

# **Determinants of R&D outsourcing at foreign locations: Evidence from Spanish companies**

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Abstract

We investigate the determinants of innovative outsourcing using a cross-section database of Spanish companies. We distinguish between outsourcing from companies in the national market, and at foreign locations. We show that firms that face financial constraints tend to outsource R&D in the domestic market. However, as the firm becomes more global, through trade, companies tend to outsource abroad, substituting financial difficulties by the sources of information from the market as a major determinant to outsource. These results highlight the relevance of market information in competitive markets, and the role of trade to induce companies to engage in other globalization modes.

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## **1.- Introduction**

It seems widely believed that companies outsource routine activities of their production process while at the same time keep their knowledge intensive tasks domestically (Antràs *et al.*, 2006a,b, among others). However, firms that outsource part of their innovative activities have certain advantages. As Baumol (2001, 2003) points out, companies obtain profits from the coordination and acquisition of technology from other firms, including competitors, because there is a reduction of both the cost and risk of R&D investments. Outsourcing of production has been studied by many authors (Grossman and Helpman, 2005, and Görg *et al.* 2007, among others) due to the possible negative impact on the domestic labour force. Despite the increasing relevance of innovative outsourcing, and that international R&D outsourcing can lead to a reduction in the innovative activities of a country, there have not been many studies that tackle the determinants of innovative outsourcing at foreign locations. In this paper, we analyse why companies outsource R&D abroad, specifically investigating the role of trade to enhance firm's purchase of technology.

In high competitive industries where technical change is frequent with products and process becoming rapidly obsolete, information from the market provided by other companies is a key determinant for the firm's survival<sup>1</sup>. Firms can require the development of non-core technological areas (Brusoni *et al.* 2001), and investments in multiple technologies to keep-up-to date (Quinn, 2000). R&D activities involve high fixed costs, and require a high operation scale to become profitable. For this reason, it is not feasible to create in-house specialized knowledge in some range of technologies (Mol, 2005). Furthermore, companies can benefit from buyer-supplier relations to

exchange know-how (Dyer and Nobeoka, 2000, Kinder, 2003). Technological outsourcing at foreign locations can be particularly relevant for exporters because they face a more competitive environment (Melitz, 2003, Bernard et al. 2003, Dunning and Narula, 1995), they are less financially constrained (Greenaway et al. 2007), and they can face lower costs of finding suppliers abroad (Görg et al. 2007, Sjöholm, 2003). Innovative outsourcing abroad can allow them to both the access to a wider technological network, and to adjust better their products to the specificities of the foreign market demand. Moreover, there are complementarities between different types of internationalization strategies which induce firms to follow several globalization modes simultaneously (Tomiura, 2007, Grossman et al., 2005, Yeaple, 2003).

Some articles have looked at the determinants of R&D outsourcing. Arvanitis and Hollenstein (2006) investigate the factors that promote investments in foreign R&D for Swiss firms. They find that, on the one hand, there is a relationship between market-seeking advantages and expenditures of R&D abroad. On the other hand, they document that domestic and international R&D are complementary activities. Braga and Willmore (1991), using data for Brazilian firms, also emphasize the complementarities between imports of technology and internal technological effort. They show that globalisation is an important determinant for technological purchases and R&D effort. Our study differs from the previously mentioned authors in that we can specifically analyse determinants of innovative international outsourcing such as the role of trade, financial constraints, and market information, in addition to study whether technological imports substitute domestic innovation at the firm level.

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<sup>1</sup> See Mol (2005) for a summary of the main reasons that induce outsourcing in high innovative

In order to explain the link between trade and R&D outsourcing, we propose a theoretical model with heterogeneous firms<sup>2</sup>. Companies that become more global, through trade, tend to outsource more abroad for two reasons. First of all, R&D outsourcing is an investment that requires some fixed transaction costs. As exporters are selling to larger markets than non-exporters, outsourcing at foreign locations is relatively less costly for exporters. Secondly, we show that exporters can face less financial constraints than non-exporter companies which ease the purchase of technology in other country. Our empirical results fit with the theoretical framework. Using a cross-section of Spanish companies, we find that continuous exporters, and more productive firms have more incentives to outsource R&D abroad. This result suggests that foreign R&D outsourcing is not substituting domestic innovation at the firm level. Domestic companies face financial constraints to outsource both domestically and abroad. Moreover, financial factors act as a barrier to both the decision to outsource and the quantity that companies outsource. For exporters, financial constraints do not affect domestic outsourcing. However, it negatively influences the decision to outsource abroad, although not the quantity that they outsource. This finding suggests that exporters outsource more abroad than non exporters due to lower financial constraints and not because they have advantages to find suppliers abroad. These outcomes are consistent with the financial literature that has evidenced that small and fast growing firms face tighter financial constraints (Cooley and Quadri, 2001). Furthermore, our study suggests that as firms become more global the importance of financial constraints is substituted by the information from the market as a factor that

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industries, and Arora et al. (2001) for various forms of markets of technology.

<sup>2</sup> To our knowledge, the only theoretical model that analyse innovative outsourcing is the one of Lai et al (2007). These authors study the decision of R&D outsourcing in a principal-agent framework where innovative outsourcing can lead to the leakage of information when it cannot be monitored.

affects imports of technology, and that exports and technological outsourcing abroad are complementary strategies of globalization.

The structure of the paper is as follows. In Section 2, we present a theoretical model for the determinants of R&D outsourcing. Section 3 sets out the empirical methodology, and describes the data. Section 4 presents the empirical results of the estimations. Finally, Section 5 concludes.

## **2.- The model**

We analyse an monopolistic competitive industry with a measure  $M$  of active different firms. Firms can outsource part of their innovative activities either from firms in their country, or from companies in other country. In both cases, the firm's efficiency increases. Our model follows Helpman et al. (2004) model of monopolistic competition. First, we specify the basic model in which firms cannot export, and there are no financial constraints. Then, we analyse the model with financial constraints, and finally we study the determinants of innovative outsourcing in an open economy with financial constraints.

### *2.1 Closed economy model without financial constraints*

#### *2.1.1. Demand*

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 that 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, and  $\sigma = 1/(1-\alpha)$  is the elasticity of substitution among varieties. As shown by Dixit and Stiglitz (1977), the consumer's behaviour can be modelled considering the set of varieties of the aggregate good consumed. In this set-up, the aggregate demand for any of the varieties of the differentiated product is given by

$$y_j(p) = \frac{p_j^{1/(\alpha-1)}}{P} E, \quad (2)$$

where  $E$  is 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 (see Grossman and Helpman, 1991, or Goetz, 1999, for a similar approach).

### 2.1.2 Production

As in Melitz (2003) we assume that firms are heterogeneous. Companies have different levels of productivity, denoted by  $\varphi > 1$ . Furthermore, following Helpman et al. (2004), we consider that the firm's efficiency is drawn from a Pareto distribution with support  $\varphi \in [1, \infty)$ , and shape  $k$ . More productive firms have lower marginal costs than their less productive counterparts. We assume that firms can outsource part of its innovative activities. When a company outsources its technology the firm's productivity increases. In order to simplify the model, we consider that firms that decide to outsource their R&D activities can do it either from companies in their country, or from firms in other country.

The cost to produce one unit of output is equal to  $\frac{1}{\varphi c_i}$ , where  $c_i \geq 1$ ,  $i = 0, D, F$  is a multiplicative increase<sup>3</sup> of productivity due respectively to outsourcing from companies in

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<sup>3</sup> This multiplicative form implies that firms with higher efficiency have also higher absorptive capacity than less efficient companies.

the domestic market if  $i = D$ , or<sup>4</sup> from other country if  $i = F$ . If firms do not outsource  $i = 0$ , and then there is no productivity increase, i.e.,  $c_0 = 1$ . Furthermore, we assume that  $c_F > c_D > c_0 = 1$ , i.e., the productivity increase is larger if the firm outsources in other country than in their domestic economy. This assumption is in line with the findings of Hagedoorn (1993), Brusoni et al. (2001), and Cesaroni (2004) that show that outside technology sources in some fields can be the best option for the firm to keep-up to date since it provides the possibility to buy the best available technology and an increases the firm's strategic flexibility. Moreover, Bitzer and Gershecker (?) show that international outsourcing favours knowledge spillovers. If the firm chooses do not outsource, it bears a fixed cost  $f_0$ . We model the cost of outsourcing as a transaction<sup>5</sup> fixed cost denoted by  $f_i$ , such that  $f_F > f_D > f_0$ .

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 production cost. Both the bank and the borrower are risk neutral. As in Cooley and Quadrini (2001), we assume that only one period debt contracts are signed with the bank. If the firm defaults, the bank liquidates the company, and the firm immediately exits the industry. The bank perfectly observes the firm's characteristics. It makes a take-it-or-leave-it offer to the firm at the beginning of every period, and issues funds at an interest rate  $r$ . The bank chooses the interest rate in such a way that the expected repayment from the loan is equal to the repayment of a riskless loan, as in the following equation:

$$(1 + r_0)f_i = (1 + r)f_i \lambda + (1 - \lambda)C \quad \text{where } (1 + r_0)f_i > C. \quad (3)$$

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 exogenous probability  $\lambda$ , 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  $C$ . The firm's objective consists in maximizing the profits subject to the constraints given by equations (2) and (3):

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<sup>4</sup> Since we are interested in comparing the determinants between these two types of outsourcing activities, we assume that firms either outsource completely domestically or abroad.

<sup>5</sup> See for example Feenstra et al. (2002) for a justification of outsourcing's transaction cost. We assume that the outsourcing transaction fixed cost includes the fixed production cost.

$\Pi(\varphi, c_i) = p \cdot y(p) - \left[ \frac{y(p)}{\varphi c_i} + \lambda(1+r)f_i + (1-\lambda)C \right]$ , where  $\Pi(\varphi, c_i)$  represents the profit

of a firm of type  $\varphi$  that chooses outsourcing of type  $i$ . This leads to the standard

pricing rule  $p(\varphi, c_i) = \frac{1}{\alpha \varphi c_i}$ . Firms with high levels of productivity charge lower

prices and obtain higher revenues. Furthermore, we assume that the company with lowest level of efficiency that decides do not outsource obtains zero profit, i.e.,

$\Pi(1,1) = 0$ . We show in the Appendix A that there exists two unique efficiency levels

denoted by  $\varphi_D$ , and  $\varphi_F$  such that if  $\varphi \geq \varphi_F$ , the company prefers to outsource in the

foreign country, if  $\varphi \in [\varphi_D, \varphi_F)$ , the firm outsources in the domestic market<sup>6</sup>, and finally

if  $\varphi < \varphi_D$ , the company chooses do not outsource. The threshold productivity levels are

calculated as the efficiency levels  $\varphi_D$ , and  $\varphi_F$  for which  $\Pi(\varphi_D, 1) = \Pi(\varphi_D, c_D)$ , and

$\Pi(\varphi_F, c_D) = \Pi(\varphi_F, c_F)$ . Both thresholds depend negatively on the market size  $E$ . This

reflects the simple idea that in larger markets transaction fixed costs are a lower

proportion of the total firm's income than in smaller markets. Moreover, they depend

negatively on the aggregate price in the industry, and the number of companies in the

market. This feature indicates that in more competitive markets (lower aggregate price index, and larger number of companies in the industry), the income of a given firm is

lower than in less competitive industries. Therefore, firms need to be more efficient in

order to overweight the higher transaction cost associated to outsource.

## 2.2 Closed economy model with financial constraints

We introduce financial constraints in the model assuming that banks only extend

finance to the firm if the company can offer the net revenues (operating profits) to the

creditor<sup>7</sup>, i.e.,

$$(1+r)f_i \leq \Pi^0(\varphi, c_i), \quad (4)$$

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<sup>6</sup> In this simplified model without financial constraints all firms that choose the same type of outsourcing have to pay the same interest rate independently on 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 firm's efficiency.

<sup>7</sup> For example Manova (2006) specifies the same approach.

where  $\Pi^0(\varphi, c_i)$  represents operating profits, and it is equal to  $p(\varphi, c_i)y(\varphi, c_i) - \frac{y(\varphi, c_i)}{\varphi c_i}$ .

Equations (4) and (3) determine threshold levels of efficiency denoted by  $\bar{\varphi}_D$ , and  $\bar{\varphi}_F$  needed to obtain external financial resources to outsource in the domestic market, and in the foreign market respectively. The threshold levels are obtained, on the one hand, as  $\bar{\varphi}_D$  such that  $\Pi^0(\bar{\varphi}_D, c_D) = \frac{(1+r_0)f_D - (1-\lambda)C}{\lambda}$ , on the other hand, as  $\bar{\varphi}_F$  such that  $\Pi^0(\bar{\varphi}_F, c_F) = \frac{(1+r_0)f_F - (1-\lambda)C}{\lambda}$ . In order to simplify the analysis, we assume that financial constraints bind only for outsourcing, which means that  $1 < \varphi_D < \bar{\varphi}_D < \varphi_F < \bar{\varphi}_F$  since companies can always produce without outsourcing. We show in the Appendix B the existence of two unique productivity thresholds to get credit from the bank to outsource domestically, and abroad.

### 2.3 Open economy model without financial constraints

We now assume that there are two identical countries that trade the varieties of  $Y$ . Trade for continuous exporters involve only one type of cost. There is a variable per unit cost of product that is transported<sup>8</sup>. This variable cost takes the form of an iceberg cost, so that for one unit of a good to arrive to the final destination,  $\tau > 1$  units of the good need to be shipped. While firm's prices in the domestic market are the same as before:  $p_d(\varphi, c_i) = 1/(\alpha c_i \varphi)$ , exporters set higher prices in the foreign market, due to the increase in the marginal cost. These are given by  $p_x(\varphi, c_i) = \tau/(\alpha c_i \varphi)$ . We want to know whether exporters have more incentives to outsource than non exporters. In our framework, this is equivalent to determine whether the efficiency threshold to outsource is lower for exporters than for non exporters.

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<sup>8</sup> 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.

The total profits of a non-exporter with efficiency  $\varphi$  are

$$\Pi_{nx}(\varphi, c_i) = \frac{(\varphi c_i)^\rho E (1-\alpha)}{P(\varphi_{D,x}, \varphi_{D,nx}, \varphi_{F,x}, \varphi_{F,nx})} - (1+r_0)f_i, \text{ where } P(\varphi_{D,x}, \varphi_{D,nx}, \varphi_{F,x}, \varphi_{F,nx}) \text{ is the}$$

weighted aggregate price index in the domestic economy with trade (which is equal to the aggregate price index in the foreign market). It is a function of the efficiency threshold to outsource domestically for exporters, and non-exporters (denoted respectively by  $\varphi_{D,x}$ , and  $\varphi_{D,nx}$ ), the efficiency threshold to outsource abroad for exporters, and non-exporters (denoted respectively by  $\varphi_{F,x}$ , and  $\varphi_{F,nx}$ ), and

$$\rho = \frac{\alpha}{1-\alpha} > 0.$$

The total profits of an exporter with efficiency  $\varphi$  are equal to the profits in the domestic and in the foreign market given by

$$\Pi_x(\varphi, c_i) = \frac{(\varphi c_i)^\rho E (1-\alpha)}{P(\varphi_{D,x}, \varphi_{D,nx}, \varphi_{F,x}, \varphi_{F,nx})} + \frac{(\varphi c_i)^\rho E (\tau - \alpha) \tau^{1/(\alpha-1)}}{P(\varphi_{D,x}, \varphi_{D,nx}, \varphi_{F,x}, \varphi_{F,nx})} - (1+r_0)f_i. \text{ We can}$$

express the profits of an exporter with efficiency  $\varphi$  that decides to take the decision  $i$ , in terms of its profits if it does not export as follows:

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

The threshold efficiency level for non exporters such that the company is indifferent between outsourcing or not is  $\varphi_{D,nx}$ . It satisfies the following expression,

$$\Pi_{nx}(\varphi_{D,nx}, 1) = \Pi_{nx}(\varphi_{D,nx}, c_D). \text{ Moreover, for } \varphi < \varphi_{D,nx}, \text{ then non exporters prefer do not}$$

outsource, i.e.,  $\Pi_{nx}(\varphi, 1) > \Pi_{nx}(\varphi, c_D)$ , and for  $\varphi > \varphi_{D,nx}$ , then non exporters prefer to

outsource domestically, i.e.,  $\Pi_{nx}(\varphi, 1) < \Pi_{nx}(\varphi, c_D)$ . Similarly, for exporters we know

that for  $\varphi < \varphi_{D,x}$ , then exporters do not outsource, i.e.,  $\Pi_x(\varphi, 1) > \Pi_x(\varphi, c_D)$ , and for

$\varphi > \varphi_{D,x}$ , then exporters prefer to outsource domestically, i.e.,  $\Pi_x(\varphi, 1) < \Pi_x(\varphi, c_D)$ .

The threshold efficiency level such that exporters are indifferent between outsourcing or

not satisfies that  $\Pi_x(\varphi_{D,x}, 1) = \Pi_x(\varphi_{D,x}, c_D)$ . This is equivalent to the following equation,

$$\begin{aligned} \Pi_{nx}(\varphi_{D,x}, 1) + \frac{(\varphi_{D,x})^\rho E(\tau - \alpha)\tau^{1/(\alpha-1)}}{P(\varphi_{D,x}, \varphi_{D,nx}, \varphi_{F,x}, \varphi_{F,nx})} &= \Pi_{nx}(\varphi_{D,x}, c_D) + \frac{(\varphi_{D,x}c_D)^\rho E(\tau - \alpha)\tau^{1/(\alpha-1)}}{P(\varphi_{D,x}, \varphi_{D,nx}, \varphi_{F,x}, \varphi_{F,nx})} \Leftrightarrow \\ \Leftrightarrow \Pi_{nx}(\varphi_{D,x}, 1) - \Pi_{nx}(\varphi_{D,x}, c_D) &= \frac{(\varphi_{D,x})^\rho E(\tau - \alpha)\tau^{1/(\alpha-1)}}{P(\varphi_{D,x}, \varphi_{D,nx}, \varphi_{F,x}, \varphi_{F,nx})} (c_D^\rho - 1) \quad \text{which is always} \end{aligned}$$

positive since  $\tau > \alpha$ .

First of all, we know that if  $\varphi_{D,x} < \varphi_{D,nx}$ , then  $\Pi_{nx}(\varphi_{D,x}, 1) > \Pi_{nx}(\varphi_{D,x}, c_D)$ , and that if  $\varphi_{D,x} > \varphi_{D,nx}$ , then  $\Pi_{nx}(\varphi_{D,x}, 1) > \Pi_{nx}(\varphi_{D,x}, c_D)$ . Secondly, we have just obtained that  $\Pi_{nx}(\varphi_{D,x}, 1) - \Pi_{nx}(\varphi_{D,x}, c_D) > 0$ . Therefore,  $\varphi_{D,x} < \varphi_{D,nx}$ . It follows immediately with the argument that  $\varphi_{F,x} < \varphi_{F,nx}$ . Hence, threshold efficiency for outsourcing both domestically and abroad is larger for non exporters than for exporters. This leads to the following proposition.

**Proposition 1:** *When firms become more global, through exports, they have more incentives to outsource both domestically and abroad than non exporters.*

As exporters have on average higher incomes than non exporter firms, fixed transaction cost associated to outsource becomes relatively lower in terms of the total income. Exporters need to be less efficient than non-exporters to outsource.

### 2.3 Open economy model with financial constraints

Operating profits between exporters and non-exporters differ. Therefore, the efficiency threshold to obtain financial resources is also different between the two types of companies. We denote by  $\bar{\varphi}_{D,nx}$ , and  $\bar{\varphi}_{D,x}$  the threshold efficiency to outsource domestically for non exporters and exporters respectively, while  $\bar{\varphi}_{F,nx}$ , and  $\bar{\varphi}_{F,x}$  are the

thresholds to outsource in a foreign market for non exporters and exporters. We now consider that there are financial constraints. The bank requires that companies can repay the loan. For non exporters it means that  $(1+r)f_i \leq \Pi_{nx}^0(\varphi, c_i)$ , and for exporters that  $(1+r)f_i \leq \Pi_x^0(\varphi, c_i)$ , where  $\Pi_{nx}^0(\varphi, c_i)$ , and  $\Pi_x^0(\varphi, c_i)$  are the operating profits for non-exporters and exporters respectively. We analyse, as in the closed economy model, the case in which financial constraints bind to outsource domestically and abroad. The threshold efficiency level to obtain funding to outsource for non exporters domestically can be calculated as  $\Pi_{nx}^0(\bar{\varphi}_{D,nx}, c_D) = \frac{(1+r_0)f_D - (1-\lambda)C}{\lambda}$ . A non-exporter with  $\varphi > \bar{\varphi}_{D,nx}$  obtains credit to outsource domestically, otherwise it cannot outsource. Similarly, exporters can outsource domestically if  $\varphi > \bar{\varphi}_{D,x}$ . This threshold level solves the following equation,

$$\Pi_x^0(\bar{\varphi}_{D,x}, c_D) = \frac{(1+r_0)f_D - (1-\lambda)C}{\lambda}. \quad (5)$$

Operating profits of an exporter with efficiency  $\varphi$  that decides to outsource domestically can be expressed in terms of its profits if it does not export as

$$\Pi_x^0(\varphi, c_D) = \Pi_{nx}^0(\varphi, c_D) + \frac{(\varphi c_D)^\rho E (\tau - \alpha) \tau^{1/(\alpha-1)}}{P(\bar{\varphi}_{D,nx}, \bar{\varphi}_{D,x}, \bar{\varphi}_{F,x}, \bar{\varphi}_{F,nx})},$$

where  $P(\bar{\varphi}_{D,nx}, \bar{\varphi}_{D,x}, \bar{\varphi}_{F,x}, \bar{\varphi}_{F,nx})$  is the

aggregate weighted price. Equation (5) can be written as

$$\Pi_{nx}^0(\bar{\varphi}_{D,x}, c_D) + \frac{(\bar{\varphi}_{D,x} c_D)^\rho E (\tau - \alpha) \tau^{1/(\alpha-1)}}{P(\bar{\varphi}_{D,nx}, \bar{\varphi}_{D,x}, \bar{\varphi}_{F,x}, \bar{\varphi}_{F,nx})} = \frac{(1+r_0)f_D - (1-\lambda)C}{\lambda}.$$

Or equivalently as,

$$\Pi_{nx}^0(\bar{\varphi}_{D,x}, c_D) = \frac{(1+r_0)f_D - (1-\lambda)C}{\lambda} - \frac{(\bar{\varphi}_{D,x} c_D)^\rho E (\tau - \alpha) \tau^{1/(\alpha-1)}}{P(\bar{\varphi}_{D,nx}, \bar{\varphi}_{D,x}, \bar{\varphi}_{F,x}, \bar{\varphi}_{F,nx})} < \frac{(1+r_0)f_D - (1-\lambda)C}{\lambda},$$

which implies that  $\bar{\varphi}_{D,x} < \bar{\varphi}_{D,nx}$ . It is straight forward to see that also  $\bar{\varphi}_{F,x} < \bar{\varphi}_{F,nx}$ . These results can be expressed as the following proposition.

**Proposition 2:** *As the firms become more global through exports, financial constraints become a less important factor in order to outsource innovative activities.*

Continuous exporters have more operating profits than non exporters. Our model shows that this reason leads to a decrease in the financial constraints of continuous exporters. This outcome is supported by the results of Greenaway *et al.* (2007) who find that continuous exporters tend to be financially healthier than non-exporters. The model illustrates that when a firm exports it becomes relatively easier to outsource both domestically and also abroad. We show that trade can reduce the financial requirements to obtain funding to outsource. We might observe that trade and outsourcing are complementary strategies in the firms' internationalization pattern. We now turn to examine empirically this issue.

### 3.- The empirical model and the data

The aim of this section is to describe the factors that determine R&D outsourcing at foreign locations. For this reason, in the empirical analysis we only consider firms that contract externally R&D activities. The empirical model consists of two equations to be estimated simultaneously. The first one describes the firm's decision to contract technological activities at foreign locations. The second equation refers to the intensity of this specific external R&D expenditure.

The selection equation describing whether a firm is reporting R&D expenditures at foreign locations or not, is given by:

$$rd_i = \begin{cases} 1 & \text{if } rd_i^* = w_i' \alpha + \varepsilon_i > c \\ 0 & \text{if } rd_i^* = w_i' \alpha + \varepsilon_i \leq c \end{cases} \quad (6)$$

where  $rd_i$  is the observed binary endogenous variable equal to zero for non-R&D and one for R&D reporting firms. The vector  $w_i$  reflects the firm's characteristics that influence the decision to buy R&D abroad. Conditional on firm  $i$  reporting R&D activities, we observe the amount of resources devoted to R&D abroad:

$$r_i = \begin{cases} r_i^* = z_i' \beta + e_i & \text{if } rd_i = 1 \\ 0 & \text{if } rd_i = 0 \end{cases} \quad (7)$$

We denote by  $e_i$  and  $\varepsilon_i$  the error terms, and we assume that there are distributed as a normal bivariate with zero mean, variances  $\sigma_\varepsilon^2 = 1$  and  $\sigma_e^2$ , and correlation coefficient  $\rho_{e\varepsilon}$ .

The sample used in this paper to estimate the depicted model comes from *PITEC (Panel de Innovación Tecnológica)*. It is a panel database constructed from two ongoing statistics: the Technological innovation survey, and the Statistics about R&D activities, carried out by the Spanish National Institute of Statistics in a coordinated way since 2002. This survey is specifically designed to analyse R&D and other innovative 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 correspond to sections C, D, and E of NACE 93, except non industrial companies because of the imprecision of methodological mark in the international context by other branches of activity.

Initially, the panel was integrated by two samples of firms surveyed on a census base: 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 less than 200 employees: firms with external R&D expenditure but without internal R&D expenditure, and non-innovative firms. Therefore, although 2003 is the first year of the panel, in this paper we only use the cross section for 2004 that includes 5095 innovative firms, that is, firms that either perform internally or contract R&D activities. The final

sample consists of 2710 firms with external R&D expenditure from which 410 are at foreign locations.

The definitions of the variables in the model are reported in the Appendix 2. With respect to external R&D expenditure, each firm indicates, first of all, whether it has contracted external R&D in Spain and/or at foreign locations, and, secondly, the percentage of expenditure in each case. During 2004, around half of the firms in the sample were engaged in external R&D expenditures, but only a small part of these (28.4%) were located outside Spain (see Figure 1). The database also distinguishes the firm's R&D provider: firms in the same group, other firms, public administration, universities, non-profitable institutions, and other international organizations. As it can be seen in Figure 2, a relevant set of firms (32%) contract R&D expenditure from firms belonging to the same group.

The descriptive statistics in Table 1 point out that the frequencies of the qualitative variables are quite similar between the sample of innovative firms, and the sub-sample of innovative firms with external R&D expenditures. The same feature happens with respect to the means of the variables characterizing obstacles to innovate. However, firms that locate their external expenditures outside Spain show a different behaviour. In particular, obstacles to innovate appear to be smaller in this group (see Figure 3).

In our empirical estimations, we consider three different types of variables that can affect firm's decisions to outsource R&D. Firstly, firms can need certain type of absorptive capacities to profit from R&D outsourcing, such as economies of scale coming from specialization. We take into account this argument using variables that

reflect firm's specific advantages. In this group of explanatory variables, we include the company's internal R&D resources, and its size. Additionally, we include two dummy variables denoting whether the firm has applied for patents, and whether it is part of a multinational. To capture the level of human capital within the firm, we use the proportion of R&D employment, and a binary variable for companies that are continuous R&D performers. As usual, a positive effect of firm's size is expected under the existence of economies of scale; for example, Chang and Robin (2006) show that firm's size is a key variable to explain technology imports in Taiwanese firms. An important result in the literature refers to the fact that multinationals produce with intensive technological techniques<sup>9</sup>. Being a multinational can reflect management and organization advantages or a superior knowledge capital. The same happens if the company has applied for a patent. This group of determinants is completed with a set of dummies reflecting if the firm belongs to a low-tech, medium-tech or high-tech manufacturing industry.

Secondly, we consider variables related to efficiency and resource-seeking motives. In particular, we use indexes characterising the firm's perception of the obstacles to innovate, and the importance of different sources of information. In our empirical model, we consider four types of innovation barriers; firstly, the company's lack of financial resources. Since it is widely believed that financially constraint companies use internal resources to finance their R&D activities (Bougheras *et al.* 2003), we expect that more financially constrained companies prefer to outsource within their group. Secondly, the company indicates its lack of qualified personnel. Thirdly, the firm can consider that there is no need to innovate because of earlier innovations or because

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<sup>9</sup> See for example, Girma and Görg (2002).

customers show little interest for them. And, finally, the firm expresses its lack of information for innovation, either on the technology or on the markets. The need to have access to new sources of information, especially from foreign customers, can stimulate the outsourcing of R&D activities at foreign locations. However, the existence of high transaction costs associated with the transfer of technology and the availability of domestic sources of knowledge can discourage this process. In our analysis, we include the importance of the internal sources of information. We expect that companies that outsource more within the group have better communication channels in their organizations than firms that do not outsource internally. Consequently, internal sources of information might be a determinant for outsourcing within the group. Finally, for companies that obtain innovations from institutions such as Universities or other public research centres, we expect that generally they are less market focus and tend to outsource less, independently on the type of R&D provider.

The third group of variables reflects other type of internationalisation strategies that the firm is undertaking. We include the dummy variable “being an exporter” in order to account for previous experience in foreign markets. The reason to introduce the variable R&D cooperation is that technological agreements, in particular with international partners, can be an alternative via to internalise technological spillovers, keeping at the same time the access to foreign sources of information. In addition, this allows us to capture in a simple way, the potential complementarities among these strategies.

#### **4.- Empirical results**

In this section we present the results of the estimation of the model depicted in section 3. In order to get a first approximation on the determinants of contracting external R&D

activities (at domestic and/or foreign locations), we estimate a probit model for the probability of this decision<sup>10</sup>. The results are presented in Table 2. We find that being a multinational, the application for patents, the maintenance of technological agreements, the importance of institutional and market sources of information, and belonging to a high-tech manufacturing sector are the most relevant elements that increase the propensity to buy R&D. On the contrary, internal firm's R&D capabilities, denoted by a continuous intramural R&D activity and a high ratio of R&D employment, diminish this propensity.

Having in mind the previous results, the analysis in Table 3 refers only to firms with positive R&D expenditures in 2004. A Generalized Tobit model including the participation and the intensity equations (6) and (7) is estimated consistently by maximum likelihood. Table 3 shows the results of the Tobit model estimation. The first column exhibits the coefficients of the probit model for the participation decision, while the second one corresponds to the R&D intensity that has been estimated by maximum likelihood taking into account the selection term. Initially, we tried the same set of explanatory variables for both equations ( $z_{it} = w_{it}$ ), but finally we include in the specification only those variables that result statistically significant. Notice that the correlation term  $\rho_{e\varepsilon}$  is significant pointing out the necessity of estimating a selection model for the observed intensity.

The results in column (1) show that, conditional on reporting external R&D expenditures, the majority of variables reflecting the firm's specific advantages (continuous R&D engagement, R&D employment, size, belonging to a medium or high-tech manufacturing

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<sup>10</sup> One should note that a more accurate exercise would imply the joint analysis of the make and/or buy decisions (see, for example, Cassiman and Veugelers, 1999). However, this is not the objective of this

sector) have the expected positive impact on the propensity to contract the R&D abroad. In particular, subsidiaries have a 3% more of probability, while parent companies do not differ statistically from the average. With respect to efficiency and resource-seeking motives, firms that consider internal sources of information as crucial are keener to outsource at foreign locations. However, when companies find important institutional sources of information, they give priority to domestic locations. The lack of finance and information also discourages that decision. Finally, being an exporter increases the probability of locating R&D abroad in 9%, which supports the hypothesis of complementarities between both types of internationalisation strategies. The coefficients in column (2) of Table 3 point out that the intensity of foreign R&D depends also on the export intensity decision. Furthermore, firms with a higher proportion of R&D employment invest more abroad. The result is coherent with the idea that these firms can benefit more from this kind of outsourcing because they have a larger absorptive capacity.

The estimates in columns (3) and (4) refer specifically to firms that belong to medium or high-tech manufacturing industries. We find that these companies have both more probability and intensity of buying foreign R&D. The obtained results are quite similar to previous estimations, although the variables that reflect firm's internal R&D resources are less significant. We detect two remarkable exceptions: On the one hand, the maintenance of technological agreements is positively related to the decision of locating R&D abroad. On the other hand, if there is little interest for innovations by customers or no need for innovation because of earlier innovations, the quantity of resources allocated by the firm to these activities diminishes. This last outcome suggests that for Spanish manufacturing firms, the reasons to outsource R&D abroad are less related to adapt their products,

processes or materials to the foreign market, than to have access to better inputs for innovation. However, this interpretation must be taken with caution, since R&D internationalisation strategies of firms in multinationals can be different from those of firms that do not belong to any group. As we previously mentioned, in this study we can specifically distinguish R&D outsourcing by type of provider, including for companies that are not part of any group. In order to address this issue, Table 4 presents the estimates of the determinants of locating foreign R&D expenditure only for firms that belong to the same group. The results are quite different from previous ones. The estimated coefficients of the indexes “exporter” and “lack of finance” keep sign and significance. However, unsurprisingly, being a subsidiary does not affect the propensity to locate R&D abroad, while being a parent company reduces this propensity. Internal sources of information appear now as a positive determinant of the participation decision, and the opposite effect happens with respect to the institutional sources of information. The proportion of R&D employment only affects the decision on the quantity of expenditure. In this case, the results for the complete sample are very similar to the ones of manufacturing firms.

Table 5 shows the estimations when the provider of the R&D services is not a firm of the same group. We find different patterns. Multinationals –subsidiaries and parent companies- tend to outsource in more proportion and intensity than other firms. Now, the crucial source of information to stimulate these decisions is the market instead of the firm or the group. In contrast with the estimates in Table 4, the great majority of variables reflecting firm’s R&D internal advantages show again a positive impact.

## **5.- Conclusions**

This paper enlarges the literature on the determinants of R&D outsourcing by analysing the role of trade, financial constraints, and market information. After controlling for size, our results show robust evidence for negative effects of financial constraints on the quantity of R&D outsourced at foreign locations for domestic firms. By contrast, we find no relationship for exporters. A possible reason for this result is that as firms become more global, they trade more and become less financially constrained, and at the same time, they rely more on market sources of information. -Particularly, we show that firms that outsource at foreign locations substitute financial difficulties by the sources of information from the market as a major determinant to outsource. We find that more R&D intensive companies also tend to outsource more. This finding indicates that foreign R&D is not substituting domestic innovation at the firm level. Overall, our results suggest that trade and imports of technology abroad are two complementary globalization strategies.

Our empirical results also reflect that firms that obtain part of their knowledge base from Universities, and public research centres tend to outsource less than companies that are more market focus. This outcome suggests that public R&D can either be a substitute of private R&D or that it is not used for market orientated companies. We cannot distinguish in our analysis between these alternatives. We consider that this is an important issue from a public policy perspective to analyse in future research.

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## Appendix 1: Proofs

A. *Proof of the existence of  $\varphi_D$  and  $\varphi_F$  in autarky without financial constraints.*

We want to show that in the closed economy without financial constraints there exists two unique efficiency levels denoted by  $\varphi_D$ , and  $\varphi_F$ , such that  $\Pi(\varphi_D, 1) = \Pi(\varphi_D, c_D)$ , and  $\Pi(\varphi_F, c_D) = \Pi(\varphi_F, c_F)$ . Furthermore, for  $\varphi > \varphi_F$ , then  $\Pi(\varphi, 1) < \Pi(\varphi, c_D) < \Pi(\varphi, c_F)$ , for  $\varphi \in (\varphi_D, \varphi_F)$ , then  $\Pi(\varphi, c_F) < \Pi(\varphi, c_D)$ , and  $\Pi(\varphi, 1) < \Pi(\varphi, c_D)$ , and for  $\varphi < \varphi_D$ , then  $\Pi(\varphi, c_F) < \Pi(\varphi, 1)$ , and  $\Pi(\varphi, c_D) < \Pi(\varphi, 1)$ .

If there exists two unique efficiency thresholds the price index can be expressed as

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

where  $\mu(\varphi) = \frac{k}{\varphi^{k+1}}$ , since we consider that the firm's efficiency is drawn from a Pareto distribution with support  $\varphi \in [1, \infty)$ , and shape  $k$ . After some arithmetic calculations,

we obtain that  $\int_0^M p_z^{\alpha/(\alpha-1)} dz = \frac{M \alpha^\rho k}{k - \rho} \left[ (c_D^\rho - 1)\varphi_D^{\rho-k} + (c_F^\rho - c_D^\rho)\varphi_F^{\rho-k} + 1 \right]$ , with

$\rho = \frac{\alpha}{1-\alpha} > 0$ . Additionally, we have assumed that  $k > \rho$  to ensure that the integral converges. The profits of a firm with efficiency  $\varphi$ , given that the threshold efficiency that separates firms between those that outsource within the group and outside the group is  $\hat{\varphi}$ , is equal to:

$$\begin{aligned} \Pi(\varphi, c_i) &= p(\varphi, c_i) y(\varphi, c_i) - \frac{y(\varphi, c_i)}{\varphi c_i} - (1+r_0)f_i = \\ &= \frac{E(1-\alpha)}{M \frac{k}{k-\rho}} \frac{(\varphi c_i)^\rho}{\left[ (c_D^\rho - 1)\varphi_D^{\rho-k} + (c_F^\rho - c_D^\rho)\varphi_F^{\rho-k} + 1 \right]} - (1+r_0)f_i. \end{aligned}$$

$\varphi_D$  such that  $\Pi(\varphi_D, 1) = \Pi(\varphi_D, c_D)$ , it would imply that

$$\begin{aligned}
& \frac{E(1-\alpha)}{M \frac{k}{k-\rho}} \frac{(\varphi_D)^\rho}{\left[ (c_D^\rho - 1)\varphi_D^{\rho-k} + (c_F^\rho - c_D^\rho)\varphi_F^{\rho-k} + 1 \right]} - (1+r_0)f_0 = \\
& = \frac{E(1-\alpha)}{M \frac{k}{k-\rho}} \frac{(\varphi_D c_D)^\rho}{\left[ (c_D^\rho - 1)\varphi_D^{\rho-k} + (c_F^\rho - c_D^\rho)\varphi_F^{\rho-k} + 1 \right]} - (1+r_0)f_D, \text{ which is equivalent to} \\
(1+r_0)(f_D - f_0) &= \frac{E(1-\alpha)}{M \frac{k}{k-\rho}} \frac{\varphi_D^\rho (c_D^\rho - 1)}{\left[ (c_D^\rho - 1)\varphi_D^{\rho-k} + (c_F^\rho - c_D^\rho)\varphi_F^{\rho-k} + 1 \right]}. \tag{A.1}
\end{aligned}$$

If there exists a unique  $\varphi_F$  such that  $\Pi(\varphi_F, c_D) = \Pi(\varphi_F, c_F)$ , it would imply that

$$\begin{aligned}
& \frac{E(1-\alpha)}{M \frac{k}{k-\rho}} \frac{(\varphi_F c_D)^\rho}{\left[ (c_D^\rho - 1)\varphi_D^{\rho-k} + (c_F^\rho - c_D^\rho)\varphi_F^{\rho-k} + 1 \right]} - (1+r_0)f_D = \\
& = \frac{E(1-\alpha)}{M \frac{k}{k-\rho}} \frac{(\varphi_F c_F)^\rho}{\left[ (c_D^\rho - 1)\varphi_D^{\rho-k} + (c_F^\rho - c_D^\rho)\varphi_F^{\rho-k} + 1 \right]} - (1+r_0)f_F, \text{ which is equivalent to} \\
(1+r_0)(f_F - f_D) &= \frac{E(1-\alpha)}{M \frac{k}{k-\rho}} \frac{\varphi_F^\rho (c_F^\rho - c_D^\rho)}{\left[ (c_D^\rho - 1)\varphi_D^{\rho-k} + (c_F^\rho - c_D^\rho)\varphi_F^{\rho-k} + 1 \right]}. \tag{A.2}
\end{aligned}$$

Dividing equation (A.2) over (A.1) we obtain that

$$\varphi_D^\rho = \frac{(c_F^\rho - c_D^\rho)}{(c_D^\rho - 1)} \frac{(f_D - f_0)}{(f_F - f_D)} \varphi_F^\rho. \tag{A.3}$$

Equation (A.3) implies that for any  $\varphi_D$  there exists a unique  $\varphi_F$ . From the zero profit condition, i.e.,  $\Pi(1,1) = 0$ , we get that

$$\left\{ \left[ \frac{E(1-\alpha)}{M \frac{k}{k-\rho}} \right] / [(1+r_0)f_0] \right\} - 1 = (c_D^\rho - 1)\varphi_D^{\rho-k} + (c_F^\rho - c_D^\rho)\varphi_F^{\rho-k}. \tag{A.4}$$

Substituting equation (A.3) into (A.4), and after some calculations we find that there exists a unique threshold efficiency value  $\varphi_F$  given by

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

which ends the proof.

Note that if  $E$  increases, or if  $M$  decreases, the threshold value  $\varphi_F$  decreases since  $k > \rho$ .

*B. Proof of the existence of  $\bar{\varphi}_D$ , and  $\bar{\varphi}_F$  in autarky with financial constraints.*

We want to show that in the closed economy model with financial constraints there exists two unique efficiency thresholds denoted by  $\bar{\varphi}_D$ , and  $\bar{\varphi}_F$ , such that all firms can obtain financial resources to produce. However, firms with efficiency  $\varphi < \bar{\varphi}_D$ , cannot get external resources to outsource neither domestically nor in the foreign market, and only firms with efficiency  $\varphi > \bar{\varphi}_F$  can outsource abroad. In order to simplify the analysis, we are analysing only the case in which financial constraints bind for outsourcing (i.e., if  $1 < \varphi_D < \bar{\varphi}_D < \varphi_F < \bar{\varphi}_F$ ). Note that companies with  $\varphi \in [\varphi_D, \bar{\varphi}_D)$  would outsource domestically in an economy without financial constraints, and companies with  $\varphi \in [\varphi_F, \bar{\varphi}_F)$  would outsource abroad without financial constraints.

The aggregate weighted price given by the following expression.

$$\begin{aligned} \int_0^M p_z^{\alpha/(\alpha-1)} dz &= M \left[ \int_1^{\bar{\varphi}_D} \left( \frac{1}{\alpha\varphi} \right)^{\frac{\alpha}{\alpha-1}} \mu(\varphi) d\varphi + \int_{\bar{\varphi}_D}^{\bar{\varphi}_F} \left( \frac{1}{\alpha\varphi c_D} \right)^{\frac{\alpha}{\alpha-1}} \mu(\varphi) d\varphi + \int_{\bar{\varphi}_F}^{\infty} \left( \frac{1}{\alpha\varphi c_F} \right)^{\frac{\alpha}{\alpha-1}} \mu(\varphi) d\varphi \right] = \\ &= \frac{M \alpha^\rho k}{k-\rho} \left[ (c_D^\rho - 1) \bar{\varphi}_D^{\rho-k} + (c_F^\rho - c_D^\rho) \bar{\varphi}_F^{\rho-k} + 1 \right]. \end{aligned}$$

We want to know whether there exists a unique  $\bar{\varphi}_D$  such that

$$\Pi^0(\bar{\varphi}_D, c_D) = \frac{(1+r_0)f_D - (1-\lambda)C}{\lambda}, \quad (\text{A.5})$$

$$\text{and a unique } \bar{\varphi}_F \text{ such that } \Pi^0(\bar{\varphi}_F, c_F) = \frac{(1+r_0)f_F - (1-\lambda)C}{\lambda}, \quad (\text{A.6})$$

assuming the zero profit condition  $\Pi(1,1) = 0$ .

The zero profit condition implies that

$$\begin{aligned} \Pi(1,1) &= \frac{\frac{E(1-\alpha)(k-\rho)}{Mk}}{\left[ (c_D^\rho - 1)\bar{\varphi}_D^{\rho-k} + (c_F^\rho - c_D^\rho)\bar{\varphi}_F^{\rho-k} + 1 \right]} - (1+r_0)f_0 = 0, \text{ which is equivalent to} \\ \frac{E(1-\alpha)(k-\rho)}{Mk(1+r_0)f_0} - 1 &= (c_D^\rho - 1)\bar{\varphi}_D^{\rho-k} + (c_F^\rho - c_D^\rho)\bar{\varphi}_F^{\rho-k}. \end{aligned} \quad (\text{A.7})$$

From the financial constraints (A.5), we obtain the following equation,

$$\frac{E(1-\alpha)(k-\rho)}{Mk} \frac{\bar{\varphi}_D^\rho c_D^\rho}{\left[ (c_D^\rho - 1)\bar{\varphi}_D^{\rho-k} + (c_F^\rho - c_D^\rho)\bar{\varphi}_F^{\rho-k} + 1 \right]} = \frac{(1+r_0)f_D - (1-\lambda)C}{\lambda}. \quad (\text{A.8})$$

From (A.6), we get that

$$\frac{E(1-\alpha)(k-\rho)}{Mk} \frac{\bar{\varphi}_F^\rho c_F^\rho}{\left[ (c_D^\rho - 1)\bar{\varphi}_D^{\rho-k} + (c_F^\rho - c_D^\rho)\bar{\varphi}_F^{\rho-k} + 1 \right]} = \frac{(1+r_0)f_F - (1-\lambda)C}{\lambda}. \quad (\text{A.9})$$

Dividing (A.9) over (A.8) and after some arithmetic operations, we find that for any value of  $\bar{\varphi}_F$  there exists a unique  $\bar{\varphi}_D$ , as in the case without financial constraints, as follows,

$$\bar{\varphi}_D^\rho = \frac{c_F^\rho (1+r_0)f_D - (1-\lambda)C}{c_D^\rho (1+r_0)f_F - (1-\lambda)C} \bar{\varphi}_F^\rho \quad (\text{A.10})$$

Substituting (A.10) into (A.7), we get a unique  $\bar{\varphi}_F$  that can be solved from the following expression,

$$\bar{\varphi}_F^{\rho-k} = \frac{E (1-\alpha)(k-\rho) - (1+r_0)f_0 M k}{M k(1+r_0)f_0} \frac{1}{(c_D^\rho - 1) \frac{c_F^{\rho-k}}{c_D^{\rho-k}} \left[ \frac{(1+r_0)f_D - (1-\lambda)C}{(1+r_0)f_F - (1-\lambda)C} \right]^{(\rho-k)/\rho} + (c_F^\rho - c_D^\rho)}$$

which ends the proof.

## **Appendix 2: Variable Definition**

**Continuous R&D engagement:** Dummy variable, which takes the value 1 if the enterprise reports continuous R&D engagement in intramural R&D activities during the period 2002-2004.

**Cooperation:** Dummy variable, which takes the value 1 if the enterprise had some co-operative arrangements on innovation activities during 2002-2004.

**Exporter:** Dummy variable, which takes the value 1 if the enterprise has exported in 2004.

**Export intensity:** Exports per employee in 2004 (in log.).

**Merger:** Dummy variable, which takes the value 1 if the firm's turnover has increased due to a merger during 2002-2004.

**Patent:** Dummy variable, which takes the value 1 if the firm has applied for patents during 2002-2004.

**R&D employment:** R&D employment over total employment in 2004.

**R&D expenditure at foreign locations:** R&D expenditure at foreign locations in 2004 (in log.)

**Size:** Number of employees in 2004.

### ***Obstacles to innovation***

**Lack of finance:** Average of scores of importance of cost obstacles for innovation by the firm (no suitable internal or external financing available, high costs of innovation). Number between 0 (unimportant) and 3 (crucial).

**Lack of personnel:** Score of importance of lack of qualified personnel for innovation as an obstacle to innovation by the firm. Number between 0 (unimportant) and 3 (crucial).

**Lack of information:** Average of scores of importance of lack of information for innovation as an obstacle to innovation by the firm (lack of information on technology, lack of market information). Number between 0 (unimportant) and 3 (crucial).

**No need for innovation:** Average of scores of importance of no need for innovation as an obstacle to innovation by the firm (little interest for innovations by customers, no need for innovation because of earlier innovations). Number between 0 (unimportant) and 3 (crucial).

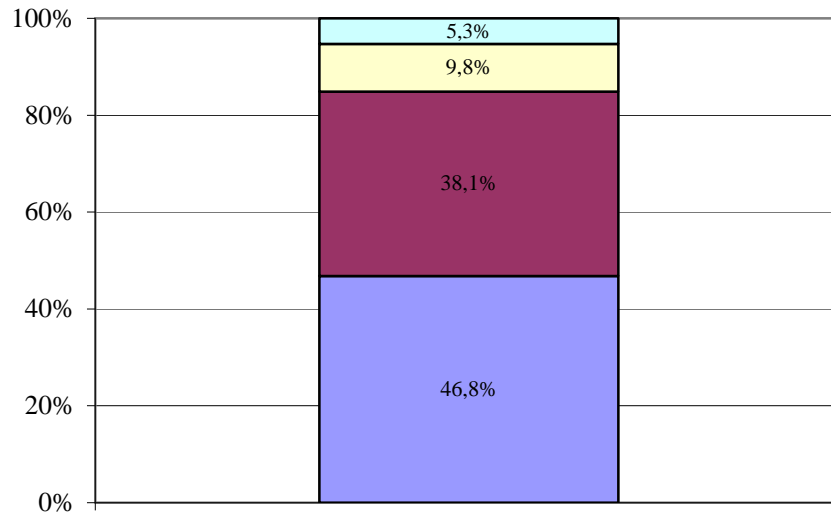
### ***Sources of information***

**Internal sources of information:** Dummy variable, which takes the value 1 if information from internal sources within the enterprise or the firm's group were of high importance during 2002-2004.

**Institutional sources of information:** Dummy variable, which takes the value 1 if information from universities or other higher education or research institutes were of high importance during 2002-2004.

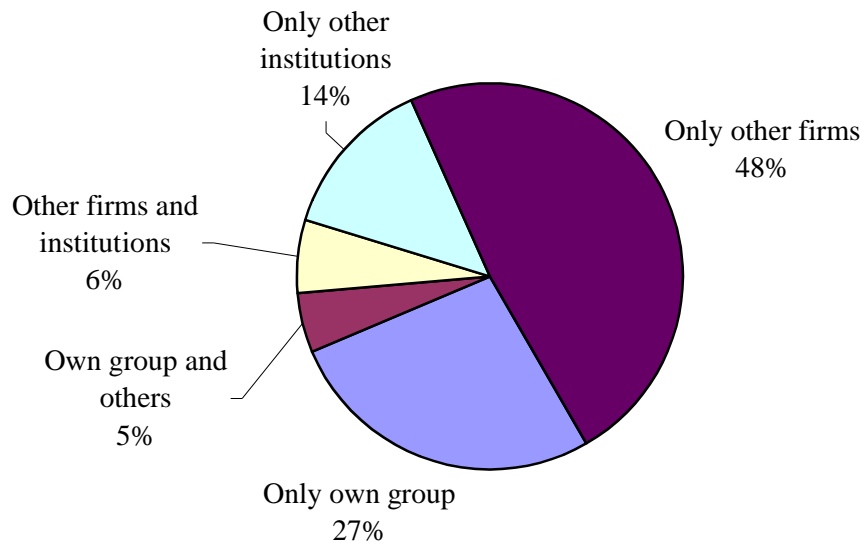
**Market sources of information:** Dummy variable, which takes the value 1 if information from suppliers, costumers, competitors, scientific media or professional associations were of high importance.

Figure 1  
External R&D expenditure by location  
(Percentage of firms in the sample of innovative firms)



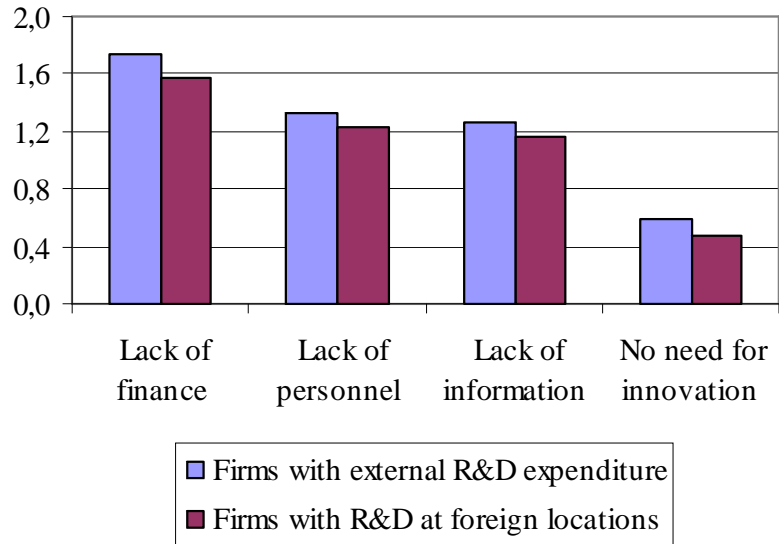
- Domestic and foreign external R&D
- Only foreign external R&D
- Only domestic external R&D
- Without external R&D expenditure

**Figure 2**  
External R&D expenditure at foreign locations by provider  
(Percentage of firms)



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

**Figure 3**  
**Obstacles to innovation**  
(Average of scores)



**Table 1**  
Descriptive Statistics

	<b>Firms with R&amp;D expenditure</b>		<b>Firms with external R&amp;D expenditure</b>		<b>Firms with foreign external R&amp;D expenditure</b>	
Qualitative (binary) variables:	Frequency		Frequency		Frequency	
Continuous R&D engagement	0.69		0.63		0.75	
Multinational: subsidiary	0.16		0.18		0.23	
Multinational: parent company	0.07		0.08		0.10	
Exporter	0.66		0.66		0.86	
Patent	0.22		0.24		0.35	
Technological cooperation	0.41		0.55		0.62	
Internal sources of information	0.58		0.58		0.70	
Institutional sources of information	0.17		0.23		0.20	
Market sources of information	0.50		0.54		0.58	
Merger	0.02		0.02		0.02	
Low-tech manufacturing	0.17		0.17		0.13	
Medium-tech manufacturing	0.35		0.35		0.43	
High-tech manufacturing	0.13		0.14		0.22	
Quantitative variables:	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
R&D expenditure at foreign locations (in log.)	0.92	3.16	1.72	4.16	11.4	2.06
At firms belonging to the same group	0.44	2.71	0.82	3.68	5.43	8.03
Except firms belonging to the same group	0.64	2.60	1.20	3.46	7.93	5.10
Export intensity (exports over total employment, in log.)	6.53	4.94	6.67	4.98	9.03	3.94
R&D employment (% over total employment)	0.16	0.24	0.15	0.25	0.18	0.26
Lack of finance	1.73	0.90	1.73	0.90	1.58	0.91
Lack of personnel	1.29	0.90	1.32	0.91	1.23	0.88
Lack of information	1.24	0.77	1.26	0.77	1.16	0.73
No need for innovation	0.59	0.74	0.59	0.75	0.48	0.65
Size (number of employees)	328.2	1840.9	402.6	2343.6	420.2	1029.6

Table 2  
Determinants of external R&D expenditure in 2004  
Probit model

	<b>All firms</b>		<b>Manufacturing</b>	
	dy/dx	Std. E.	dy/dx	Std. E.
Continuous R&D engagement	-0.203	0.016***	-0.207	0.020***
Multinational: subsidiary	0.065	0.020***	0.074	0.025***
Multinational: parent company	0.090	0.028***	0.116	0.035***
Exporter	0.020	0.018	0.013	0.024
R&D employment	-0.078	0.036**	-0.130	0.060**
Patent	0.050	0.018***	0.056	0.021***
Technological cooperation	0.280	0.015***	0.293	0.018***
Internal sources of information	-0.011	0.015	0.001	0.019
Institutional sources of information	0.191	0.020***	0.216	0.025***
Market sources of information	0.038	0.015**	0.026	0.019
Merger	-0.040	0.054	-0.084	0.070
Lack of finance	-0.022	0.009**	-0.019	0.011
Lack of personnel	0.017	0.016	0.024	0.020
Lack of information	-0.007	0.020	-0.016	0.025
No need for innovation	0.009	0.010	-0.005	0.013
Low-tech manufacturing	0.011	0.024		
Medium-tech manufacturing	0.011	0.020	0.000	0.022
High-tech manufacturing	0.079	0.025***	0.071	0.028**
Size	-0.1E-05	1.3E-05	0.7E-04	3.8E-05
Size squared	3.7E-10	5.0E-10	-7.8E-09	4.1E-09
Pseudo R2	0.11		0.12	
Log likelihood	-3150.55		-2036.94	
Number of observations	5095		3353	

Std. E.: Estimated standard error. All regressions include the constant. 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 R&D expenditure at foreign locations

	All firms				Manufacturing			
	(1)		(2)		(3)		(4)	
	Locating R&D abroad	Foreign R&D expenditure	Locating R&D abroad	Foreign R&D expenditure	Locating R&D abroad	Foreign R&D expenditure	Locating R&D abroad	Foreign R&D expenditure
	dy/dx	Std. E.	dy/dx	Std. E.	dy/dx	Std. E.	dy/dx	Std. E.
Continuous R&D engagement	0.025	0.012**			0.024	0.018		
Multinational: subsidiary	0.030	0.017*	0.240	0.219	0.026	0.024	0.006	0.250
Multinational: parent company	0.008	0.021	-0.304	0.335	0.029	0.034	-0.242	0.350
Exporter	0.089	0.013***			0.091	0.019***		
Export intensity			0.098	0.030***			0.047	0.031
R&D employment	0.108	0.026***	1.184	0.478**	0.047	0.060	0.907	0.745
Patent	0.021	0.014	-0.220	0.222	0.032	0.020	-0.193	0.243
Technological cooperation	0.012	0.012	-0.279	0.204	0.031	0.018**	-0.353	0.219
Internal sources of information	0.033	0.012***	-0.014	0.204	0.047	0.018***	-0.028	0.223
Institutional sources of information	-0.037	0.012***	-0.205	0.236	-0.054	0.019***	-0.202	0.274
Market sources of information	0.014	0.012	-0.134	0.201	0.016	0.018	-0.216	0.217
Merger	-0.040	0.030	1.318	0.783*	-0.021	0.057	0.979	0.788
Lack of finance	-0.018	0.007**	-0.197	0.115*	-0.019	0.011*	-0.174	0.122
Lack of personnel	0.018	0.013	0.183	0.213	0.017	0.020	0.001	0.255
Lack of information	-0.030	0.016*	-0.397	0.254	-0.038	0.024	-0.367	0.301
No need for innovation	-0.003	0.008	-0.187	0.153	-0.004	0.013	-0.369	0.176**
Low-tech manufacturing	0.003	0.020	-0.174	0.345				
Medium-tech manufacturing	0.058	0.018***	0.636	0.292**	0.057	0.022***	0.780	0.249***
High-tech manufacturing	0.081	0.025***	0.963	0.307***	0.090	0.031***	1.123	0.302***
Size	0.7E-04	0.1E-04***	1.0E-03	2.3E-04***	1.2E-04	0.2E-04***	1.1E-03	2.5E-04***
Size squared	-5.6E-09	0.0E-10**	-4.1E-08	0.0E-10*	-9.2E-09	0.0E-10***	-4.7E-08	0.0E-10**
rho			0.786	0.072			0.757	0.106
Log likelihood				-1871.50				-1452.23
Number of observations		2710		410		1818		328

Std. E.: Estimated standard error. All regressions include the constant. Reported are marginal effects (dy/dx) 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, respectively. \* Significant at 10%, \*\* significant at 5%, \*\*\* significant at 1%.

Table 4  
Determinants of foreign R&D expenditure at firms belonging to the same group

	All firms				Manufacturing			
	(1)		(2)		(3)		(4)	
	Locating R&D abroad	Foreign R&D expenditure	Locating R&D abroad	Foreign R&D expenditure	Locating R&D abroad	Foreign R&D expenditure	Locating R&D abroad	Foreign R&D expenditure
	dy/dx	Std. E.	dy/dx	Std. E.	dy/dx	Std. E.	dy/dx	Std. E.
Continuous R&D engagement	0.004	0.006			0.008	0.009		
Multinational: subsidiary	0.004	0.006	-0.145	0.455	-0.002	0.009	-0.275	0.505
Multinational: parent company	-0.021	0.004***	-3.563	1.551**	-0.028	0.008***	-3.646	1.563**
Exporter	0.031	0.006***			0.028	0.008***		
Export intensity			0.033	0.056			-0.021	0.051
R&D employment	-0.012	0.017	2.636	0.924***	-0.126	0.061**	3.139	1.304**
Patent	-0.004	0.005	-0.271	0.504	-0.002	0.008	-0.213	0.549
Technological cooperation	0.000	0.005	-0.414	0.329	0.002	0.008	-0.266	0.354
Internal sources of information	0.016	0.005***	0.006	0.364	0.021	0.008***	0.117	0.399
Institutional sources of information	-0.014	0.005**	-0.488	0.547	-0.021	0.008**	-0.368	0.631
Market sources of information	-0.008	0.005	0.154	0.377	-0.011	0.008	-0.118	0.397
Merger	0.012	0.019	0.559	0.800	0.059	0.046	0.709	0.733
Lack of finance	-0.012	0.003***	0.213	0.253	-0.016	0.005***	0.132	0.249
Lack of personnel	0.005	0.005	0.318	0.487	0.001	0.009	-0.284	0.493
Lack of information	-0.010	0.007	-1.173	0.626*	-0.010	0.011	-0.460	0.632
No need for innovation	-0.003	0.003	0.143	0.253	-0.003	0.006	0.046	0.260
Low-tech manufacturing	-0.011	0.007	0.012	0.706				
Medium-tech manufacturing	0.020	0.009**	1.190	0.485**	0.048	0.012***	0.954	0.618
High-tech manufacturing	0.016	0.011	0.974	0.605	0.065	0.024***	0.700	0.669
Size	0.1E-04	0.0E-10***	1.5E-03	3.1E-04***	2.6E-05	0.1E-04***	1.6E-03	0.4E-04***
Size squared	-8.5E-10	0.0E-10	-8.3E-08	0.0E-10***	-1.6E-09	0.0E-10	-8.3E-08	0.0E-10***
Rho			0.323	0.397			0.443	0.300
Log likelihood				-698.77				-572.72
Number of observations		2710		131		1818		110

Std. E.: Estimated standard error. All regressions include the constant. Reported are marginal effects (dy/dx) 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, respectively. \* Significant at 10%, \*\* significant at 5%, \*\*\* significant at 1%.

**Table 5**  
Determinants of foreign R&D expenditure except at firms belonging to the same group

	All firms				Manufacturing			
	(1)		(2)		(3)		(4)	
	Locating R&D abroad		Foreign R&D expenditure		Locating R&D abroad		Foreign R&D expenditure	
	dy/dx	Std. E.	dy/dx	Std. E.	dy/dx	Std. E.	dy/dx	Std. E.
Continuous R&D engagement	0.018	0.008**			0.026	0.014*		
Multinational: subsidiary	0.025	0.013**	0.390	0.228*	0.035	0.021*	0.220	0.265
Multinational: parent company	0.039	0.020*	0.192	0.332	0.076	0.032**	0.020	0.351
Exporter	0.042	0.011***			0.055	0.016***		
Export intensity			0.067	0.032**			0.028	0.031
R&D employment	0.091	0.022***	1.708	0.498***	0.121	0.042***	2.174	0.705***
Patent	0.027	0.011**	-0.083	0.230	0.046	0.017***	-0.076	0.260
Technological cooperation	0.012	0.008	-0.315	0.231	0.031	0.015**	-0.394	0.249
Internal sources of information	0.010	0.008	-0.148	0.217	0.019	0.015	-0.180	0.240
Institutional sources of information	-0.018	0.009**	-0.003	0.246	-0.029	0.016*	0.065	0.288
Market sources of information	0.023	0.009**	0.012	0.221	0.036	0.015**	-0.018	0.239
Merger	-0.040	0.015***	1.244	0.848	-0.070	0.027***	0.030	0.427
Lack of finance	-0.001	0.005	-0.072	0.117	0.002	0.009	-0.113	0.126
Lack of personnel	0.011	0.009	0.338	0.202*	0.018	0.016	0.217	0.243
Lack of information	-0.014	0.011	-0.272	0.247	-0.027	0.020	-0.285	0.291
No need for innovation	-0.003	0.005	-0.219	0.178	-0.003	0.010	-0.438	0.204**
Low-tech manufacturing	0.014	0.015	-0.101	0.392				
Medium-tech manufacturing	0.022	0.013*	0.434	0.329	0.002	0.018	0.419	0.268
High-tech manufacturing	0.050	0.020**	0.938	0.328***	0.037	0.024	0.857	0.325***
Size	4.7E-03	0.1E-04***	1.5E-03	3.6E-04***	0.9E-04	0.2E-04***	2.2E-03	0.5E-04***
Size squared	-6.5E-09	0.0E-10**	-1.9E-07	0.0E-10***	-0.1E-07	0.0E-10***	-3.6E-07	0.0E-10***
Rho			0.838	0.066			0.810	0.091
Log likelihood				-1432.23				-1086.98
Number of observations		2710		299		1818		233

Std. E.: Estimated standard error. All regressions include the constant. Reported are marginal effects (dy/dx) 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, respectively. \* Significant at 10%, \*\* significant at 5%, \*\*\* significant at 1%.