φ_D decrease since $\psi > \rho$. Moreover, since $c_F = \zeta c_D$, the threshold value φ_F increases if ζ increases.

Proof that the threshold efficiency for outsourcing (both domestically and abroad) is larger for non-exporters than for exporters.

Let $\varphi_{D,nx}$ be the threshold efficiency levels for non-exporters such that outsourcing domestically or not outsourcing imply the same maximum profits for the company. It satisfies the following expression, $\Pi_{nx}(\varphi_{D,nx}, c_0) = \Pi_{nx}(\varphi_{D,nx}, c_D)$. Moreover, for $\varphi < \varphi_{D,nx}$, non-exporters prefer not to outsource, i.e., $\Pi_{nx}(\varphi, c_0) > \Pi_{nx}(\varphi, c_D)$, and for $\varphi > \varphi_{D,nx}$, non-exporters prefer to outsource domestically, i.e., $\Pi_{nx}(\varphi, c_0) < \Pi_{nx}(\varphi, c_D)$. Similarly, for exporters we know that for $\varphi < \varphi_{D,x}$, exporters do not outsource, i.e., $\Pi_x(\varphi, c_0) > \Pi_x(\varphi, c_D)$, and for $\varphi > \varphi_{D,x}$, exporters prefer to outsource domestically, i.e., $\Pi_x(\varphi, c_0) < \Pi_x(\varphi, c_D)$. The threshold efficiency level such that outsourcing domestically or not outsourcing imply the same maximum profits for exporters satisfies: $\Pi_x(\varphi_{D,x}, c_0) = \Pi_x(\varphi_{D,x}, c_D)$. This is equivalent to the following equation,

$$\Pi_{nx}(\varphi_{D,x}, c_0) + \frac{(\varphi_{D,x}\ c_0)^{\rho} E\ (\tau - \alpha)\tau^{1/(\alpha-1)}}{P(\phi)} = \Pi_{nx}(\varphi_{D,x}, c_D) + \frac{(\varphi_{D,x} c_D)^{\rho} E\ (\tau - \alpha)\tau^{1/(\alpha-1)}}{P(\phi)} \Leftrightarrow$$

$$\Leftrightarrow \Pi_{nx}(\varphi_{D,x}, c_0) - \Pi_{nx}(\varphi_{D,x}, c_D) = \frac{(\varphi_{D,x})^{\rho} E\ (\tau - \alpha)\tau^{1/(\alpha-1)}}{P(\phi)}(c_D^{\rho} - c_0^{\rho}) ,$$

which is always positive since $\tau > 1 > \alpha$. In summary, first of all, we know that if $\varphi_{D,x} < \varphi_{D,nx}$, then $\Pi_{nx}(\varphi_{D,x}, c_0) > \Pi_{nx}(\varphi_{D,x}, c_D)$, and that if $\varphi_{D,x} > \varphi_{D,nx}$, then $\Pi_{nx}(\varphi_{D,x}, c_0) > \Pi_{nx}(\varphi_{D,x}, c_D)$. Secondly, we have just obtained that $\Pi_{nx}(\varphi_{D,x}, c_0) - \Pi_{nx}(\varphi_{D,x}, c_D) > 0$. Therefore, $\varphi_{D,x} < \varphi_{D,nx}$. It follows immediately with the same argument that $\varphi_{F,x} < \varphi_{F,nx}$ if $c_F > c_D$. Hence, threshold efficiency for outsourcing both domestically and abroad is larger for non-exporters than for exporters if $\zeta > 1$. Q.E.D.

Proof that the efficiency threshold to obtain financial resources for outsourcing is lower for exporters than for non-exporters.

Operating profits of an exporter with efficiency φ that decides to outsource can be expressed in terms of its profits if it does not export as: $\Pi_x^0(\varphi, c_i) = \Pi_{nx}^0(\varphi, c_i) + \frac{(\varphi\, c_i)^\rho E\ (\tau-\alpha)\tau^{1/(\alpha-1)}}{P(\bar{\phi})}$ for $i = D, F$ where $P(\bar{\phi}) = P(\bar{\varphi}_{D,nx}, \bar{\varphi}_{D,x}, \bar{\varphi}_{F,x}, \bar{\varphi}_{F,nx})$ is the aggregate weighted price. Therefore, equation (4) can be written as $\Pi_{nx}^0(\bar{\varphi}_{i,x}, c_i) + \frac{(\bar{\varphi}_{i,x}\ c_i)^\rho E\ (\tau-\alpha)\tau^{1/(\alpha-1)}}{P(\bar{\phi})} = \frac{(1+r_0) f_i - (1-\lambda)C}{\lambda}$. Or equivalently as:

$$\Pi_{nx}^0(\bar{\varphi}_{i,x}, c_i) = \frac{(1+r_0) f_i - (1-\lambda)C}{\lambda} - \frac{(\bar{\varphi}_{i,x}\ c_i)^\rho E\ (\tau-\alpha)\tau^{1/(\alpha-1)}}{P(\bar{\phi})} < \frac{(1+r_0) f_i - (1-\lambda)C}{\lambda},$$

which implies that $\bar{\varphi}_{i,x} < \bar{\varphi}_{i,nx}$, for $i = D, F$.

Proof that the increase in the efficiency threshold needed to outsource when there are financial constraints is larger for non-exporters than for exporters: $\bar{\varphi}_{i,x} - \varphi_{i,x} < \bar{\varphi}_{i,nx} - \varphi_{i,nx}$ for $i = D, F$.

We present the proof for $i = D$. The analysis is the same for international outsourcing, i.e., for $i = F$. We know that the efficiency threshold to outsource domestically without financial constraints solves the following equation: $\Pi_{nx}(\varphi_{D,nx}, c_0) = \Pi(\varphi_{D,nx}, c_D)$. Therefore, we obtain that $\varphi_{D,nx}^\rho = (1+r_0)(f_D - f_0)\frac{P(\phi)}{(c_D^\rho - c_0^\rho)E(1-\alpha)}$, where $P(\phi)$ represents the aggregate price under free trade without financial constraints. The minimum efficiency level to outsource domestically with financial constraints is given by $\Pi_{nx}^0(\bar{\varphi}_{D,nx}, c_D) = \frac{(1+r_0) f_D - (1-\lambda)C}{\lambda}$. Consequently, $\bar{\varphi}_{D,nx}^\rho = \frac{(1+r_0) f_D - (1-\lambda)C}{\lambda}\frac{P(\bar{\phi})}{c_D^\rho E(1-\alpha)}$ where $P(\bar{\phi})$ is the aggregate price under free trade with financial constraints. In a similar way, we obtain the values for $\varphi_{D,x}^\rho$, and $\bar{\varphi}_{D,nx}^\rho$. In particular, we get:

$$\varphi_{D,x}^\rho = (1+r_0)(f_D - f_0)\frac{P(\phi)}{(c_D^\rho - c_0^\rho)[(1-\alpha)+(\tau-\alpha)\tau^{1/(\alpha-1)}]E}, \text{ and } \bar{\varphi}_{D,nx}^\rho = \frac{(1+r_0) f_D - (1-\lambda)C}{\lambda}\frac{P(\bar{\phi})}{c_D^\rho[(1-\alpha)+(\tau-\alpha)\tau^{1/(\alpha-1)}]E}.$$

Now, we substitute the previous values and calculate $\frac{\bar{\varphi}_{D,nx} - \varphi_{D,nx}}{\bar{\varphi}_{D,x} - \varphi_{D,x}} = \left[1 + \frac{(\tau-\alpha)\tau^{1/(\alpha-1)}}{(1-\alpha)}\right]^{1/\rho}$, which is larger than one since $\rho > 0$, and $\frac{(\tau-\alpha)\tau^{1/(\alpha-1)}}{(1-\alpha)} > 0$, which ends the proof.

Appendix 2: Definitions of variables

Continuous R&D engagement: It is a dummy variable that takes the value one if the enterprise reports continuous R&D engagement in intramural R&D activities during the period 2003-2005.

Cooperation: It is a dummy variable that takes the value one if the enterprise had some co-operative arrangements on innovation during the period 2003-2005.

Exporter (t-1): It is a dummy variable that takes the value one if the enterprise exported in 2004.

Export intensity (t-1): Exports per employee in 2004 (in logarithms).

Geographical regions:

Basque Country: It is a dummy variable that takes the value one if the firm is located in the Basque Country.
Catalonia: It is a dummy variable that takes the value one if the firm is located in Catalonia.
Madrid: It is a dummy variable that takes the value one if the firm is located in Madrid.

Lack of finance: In the database, the companies are asked: *"During the three years 2003 to 2005, how important were the following factors for hampering your innovation activities? Lack of funds within your enterprise or group, lack of finance from sources outside your enterprise, and innovation costs too high"*

For each of the factors, the company can answer that the importance of the factor was high, intermediate, or low, or that the factor was not experienced. We assign a number that varies from zero (not experienced) to three (high importance) for each answer. Then, we calculate the average importance of the cost factors. This is our variable *lack of finance.*

Lack of information: In the database, the companies are asked: *"During the three years 2003 to 2005, how important were the following factors for hampering your innovation activities? Lack of information on technology, and lack of information on markets"*

For each of the factors, the company can answer that the importance of the factor was high, intermediate, or low, or that the factor was not experienced. We assign a number that varies from zero (not experienced) to three (high importance) for each answer. Then, we calculate the average of the importance of the knowledge factors. This is our *lack of information* variable.

Patent: It is a dummy variable that takes the value one if the firm applied for patents during the period 2003-2005.

Proxies for market proximity: In the database, the companies are asked: *"In the period 2003-2005, what was the importance of each of the following sources of information in order to innovate?"* For each of the sources, the company can answer that the importance of the source was high, intermediate, or low.

Internal sources of information: It is a dummy variable that takes the value one if information from internal sources (within the company or the firm's group) were of high importance. It takes the value zero otherwise.
Institutional sources of information: It is a dummy variable that takes the value one if information from universities or other higher education or research institutes were of high importance. It takes the value zero otherwise.
Market sources of information: It is a dummy variable that takes the value one if information from suppliers, customers, competitors, scientific media or professional associations were of high importance. It takes the value zero otherwise.

R&D employment: R&D employment over total employment in 2005.

R&D expenditure at foreign locations: In the database, the companies are asked about the expenditures in 2005 corresponding to *"acquisitions of R&D services outside the firm from foreign providers through contracts, informal agreements…"*. (This variable is included in logarithms).

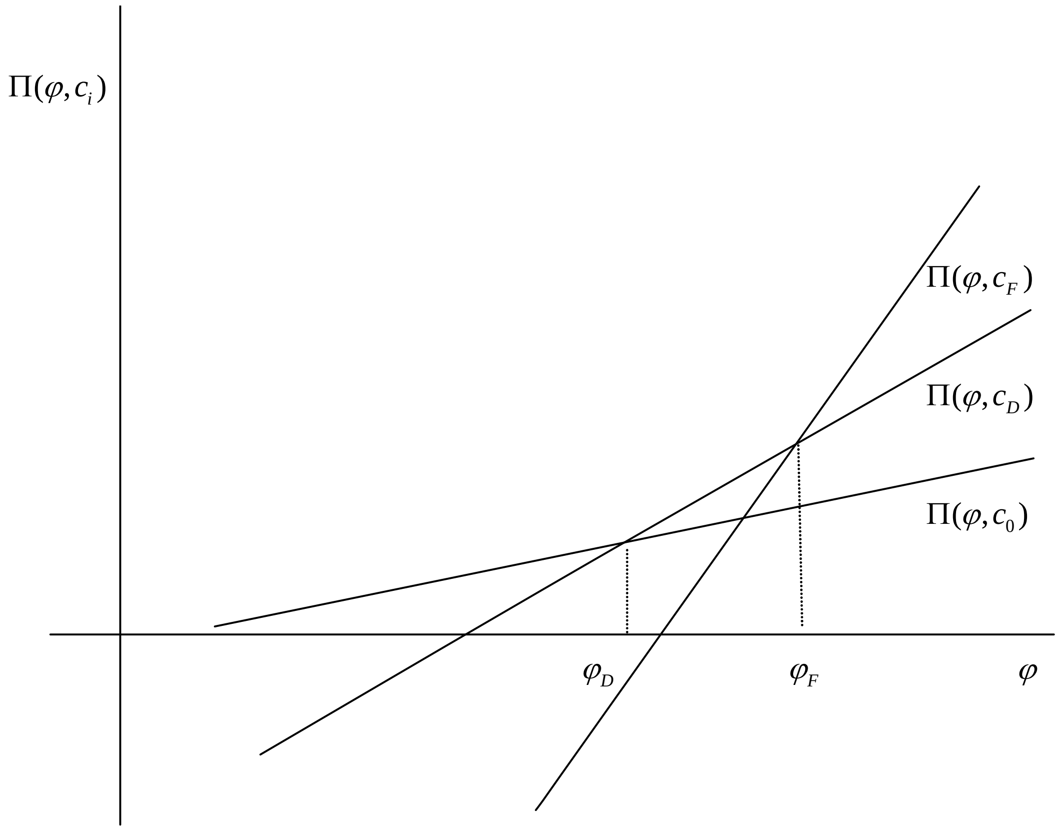
Size: Number of employees in 2005.

Table A1

Classification of high and mid-high technology sectors

NACE-Rev.1	Sectors
	High and mid-high technology manufacturing sectors
24	Chemicals and chemical products
29	Machinery and equipment n.e.c.
30	Office machinery and computers
31	Electrical machinery and apparatus n.e.c.
32	Radio, television and communication equipment…
33	Medical, precision and optical instruments…
34	Motor vehicles, trailers and semi-trailers
35	Other transport equipment
	High technology services
64	Post and telecommunications
72	Computer and related activities
73	Research and development

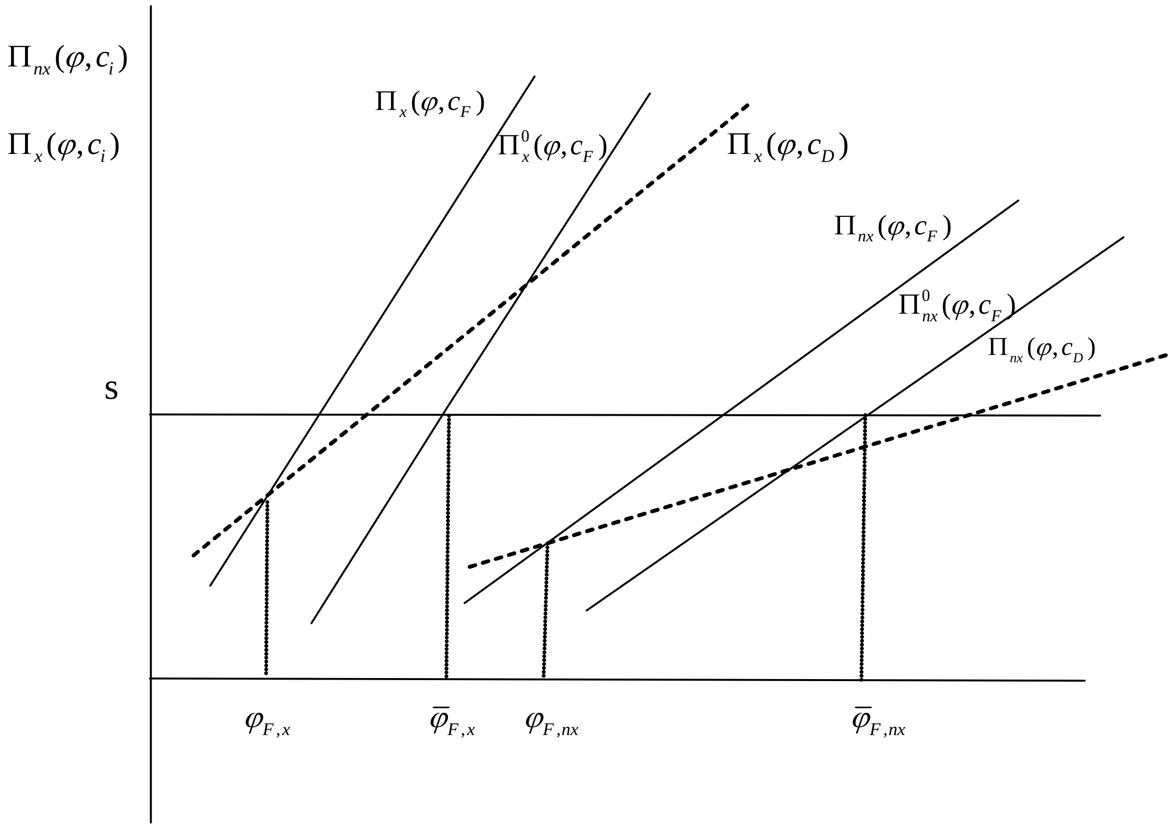
Figure 1
Efficiency thresholds to outsource domestically and abroad in autarky



Note: The function $\Pi(\varphi, c_i)$ with $i = 0, D, F$ is the profit function for a firm with efficiency φ that decides not to outsource ($i = 0$), to outsource domestically ($i = D$), or to outsource abroad ($i = F$).

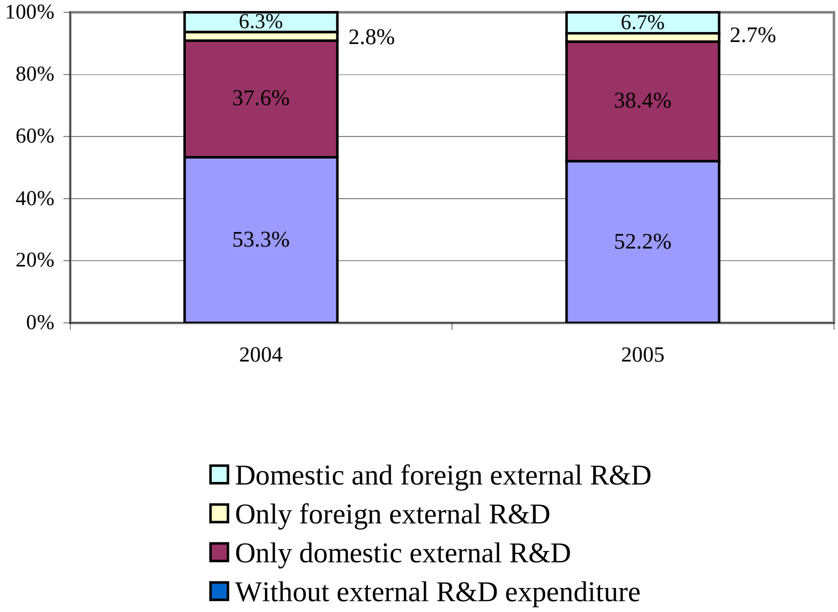
<u>Figure 2</u>

Efficiency thresholds to outsource R&D internationally for exporters and non-exporters with financial constraints.

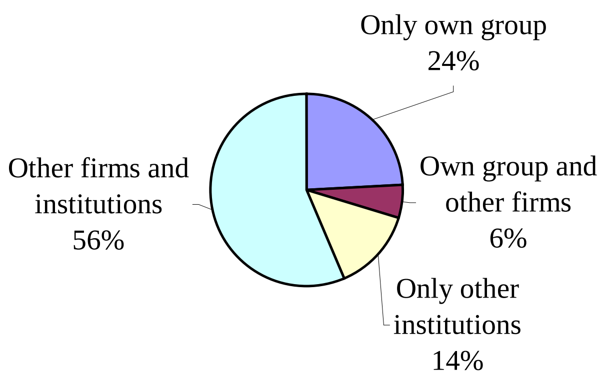


Note: The function $\Pi_{nx}(\varphi, c_D)$ is the profit function of a non-exporter when it outsources domestically, $\Pi_{nx}(\varphi, c_F)$ is the profit function for a non-exporter when it outsources abroad, $\Pi_{x}(\varphi, c_D)$ is the profit function of an exporter when it outsources domestically, $\Pi_{x}(\varphi, c_F)$ is the profit function for an exporter when it outsources abroad, Π^0_{nx} and Π^0_{x} are operating profits for non-exporters and exporters, respectively, and s is the firm's financial constraint to outsource abroad, i.e., $s = [(1+r_0)f_F - (1-\lambda)C]/\lambda$.

<u>Figure 3</u>
External R&D expenditure by location in 2004 and 2005
(Percentage of firms in the sample of continuous innovators)



<u>Figure 4</u>
External R&D expenditure at foreign locations by provider in 2005
(Percentage of firms)



Note: Other institutions include public administration, universities, non-profitable institutions and other international organizations.

Figure 5

R&D outsourcing by exporting activity in 2005.

(Percentage of firms in the sample of firms with external R&D expenditures)

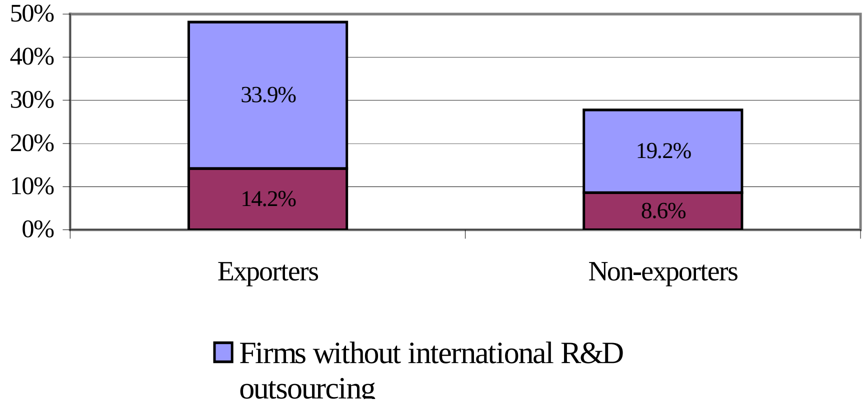


Figure 6

Lack of finance by exporting activity in 2005

(Mean value in the sample of firms with external R&D expenditures)

Figure 7

Lack of information by exporting activity in 2005

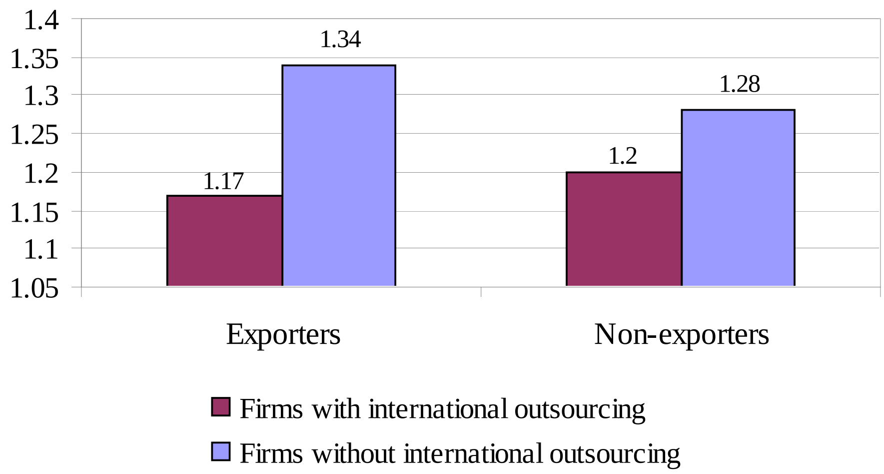


Table 1
Descriptive Statistics

	Firms with R&D expenditure		Firms with external R&D expenditure		Firms with international outsourcing	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
R&D expenditure at foreign locations (in log.)	0.53	2.35	1.28	3.52	10.56	2.08
Exporter	0.57	0.49	0.63	0.48	0.74	0.44
Exporter (t-1)	0.37	0.48	0.45	0.50	0.59	0.49
Export intensity (in log.)	5.70	5.11	6.32	5.09	7.64	4.85
Lack of finance	1.80	0.89	1.80	0.88	1.75	0.88
Lack of information	1.27	0.78	1.30	0.77	1.18	0.73
Proxies for market proximity						
Internal sources of information	0.62	0.48	0.64	0.48	0.69	0.46
Institutional sources of information	0.18	0.38	0.26	0.44	0.26	0.44
Market sources of information	0.53	0.50	0.58	0.49	0.69	0.46
Absorptive capacity						
Continuous R&D engagement	0.69	0.46	0.70	0.46	0.84	0.37
R&D employment (% over total employment)	23.14	28.41	24.64	30.14	27.10	30.57
Multinational: subsidiary	0.13	0.34	0.16	0.37	0.22	0.41
Multinational: parent company	0.07	0.25	0.09	0.29	0.11	0.31
Patent	0.17	0.38	0.22	0.41	0.33	0.47
Technological cooperation	0.39	0.49	0.55	0.50	0.59	0.49
Size (number of employees)	241.8	1554.8	336.7	2050.8	353.1	930.8
Geographical regions						
Basque country	0.13	0.34	0.14	0.35	0.12	0.33
Catalonia	0.26	0.44	0.22	0.42	0.32	0.46
Madrid	0.14	0.35	0.13	0.33	0.17	0.38

Table 2

Determinants of R&D outsourcing (both nationally and internationally)

Probit model

	All firms			**Manufacturing**			**Services**		
	dy/dx		Std. E.	*dy/dx*		Std. E.	*dy/dx*		Std. E.
Exporter (t-1)	0.056	***	0.015	0.047	***	0.018	0.055	*	0.030
Export intensity (t-1)	0.006	***	0.001	0.006	***	0.002	0.006	**	0.003
Lack of finance	-0.006		0.007	-0.005		0.010	-0.007		0.012
Lack of information	0.009		0.008	0.009		0.011	0.014		0.014
Proxies for market proximity									
Internal sources of information	0.018		0.013	0.032	*	0.016	-0.001		0.021
Institutional sources of information	0.161	***	0.017	0.205	***	0.023	0.106	***	0.025
Market sources of information	0.026	**	0.012	0.017		0.016	0.046	**	0.020
Absorptive capacity									
Continuous R&D engagement	0.065	***	0.014	0.075	***	0.018	0.028		0.023
R&D employment	0.085	***	0.024	0.162	***	0.047	0.096	***	0.029
Multinational: subsidiary	0.069	***	0.019	0.053	**	0.024	0.074	**	0.033
Multinational: parent company	0.081	***	0.024	0.054	*	0.032	0.124	***	0.039
Patent	0.077	***	0.016	0.082	***	0.020	0.056	*	0.030
Technological cooperation	0.238	***	0.013	0.235	***	0.017	0.226	***	0.020
Size	2.3E-05	**	9.1E-06	1.7E-04	***	3.8E-05	1.2E-05		1.1E-05
Size squared	-3.0E-10		2.2E-10	-2.0E-08	***	4.7E-09	-4.4E-11		2.4E-10
High and mid-tech manufacturing	0.007		0.014	-0.008		0.016			
High-tech services	-0.079	***	0.019				-0.046	**	0.021
Pseudo R2	0.11			0.12			0.10		
Log likelihood	-4,282.94			-2,609.11			-1,519.04		
Number of observations	7,205			4,378			2,602		

Note: Std. E.: Estimated standard error. All regressions include the constant and dummies for geographical regions. Marginal effects (*dy/dx*) are computed at sample means. For dummy variables. the marginal effect corresponds to the discrete change from 0 to 1. * Significant at 10%. ** significant at 5%. *** significant at 1%.

Table 3
Determinants of international R&D outsourcing
Generalized Tobit model

	All firms					
	(1) Locating R&D abroad			(2) Foreign R&D expenditure		
	Coefficient		Std. E.	Coefficient		Std. E.
Exporter (t-1)	0.302	***	0.068			
Export intensity (t-1)				0.060	**	0.026
Lack of finance	-0.002		0.040	-0.259	**	0.127
Lack of information	-0.127	***	0.044	-0.266		0.167
Proxies for market proximity						
Internal sources of information	0.031		0.068	-0.252		0.218
Institutional sources of information	-0.163	**	0.072	0.096		0.287
Market sources of information	0.241	***	0.067	0.632	**	0.248
Absorptive capacity						
Continuous R&D engagement	0.146		0.089			
R&D employment	0.350	***	0.111	0.928		0.894
Multinational: subsidiary	0.212	***	0.080	0.725	**	0.289
Patent	0.235	***	0.070	0.640	**	0.290
Size	0.0003	***	0.9E-04	0.001	***	0.0004
Size squared	-3.0E-08	**	1.2E-08	-1.2E-07		7.4E-08
High and mid-tech manufacturing	0.164	**	0.070	0.850	***	0.253
High-tech services	0.166		0.102	0.502		0.408
Selection term				0.677	**	0.179
	dy/dx		Std. E.	*dy/dx*		Std. E.
Exporter (t-1)	0.054	***	0.013			
Export intensity (t-1)				0.060	**	0.026
Lack of finance	0.000		0.007	-0.256	**	0.117
Lack of information	-0.022	***	0.008	-0.095		0.137
Proxies for market proximity						
Internal sources of information	0.005		0.012	-0.294		0.198
Institutional sources of information	-0.027	**	0.011	0.314		0.241
Market sources of information	0.041	***	0.011	0.309		0.218
Absorptive capacity						
Continuous R&D engagement	0.024	*	0.014			
R&D employment	0.061	***	0.019	0.459		0.837
Multinational: subsidiary	0.040	**	0.017	0.444	*	0.235
Patent	0.044	***	0.014	0.327		0.242
Log likelihood:				-1,734.11		
Number of observations	2,759			359		

Note: Std. E.: Estimated standard error. All regressions include the constant and dummies for geographical regions. Apart from coefficients. marginal effects (*dy/dx*) are reported at sample means for the probability of locating R&D abroad and for the expected value of R&D expenditures at foreign locations (in log.) conditional on locating R&D abroad. * Significant at 10%. ** significant at 5%. *** significant at 1%.

Table 4
Determinants of international R&D outsourcing
Generalized Tobit model

	(1) Locating R&D abroad		(2) Foreign R&D expenditure		(3) Locating R&D abroad		(4) Foreign R&D expenditure	
	Coefficient	Std. E.	Coefficient	Std. E.	Coefficient	Std. E.	Coefficient	Std. E.
Exporter (t-1)	0.257 ***	0.076			0.295 ***	0.075		
Export intensity (t-1)			0.049 *	0.029			0.075 **	0.029
Lack of finance: exporters	0.039	0.045	-0.151	0.138	0.031	0.045	-0.156	0.149
Lack of finance: non-exporters	-0.089	0.059	-0.537 **	0.248	-0.096 *	0.058	-0.610 **	0.256
Lack of information: exporters	-0.159 ***	0.053	-0.345 **	0.172	-0.165 ***	0.052	-0.459 **	0.183
Lack of information: non-exporters	-0.060	0.072	-0.037	0.336	-0.057	0.071	-0.048	0.340
Proxies for market proximity								
Internal sources of information	0.034	0.068	-0.224	0.213	0.042	0.067	-0.148	0.232
Institutional sources of information	-0.164 **	0.072	0.074	0.278	-0.158 **	0.072	0.107	0.275
Market sources of information	0.232 ***	0.067	0.596 **	0.248	0.240 ***	0.067	0.775 ***	0.264
Absorptive capacity								
Continuous R&D engagement	0.149	0.091			0.138	0.088		
R&D employment	0.375 ***	0.113	1.007	0.864	0.293 ***	0.110	0.451	0.788
Multinational: subsidiary	0.213 ***	0.080	0.748 **	0.295	0.227 ***	0.080	0.883 ***	0.306
Patent	0.238 ***	0.071	0.654 **	0.288	0.262 ***	0.070	0.816 ***	0.298
Size	2.9E-04 ***	8.5E-05	0.001 ***	0.0004				
Size squared	-3.0E-08 ***	1.2E-08	-1.2E-07 *	7.4E-08				
High and mid-tech manufacturing	0.159 **	0.070	0.846 ***	0.248	0.153 **	0.070	0.835 ***	0.260
High-tech services	0.177 *	0.104	0.517	0.411	0.176 *	0.102	0.661	0.415
Selection term			0.677 **	0.176			0.767 ***	0.116
	dy/dx	Std. E.	*dy/dx*	Std. E.	*dy/dx*	Std. E.	*dy/dx*	Std. E.
Exporter (t-1)	0.045 ***	0.014			0.058 ***	0.015		
Export intensity (t-1)			0.049 *	0.029			0.075 **	0.029
Lack of finance: exporters	0.007	0.008	-0.204	0.127	0.006	0.009	-0.209	0.133
Lack of finance: non-exporters	-0.015	0.010	-0.418 *	0.245	-0.019 *	0.011	-0.448 *	0.245
Lack of information: exporters	-0.027 ***	0.009	-0.132	0.138	-0.032 ***	0.010	-0.180	0.143
Lack of information: non-exporters	-0.010	0.012	0.043	0.320	-0.011	0.014	0.048	0.321
Proxies for market proximity								
Internal sources of information	0.006	0.011	-0.269	0.194	0.008	0.013	-0.219	0.203
Institutional sources of information	-0.027 **	0.011	0.295	0.235	-0.029 **	0.013	0.375	0.231
Market sources of information	0.039 ***	0.011	0.284	0.212	0.045 ***	0.012	0.369 *	0.218
Absorptive capacity								
Continuous R&D engagement	0.024 *	0.014			0.025 *	0.015		
R&D employment	0.065 ***	0.019	0.504	0.813	0.057 ***	0.021	-0.044	0.763
Multinational: subsidiary	0.040 **	0.017	0.464 *	0.246	0.048 ***	0.018	0.504 **	0.248
Patent	0.044 ***	0.014	0.338	0.239	0.055 ***	0.016	0.378	0.243
Log likelihood			-1,731.38				-1,746.40	
Number of observations	2,759		359		2,759		359	

See notes from Table 3.

Table 5

Determinants of international R&D outsourcing: Exporters

Generalized Tobit model

	Exporters					
	(1) Locating R&D abroad			(2) Foreign R&D expenditure		
	Coefficient		Std. E.	Coefficient		Std. E.
Exporter (t-1)	0.195	**	0.195			
Export intensity (t-1)				0.068	**	0.028
Lack of finance	0.036		0.036	-0.112		0.157
Lack of information	-0.145	***	-0.145	-0.364	**	0.177
Proxies for market proximity						
Internal sources of information	0.039		0.039	-0.276		0.277
Institutional sources of information	-0.094		-0.094	0.175		0.292
Market sources of information	0.185	**	0.185	0.735	***	0.280
Absorptive capacity						
Continuous R&D engagement	0.294	***	0.294			
R&D employment	0.448	***	0.448	1.897	**	0.734
Multinational: subsidiary	0.089		0.089	0.582	*	0.336
Patent	0.151	*	0.151	0.586	**	0.287
Size	0.0004	***	9.7E-05	0.002	***	0.0004
Size squared	-3.5E-08	***	1.2E-08	-1.5E-07	**	6.8E-08
High and mid-tech manufacturing	0.135	*	0.135	0.853	***	0.274
High-tech services	0.169		0.169	0.633		0.545
Selection term				0.866	**	0.956
	dy/dx		Std. E.	*dy/dx*		Std. E.
Exporter (t-1)	0.041	**	0.017			
Export intensity (t-1)				0.068	**	0.028
Lack of finance	0.008		0.011	-0.179		0.132
Lack of information	-0.032	***	0.012	-0.088		0.139
Proxies for market proximity						
Internal sources of information	0.008		0.017	-0.351		0.233
Institutional sources of information	-0.020		0.018	0.354		0.241
Market sources of information	0.039	**	0.017	0.382	*	0.228
Absorptive capacity						
Continuous R&D engagement	0.058	***	0.018			
R&D employment	0.098	***	0.035	1.044	*	0.605
Multinational: subsidiary	0.020		0.023	0.414		0.275
Patent	0.034	*	0.019	0.301		0.249
Log likelihood:				-1,218.66		
Number of observations	1,752			265		

Note: Std. E.: Estimated standard error. All regressions include the constant and dummies for geographical regions. Apart from coefficients. marginal effects (*dy/dx*) are reported at sample means for the probability of locating R&D abroad and for the expected value of R&D expenditures at foreign locations (in log.) conditional on locating R&D abroad. * Significant at 10%. ** significant at 5%. *** significant at 1%.