Journal of Technology Management & Innovation

Received June 22, 2012 / Accepted September 13, 2012 J. Technol. Manag. Innov. 2012, Volume 7, Issue 3

Analyzing the Interaction between R&D Subsidies and Firm's Innovation Strategy

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Abstract

Innovation and Technology policies provide positive incentives to the firms to perform R&D activities. This article examines the decision of internal and external R&D expenditures of subsidized firms, estimating the impact of R&D subsidies on firms performing different innovation strategies. The Spanish survey on business strategy for manufacturing firms (ESEE) is used for the period 1998-2005. Results show that determinants of pure internal or external R&D expenditures obey to different motivations, affecting in consequence, the impact of the subsidies on firms adopting different sources of knowledge.

Keywords: innovation strategy; policy evaluation, R&D subsidies; treatment effects model; internal-external R&D.

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ISSN: 0718-2724. (http://www.jotmi.org)

Introduction

R&D subsidies are central part of innovation and technology policy in industrialized economies. According to expansion of innovation policy, direct and indirect analysis for assessing impacts and outcomes of policy measures have gained importance. It is reflected in a growing stream of literature, focused on innovation policy in general and R&D subsidies in particular (Almus and Czarnitzki, 2003; Blanes and Busom, 2004; Busom, 2000; Czarnitzki, 2006; Czarnitzki and Licht, 2006; Duguet, 2004; García-Quevedo and Afcha, 2009; González and Pazó, 2008; Herrera and Heijs, 2007; Lach, 2002).

Despite the growing attention devoted to this issue, some aspects about the effectiveness of innovation policy remain unclear. In a recent work, Jaffe (2008) remarks upon the need to advance in the understanding of how governments interact with the system they are trying to affect; similar calls have been made in other pieces of work (David, Hall and Toole, 2000; Shapira and Kuhlmann, 2003). In response to this claim, some recent studies explore new connections between, and mechanism of, the public policy and programs and their impact, studying not only their direct input or output additionality, but also going a step further in the relationship between subsidies and firm's performance. (Autio, Kanninen and Gustafsson, 2008; Busom and Fernández-Ribas, 2008; Clarysse, Wright and Mustar, 2009).

Traditionally, financial additionality, commonly interpreted as the increase of firm's R&D expenditures caused by public funds, has been the main criteria used in evaluation studies. In the most of cases, this evaluation studies discard total crowding out effects of public funds at firm or project level and even find that funded firms would not have been undertaken R&D projects without the public support (Bergman et al., 2010) Behavioral additionality argues that R&D programs impact not only at the level of project but also at organizational level. Norrman and Klofsten (2010) report long term effects in Swedish firms funded by the VINN NU grants. They found an improvement in firms' knowledge of the market and their relations with external investors, Malik and Cunningham (2006) also confirm the relevance of previous experiences in funded R&D programs and its positive effect in subsequent projects.

This organizational changes due to public funds, comes preceded by decisions related with the pool of knowledge used by the firm, and in consequence, by financial decisions about R&D expenditure allocation. Therefore, this work explores R&D decisions as response to public subsidies concession.

R&D expenditure presents a heterogeneous composition that, despite being broadly recognized (Arora and Gambardella, 1990; Granstrand and Pavitt, 1997; Narula, 2001; Pisano, 1990; Teece, 1986) has not received attention from an evaluation point of view even when its application could contribute to improve innovation policy design.

Decision between internal and external R&D has been receiving growing attention (Beneito, 2003; Cassiman and Veugelers, 2006; Love and Roper, 2002; Vega-Jurado, Gutiérrez-Gracia and Fernández-de-Lucio, 2009; Watkins and Paff, 2009). These papers found that pure or mixed, internal and external R&D strategies obey different motivations and could generate differences in firm's performance. Nevertheless, to our knowledge, there are no works incorporating this distinction in order to evaluate the connection between public subsidies and innovation business strategy. Do public subsidies affect firms performing different innovation strategies in a different way? Do innovation strategies influence the reception of R&D subsidies? These, and related questions, are the main motivation of this work.

Internal-external decision is not casual, but a response of firm's perception about technological opportunities, benefits from innovation, financial restrictions and market conditions. Therefore, innovation strategy is conditioned by some specific variables.

The main hypothesis discussed in this work is that variables influencing on public decision agency are linked to those set of variables affecting the election of a determinate innovation strategy. Studies analyzing R&D subsidies' concession process show that technological contribution, technical capabilities, level of internationalization, expected social impact and knowledge spillovers are key factors in public agency decision (Duch, García-Quevedo and Montolio, 2011; Huergo and Trenado, 2010). All these variables seem to be related in certain extent with the determinants of make or buy decision. Those contributions shed light about some aspects of technology policy relatively unknown as consequence of unavailability of data. I propose to connect this new information about public agency decisions, with decisions in innovation strategy, and explore the interaction among the types of R&D activities performed by the firm, and the assessing and concession of R&D subsidies.

Literature Review

Internal and external R&D decisions have been analyzed in numerous works. In general, R&D make-or-buy decision has been discussed following three majors motivations. The first of them is focused on the determinants influencing internal and external R&D decisions (Audretsch, Menkveld and Thurik, 1996; Beneito, 2003; Girma et al., 2010; Granstrand and Pavitt, 1997; Howells, James and Malik, 2003; Love and Roper, 2002; Mowery, 1983; Narula, 2001; Piga and Vivarelli, 2004; Pisano, 1990; Teece, 1980; Veugelers and Cassiman, 1999; Williams and Lee, 2009). Second motivation examines if make-or-buy decision is relevant in terms of firm's performance; this view is concerned to explore the relationship between firms' innovation or economic results and the use of internal or external source of knowledge (Bönte, 2003; Frenz and Ietto-Gillies, 2009; Leiblein, Reuer and Dalsace, 2002; Montoya, Zárate and Martín, 2007; Vega-Jurado et al., 2009; Vega-Jurado et al., 2008). Lastly, third point of interest analyzes complementarities between internal and external R&D activities; that is, if the productivity of the firm increases carrying out simultaneously both types of activities or, on the contrary, are substitutes (Arora and Gambardella, 1990, 1994; Becker and Dietz, 2004; Caloghirou, Kastelli and Tsakanikas, 2004; Cassiman and Veugelers, 2006; Cohen and Levinthal, 1989; Schmiedeberg, 2008; Watkins and Paff, 2009)

From this evidence, one can deduce the convenience of analyzing R&D expenditure as a concept of heterogeneous composition, which, both at the decision level and for its implications in firms' performance, could raise differences associated with the R&D combinations. Consequently, innovation strategy examined through the combination of internal and external R&D activities should be included in order to consider these heterogeneities.

The literature points out many arguments in order to explain why the firms could be interested in engaging in external or internal R&D activities. From a theoretical point of view, cost transactional theory (Coase, 1937; Williamson, 1989) suggests that externalization of activities takes place only when the transactional costs associated to these activities are lower than those associated with internal activities. This condition implies that external knowledge acquisition requires a complementary base of resources and a high level of specificity between cooperative firms and their partners, in order to allow for knowledge transfer. Based on this theory, Audretsch et al. (1996) examine internal and external investment decision in the manufacturing sector. Their results show that firms with higher levels of specificity with their partners and a high base of internal knowledge for assimilation and absorption are more prone to use external sources. In addition, their conclusions observe the importance of technological opportunities in the acquisition of external knowledge. They also found that both types of R&D are complementary in firms from high technology sectors and substitutes in low intensity technology sectors.

Arora and Gambardella's (1990; 1994) conclusions for the biotechnology sector coincide with those of Audretsch et al. (1996) and other empirical works (Watkins and Paff, 2009) in pointing out that complementarities between internal and external R&D take place specially in the sectors characterized by a complex and fast technological change. In these sectors, the learning effect produced by performing internal activities has a decisive role in assimilation of informational flows from external sources.

Absorptive capacity hypothesis rises as a relevant factor in most of the works explaining mixed innovation strategy. Often, R&D intensity at internal level appears as a relevant variable, positively influencing the adoption of external sources in general, and in the form of cooperation agreements, in particular.

This influence seems to be related with the type of partners (Vega-Jurado et al., 2009; Belderbos et al., 2004; Fritsch and Lukas, 2001) as well as the type of external relationship (outsourcing or cooperation agreement) and the number of third-party agreements established. Dhont-Peltrault and Pfister (2011) found that R&D intensive firms are more disposed to outsourcing as a means to reduce transactional cost and this type of external relationship is more frequent in standardized or generic technology.

In the same direction, other works show that adoption of mixed innovation strategies generates positive effects in firms' performance as a result of complementarities of the two types of R&D. In fact, interaction between internal R&D activities and cooperation agreements has been investigated, confirming a positive effect on firms' innovative performance (Becker and Dietz, 2004; Schmiedeberg, 2008; Veugelers, 1997).

Other motivations for external R&D are explained by cost reduction in process innovation. Love and Roper (2002) explain internal and external decision through internal innovation cost. Implicitly, their work assumes that, above a certain level of cost, firms will prefer external R&D. They identify key elements affecting internal cost of innovation as: scale economies in innovation production function, size of the firms, capacity or plant level and standardization of production process.

Regarding the size of the firm, it is not only related to increasing returns to scale, but also to appropriability regimes in product markets. Atahuene-Gima (1992) and Love and Roper (2002) emphasize the importance of appropriability conditions as key determinants of internal R&D. They argue that more the market power and market concentration the firms have, the more reluctant to contract external knowledge acquisition in R&D projects or pay for licensing the firm will be. It is a consequence of the risk related with imitations or limited appropriability caused by incomplete property rights on innovation products. Nevertheless, some works present difference in relation to this point. Beneito (2003) expose in the opposite direction that, as strong source of competitive advantage, R&D internal capabilities are related to a higher level of competition.

Lastly, there are elements related with financial market imperfections and the risk associated with R&D investment, which could suppose important restrictions in the make-or-buy decision. Incursion on internal activities imposes strong sunk costs to the firms. These costs are, to a great extent, irreversible and in some cases (i.e. labor costs) also recurrent (Atuahene-Gima, 1992; Hall, 2002; Narula, 2001; Watkins and Paff, 2009).

Alternatively, external acquisition supposes a lower economic effort and it is a priori secure than internal activities (contracting firm acquires developed innovations or assumes a shared risk on the development of a project with one or more partners), but it involves another kind of risk whose nature is associated to the threat of the competence. Firms contracting external R&D are not always in the position to enforce contractual clauses or control property rights on the contracted activities.

Therefore, in a competitive market scheme, external acquisition could suppose the reduction of market share or the loss of exclusivity on the sales of new products in the market.

Innovation Strategy and R&D Subsidies

In order to analyze the impact of R&D subsidies on firms three elements are considered, the temporality dimension, the appropriability mechanisms and the financial problems. The temporality dimension is defined by the state-dependence nature of innovative activities. Most papers evaluating the effect of R&D subsidies, underscore the importance to consider sensitivity of firms' decisions to the reception of subsidies and innovative performance in the past (González and Pazó, 2008; Huergo and Trenado, 2010). The choice between internal and external R&D, is especially affected by this fact. Internal activities have a strong component of recurrent expenditures, and it is reasonably suppose that core innovative activities are performed by the firm with independence of the reception of public funds. In contrast, external R&D could be considered as complementary or eventual decision, influenced by financial factors and discontinuous technological changes cycle life stage. In other words, in absence of any clauses restricting the allocation of public funds, one can expect that R&D subsidies stimulate increasing internal R&D in those firms with low rates of R&D effort, or in the case of firms previously performing internal R&D activities, an increase of external R&D.

From a financial point of view, R&D subsidies applications are influenced by the difficulty to access private financial markets (Huergo and Trenado, 2010). Moreover, External R&D exhibit lower costs than internal R&D (Love and Roper, 2002). Taking into account these two premises jointly, external acquisition of technology raise as alternative to those firms financially constrained. The issue we try to explore is how the technology strategy changes when R&D subsidies gradually solves this barrier, and more important, what happens when public financed project ends.

Tsai and Wang (2007) and Jones (2001) found that firms performing internal R&D have a better performance that firms performing external R&D. If public intervention mitigates the financials restrictions, one could suppose that subsidized firms will be more prone to carry out internal R&D.

In respect to the continuity of innovative activities, empirical evidence show that in some cases, once a firm receive a subsidy and develop a public financed innovative project, it acts as signal in the financial markets and eases the access to finance subsequent R&D projects. Past experience on public subsidy application, also allow to the firm knowledge accumulation and expertise to exploit new products and process and capacity to generate new R&D projects. Based on these arguments the idea that R&D subsidies conduct to higher internal R&D is supported.

Finally, is necessary to consider the appropriablity mechanism behind internal and external R&D. Appropriability conditions, conceived as the set of rights allowing capturing and claiming the returns of innovation activities, are strongly related with the type of activity performed. Firms contracting external R&D are not always in the position to enforce contractual clauses or control property rights on the contracted activities.

Atuahene-Gima (1992) and Love and Roper (2002) emphasize the importance of this appropriability conditions as key determinants of internal R&D, arguing that the more market power and market concentration the firms have, the more reluctant to contract external knowledge acquisition in R&D projects or pay for licensing, the firm will be. It is a consequence of the risk related with imitations or limited appropriability caused by incomplete property rights on innovations products.

Therefore, in a competitive market scheme, external acquisition could suppose the reduction of market share or the loss of exclusivity on the sales of new products in the market. In consequence, the mix of R&D activities proposed by the firm to be financed, is also linked to those variables influencing on the appropriability regimes like size, market conditions of cooperative behavior.

Public agency, on the other hand, gives priority to projects with pre-established characteristics. According to Huergo and Trenado (2010, p.248) three major goals pursued by the national public agency (CDTI) in Spain:

"funding R&D projects that would not be otherwise carried out; second, to encourage the technological upgrading of firms that are of particular importance in declining or traditional industries; and third, to foster national champions, independent of the gap between social and private benefits. Other objectives can include the development of projects with a high capacity for diffusion and a profound economic impact, or giving priority to projects that generate behavioral additionality by stimulating, for example, cooperation among firms."

Similar objectives are present in the analysis of public agency decision carried out by Duch et al. (2011) for the region of Catalonia, in Spain.

A priori, firms with mixed strategies could increase its likelihood to satisfy some of these points of evaluation. Firms performing only internal R&D, could develop projects with high levels of innovation, but its probabilities to engage with external partners are lower in absence of external R&D expenditures. Similarly, firms developing only external R&D could need internal capabilities in order to take advantage from external sources of knowledge and achieve higher level of innovation or increase its R&D expenditures. Finally, firms with combined strategy tend to apply with projects characterized by higher internal commitment with R&D activities and are more likely to engage with external partners.

Data Description and Methodology.

The database

The data used corresponds to the Survey on Business Strategy (ESEE for its Spanish acronym) for the period 1998-2005. This survey offers a rich panel data on different dimensions of firms' strategy. This allows controlling for different aspects of the business strategy, deepening both at the decision process, and in the changes induced by these decisions. The sample includes firms from manufacturing sector with positive R&D expenditure during at least one year in the period 1998-2005.

The ESEE is not exclusively centered on innovation. So there is information related with diverse areas in business strategy. It is a great advantage because, as commented previously, internal and external decision of R&D is not only affected by technological factors but also by organizational, human, financial and other strategic areas in the firm. The complexity of this interaction is the main reason to use this information in order to capture its influences on innovation strategy.

Methodology

One of the main problems in R&D subsidy application process is the existence of selection and endogeneity problems. Status participation is determined by both the firms' application and public agency concession of the subsidy. Since data about firms applying for a subsidy process is not available, it is possible to observe only those firms that are applying and obtaining a subsidy. It can be written as:

(1)

Where, Si is a censored variable indicating the reception of subsidy, and it is only observable for those firms that applied and obtained a subsidy (S=1); otherwise, firms' performance remains unobservable (S=0); xi is a set of explanatory variables influencing the probability to obtain R&D public subsidies and, ui is an error term following bivariate normal distribution.

Furthermore, potential endogeneity bias needs to be considered, because R&D subsidies are not randomly conceded and both, the decision of public agency and firms' R&D expenditures, could be determined by unobservable factors (Busom, 2000; Lichtenberg, 1984). The problems originated by this situation have been tackled through selection models (Busom, 2000; Wallsten, 2000) and matching techniques of estimation (Almus and Czarnitzki, 2003; Blanes and Busom, 2004; Czarnitzki, 2006; Czarnitzki and Licht, 2006; Duguet, 2004; González and Pazó, 2008; Herrera and Heijs, 2007; Lach, 2002).

This work estimates a two step treatment effects model, where R&D subsidies are defined as the treatment. So, it is possible to observe firms exposed to the treatment and firms that have not been exposed to the treatment. In a first stage, a probit model is estimated, in order to analyze the process of R&D subsidies. At this stage, determinants to apply and obtain a R&D subsidy are identified.

Second stage regresses a continuous outcome variable (logarithm of R&D expenditures) on a set of explanatory variables, wi.

(2)

Where, GIDi=GID*i if Si=1; wi is a set of explanatory variables influencing the level of R&D expenditure.

The Selection Equation

First stage of treatment selection model is estimated through probit regression. Selection equation has, as dependent variable, the participation status in subsidy concession, taking the value 1 for subsidized firms and 0 for unsubsidized.

ISSN: 0718-2724. (http://www.jotmi.org)

Determinant of R&D subsidies has been analyzed in numerous opportunities. The main variables used in empirical literature have been selected (Blanes and Busom, 2004; Busom, 2000; Czarnitzki and Licht, 2006; García-Quevedo and Afcha, 2009; González and Pazó, 2008; Herrera and Heijs, 2007; Huergo and Trenado, 2010). This set of explanatory variables represents vector xi in equation 1. Table 1 shows its expected sign and definition.

Variable	Expected sign	Variable definition
Cooperation with universities and technological centers.	+	Dummy=1 if firms cooperate with universities or tech. centers during the previous year, otherwise 0.
Horizontal cooperation	+	Dummy=1 if firms cooperate with competitors or is engaged in strategic alliances, otherwise 0.
Vertical cooperation	+	Dummy=1 if firms cooperate with customers or suppliers, otherwise 0.
Medium-high technology industry	+	Firms form medium-high industrial technology sectors.
Recruitment of engineers and graduates of recent graduation	+	Dummy=1 if firms recruit engineers and graduates, otherwise, 0.
R&D effort in previous year	+	Total R&D expenditure divided between total sales.
Age	+/-	Number of years.
Employees	+/-	Total number of employees.
% of Foreign capital	-	% of foreign capital.
Exports	+	Exports in euros

Table 1. Independent variables in subsidy concession process

The Outcome Equation

Variables in outcome equation represent the set of explanatory variables, wi, specified in equation 2, and influencing the level of R&D expenditure conditioned by the firms' strategy:

Technological Cooperation: One of the motives to engage in R&D cooperation with firms or public research institutions is to share the cost associated with the development of innovation products. Although there is not enough empirical evidence about the connection between the level of R&D expenditures and technological cooperation, it is reasonable to expect that total R&D expenditures increase with technological cooperation. In order to capture the influence of this variable, several variables are proposed: cooperation with university or technological centers, vertical cooperation and horizontal cooperation.

Fölster (1995) notes that R&D cooperation effects are directly related with clauses on result-sharing agreements. As a consequence, firms including these clauses in their contracts increase the likelihood of cooperation but reduce R&D investments. On the other hand, the absence of results-sharing agreements does not increase the probability of cooperation but increase incentives to conduct R&D. Recent papers describe profit sharing associated to different forms of collaboration and how this profit depends heavily on the technology input of each partner (Stein and Ginevicius, 2010). Unfortunately, information about cooperation agreements is not available in ESEE database.

Medium-High technological industry intensity: Empirical literature shows that internal and external performances in high technology industries are conceived as complementary sources rather than substitutes, and often they combine both internal and external R&D (Arora and Gambardella, 1994; Audretsch, 1996; Watkins and Paff, 2009). Following this relationship, most of the studies show that innovative industrial sectors are associated with higher level of R&D expenditures in general.

Recruitment of recent graduates and engineers: External knowledge assimilation requires qualified human resources with capabilities to adapt external knowledge and to fulfill internal requirements of the firm. Recruited qualified personnel reinforce internal capabilities in order to develop R&D activities and exchange and incorporate information from external firms or institutions in the future (Audretsch et al., 1996; Beneito, 2003; González and Pazó, 2008; Mowery, 1983)

Number of workers: Shumpeterian notion about firm's size exposes that large firms are more prone to assume successfully innovative activities. This hypothesis has been successfully tested in numerous works. Beneito (2003); Love and Roper (2002) and Piga and Vivarelli (2004); confirm that firm size has a statistically positive and significant effect on the likelihood to perform internal or external activities. These effects could have an inverted U shape on the cost of innovation, reflecting scale economies in R&D activities.

Own funds: Empirical literature coincides, identifying financial cost as main obstacle to develop R&D activities (Hall, 2002; Segarra-Blasco, García-Quevedo and Teruel-Carrizosa, 2008; Jang and Chang, 2008; Toole and Turvey, 2009; Ughetto, 2008; Watkins and Paff, 2009). This barrier diminishes in the case of external R&D activities as its cost is, in general, lower than internal R&D cost (Atuahene-Gima, 1992; Beneito, 2003; Love and Roper, 2002). Expected sign for this variable is, thus, positive for internal activities and negative in the case of external R&D activities.

No diversification: Innovation development implies the selection of a technological trajectory and the investment of specifics assets in order to develop distinctive and niche capabilities (Narula, 2001). In fact, it has important implications on specialization of the production process. As long as the firm's production process is more specific or specialized, it will be costly to carry out external R&D. In contrast, a diversified production facilitates the incorporation of generic external knowledge. Empirical results obtained by Beneito (2003) and Love and Ropper (2002) confirm this hypothesis and show that diversification is inversely related to internal R&D adoption and directly associated with external R&D.

Number of competitors: Evidence with respect to this variable is ambiguous. On one hand, the use of external R&D in concentrated markets could suppose a high risk on the appropriability of innovation results; thus, internal R&D would be preferred as acquisition source in presence of few competitors (Atuahene-Gima, 1992; Love and Roper, 2002). On the other hand, market structures characterized by intense competition could be conceived as source of competitive advantages (Baumol, 2002; Beneito, 2003). This fact could originate the opposite result: the higher the number of competitors, the lower the internal R&D expenditures.

Private effort in previous year: It is a proxy for the intensity of activities related with innovations. It is calculated as the ratio of total R&D expenditures divided between total sales of the firms in the previous year – the more the effort carried out by the firm respect to the sales the previous year, the bigger the likelihood of the firm to perform R&D activities at external or internal level.

Technological balance: This variable is calculated as the difference between incomes and payments for licenses and technical assistance from abroad. Positive values of these variables would indicate independence and technological strength as well as complete property rights on obtained innovations. This situation would be associated with carrying out internal R&D. In contrast, if technological imports are larger than exports, it could be considered an evidence of technological dependence on foreign firms. Only then we can expect a negative influence on internal R&D expenditure.

Finally, the dummy variable that indicates exposition to the subsidy is used as dependent variable in the selection equation (1). As dependent variables in equation (2), we use total R&D expenditures of firms whose innovation strategy is to perform only internal R&D's activities, only external and both internal and external activities.

Descriptive Statistics

Descriptive statistics (table 2) show the variables included in both selection and outcome equation ordered by innovation strategy. Differences principally arise among firms with mixed strategies and pure innovation (external or internal) strategies. In general, firms performing simultaneously internal and external R&D show favorable characteristics in order to adopt innovative activities and obtain a better innovative performance. These firms have a positive technological balance, a bigger effort in private R&D, recruiting a bigger number of personnel with experience in R&D, are more collaborative with public research organizations and have been awarded with more R&D subsidies.

Besides, these firms have more presence in high and medium-high industrial sectors and its average age is higher than other groups, a fact that could be interpreted as firms opting for this strategy have more experience in its market.

A fact to be noted in the group of pure-external innovation strategy is its higher average of competitors; the negative technological balance, indicating clearly that firms choosing only external R&D are net receptors of technology and, higher proportion of no-diversified firms. Regarding the group of pure-internal innovation strategy, in general, it lies in an intermediate point between mixed strategy firms and pure external strategy, although with a position closer to the last group.

These differences are also reflected in the distribution of public subsidies; 37.8% of firms performing simultaneous internal and external R&D, compared with 13% and 8% of pure internal and external strategy, respectively.

Results

Table 4 reports the results of the two-step treatment effects model. Three different regressions were estimated using logarithm of R&D expenditures as dependent variable, conditioned on innovation strategy: only internal, only external and internal and external R&D. Lambda is statistically

	Innovation Strategy		
	Only internal R&D	Only external R&D	Internal and external R&D
Rate of technological cooperation with Univ.or tech centers	34%	32%	66%
Rate of technological cooperation with competitors	10%	8%	21%
Rate of technological cooperation with suppliers or clients	65%	51%	76%
Percentage of firms belonging to High – medium-high technology sectors	41%	32%	51%
Percentage of firms declaring recruitment of recent graduates and Engineers.	24%	22%	36%
Effort in previous year (R&D expenditures / sales)	1.33	0.89	2.42
Technological balance in previous year (Technological exports-technological imports)	-376.26	-666.38	354
Nº employees	379.11	350.53	582
Own funds(own funds/ liabilities)	43.11%	44.93%	46.12%
Percentage of firms declaring no diversification of products	84%	87%	83%
Number of competitors	1.57	1.69	1.47
Age	31.42	28.53	35.87
Total exports in euros.	4.2 e^{07}	4.23 e^{07}	4.61 e^{07}
Percentage of foreign capital	33.45%	30.72%	31.97%

Table 2. Descriptives statistics

	Only internal R&D	Only external R&D	Internal and external R&D	Total
Mean	13.06%	8.21%	37.8%	24.61%
N	1822	694	2460	4976

Table 3. Conceded subsidies by R&D strategy in percentage.

significant in all the three estimations. This coefficient is a measure of correlation between the error terms ui and ei from equations 1 and 2. Therefore, it confirms that econometric strategy is adequate in order to control the endogeneity problem.

Results from the first step of the estimation show the determinants of the subsidy concession. These coincide with the previous work and the sign of the variables as expected in table 1. With the exception of the percentage of foreign capital and age for firms performing internal and external activities, the rest of variables have a positive influence on the likelihood to obtain a R&D subsidy.

Significant variables at this stage are consistent with a priori expected results about public agency decision. Technological cooperation is relevant for firms with independence of their strategy. However, considerations about the type of cooperation are interesting. For firms investing in internal R&D activities, cooperation with universities and technology centers is relevant for the public agency. Empirical works show that this type of cooperation is frequent in order to develop breakthrough innovations new to the market, which require strong innovative capabilities developed internally (Belderbos et al., 2004; Belderbos, Carree and Lokshin, 2006; Laursen and Salter, 2004; Miotti and Sachwald, 2003; Mohnen and Hoareau, 2003; Monjon and Waelbroeck, 2003; Teece, 1980, 1986; Tether, 2002). In contrast, horizontal and

	Only internal R&D		Only external R&D		External and internal R&D	
Log of R&D exp.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Coop. Univ. & Tech centers	0.598	0.14***	-0.61	0.22***	0.09	0.13
Horizontal Coop.	0.19	0.15	0.39	0.41	0.13	0.09
Vertical Coop.	0.404	0.10***	0.17	0.27	0.02	0.08
High-medium high technology industry	0.478	0.09***	1.357	0.23***	0.591	0.07***
Recruitment of recent graduates and Engineers	0.443	0.12***	0.888	0.25***	0.565	0.07***
Effort in previous year	0.248	0.04***	0.477	0.09***	0.093	0.01***
Technological balance in previous year	0.00	0.00	0.000	0.00***	0.000	0.00***
Nº employees	0.000	0.00***	0.001	0.00***	0.000	0.00***
Own funds	0.009	0.00***	0.012	0.00***	0.00	0.00
No diversification	0.03	0.10	0.01	0.28	0.256	0.08***
Number of competitors	0.01	0.04	-0.12	0.09	-0.11	0.04***
Subnac	-1.25	0.98	1.51	1.55	1.127	0.37***
Constant	3.430	0.21***	2.641	0.46***	4.415	0.15***
R&D subsidies						
Coop. Univ. & Tech centers.	0.53	0.124***	-0.254	0.243	0.771	0.090***
Horizontal Coop.	-0.233	0.189	0.687	0.379*	0.360	0.089***
Vertical Coop.	0.268	0.137**	0.80	0.262***	0.088	0.088
High-medium high technology industry	0.072	0.119	-0.289	0.286	0.104	0.078
Recruitment of recent graduates and Engineers.	0.256	0.127**	0.286	0.268	0.242	0.080***
Effort in previous year	0.136	0.027***	0.085	0.090	0.078	0.013***
Age	0.001	0.002	0.004	0.004	-0.002	0.002
Nº employees	0.000	0.000	-0.001	0.000	0.000	0.000
% foreign capital	0.000	0.001	-0.005	0.003*	-0.004	0.001***
Log of Exports	-0.007	0.030	0.091	0.061	0.086	0.020***
Constant	-1.640	0.469***	-3.164	0.932***	-2.424	0.317***
Time dummies included						
Lambda	0.877	0.530*	-0.688	0.832	-0.499	0.228**
Number of obs	913		303		1476	
Wald chi2(31)	553.93		293.13		1686.49	
Prob > chi2	0.00		0.00		0.00	

Table 4. Estimation results.

vertical cooperation are relevant in firms performing only external R&D. These forms of cooperation agreements are associated with cost-reduction oriented innovations, quality improvement and market expansion (Belderbos et al., 2006; Miotti and Sachwald, 2003; Tether, 2002), a type of cooperation agreements where technology content requirement could be more generic.

Recruitment of qualified personnel and R&D effort in previous years increases the likelihood to participate and receive a R&D subsidy in firms performing only internal R&D and mixed R&D activities. It is consistent with evaluation criteria applied by public agency in relation with the technical contribution of the project and also with technical abilities needed to carry out the project successfully.

Results from second stage show the determinants of R&D by type of innovation strategy. Firms performing only internal R&D are positively influenced by external sources of knowledge, in particular, those resulting from engaging with universities or technology centers and vertical cooperation. A priori, those firms are not acquiring disembodied technology, but are collaborating in order to develop some technological capabilities. This fact reflects the importance of internal capabilities as the key factor in order to assimilate external knowledge, adapt and exploit it, even in the absence of external expenditures in R&D.

In the case of firms with only external R&D, the sign of cooperation with universities and technological centers is negative. This type of cooperation does not always imply to allocate a financial budget. In fact, if cooperation agreement consists of a professional internship program or a professional exchange, it could represent a save for the firm. Information about cooperation agreements does not allow for a more precise explanation.

Firms from medium and high technology intensity sectors devote more resources to R&D activities – it is confirmed for innovative firms with independence of their innovation strategy. A similar picture could be observed with the recruitment of graduates and engineers. In general, firms recruiting qualified personnel are more disposed to allocate resources for R&D activities.

ISSN: 0718-2724. (http://www.jotmi.org)

In order to account for previous experience and investments in R&D, lagged effort is included. It is positive for firms performing any innovation strategy and shows that firms with previous experience in these types of activities, both at internal or external level, devote more resources to R&D.

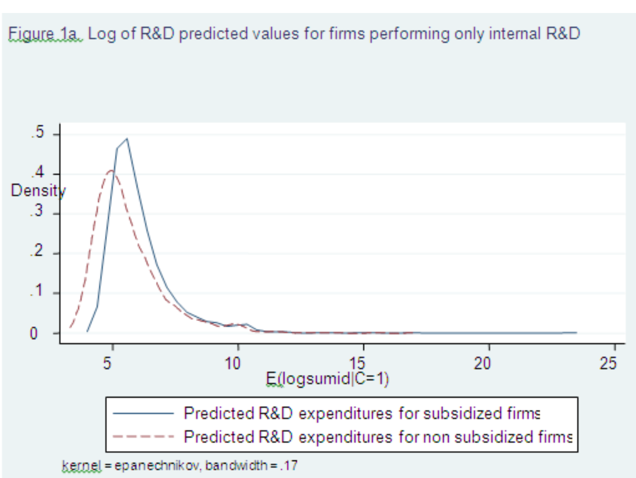
Financial restriction is considered as inclusive of firm's own fund proportion with respect to total liabilities. This variable is positive and statistically significant for firms performing pure innovation strategies. It is consistent with information in statistical descriptions which show that on average, firms with only internal or external R&D are smaller and have lesser availability of resources.

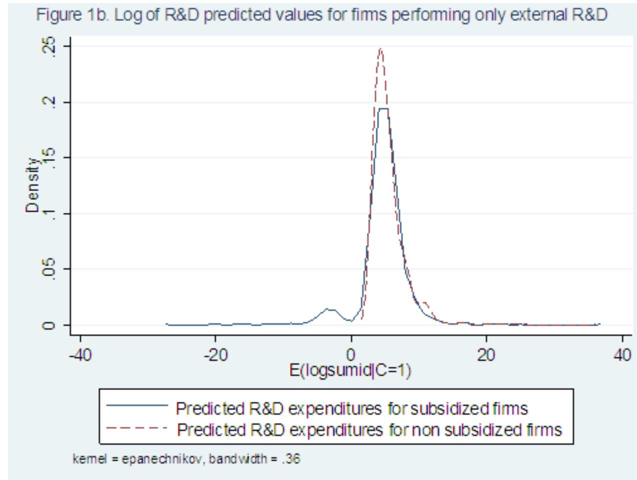
Variable related with diversification of product is significant only in the case of mixed strategy. This variable has the value of 1 for firms not diversified and 0 otherwise. A more diversified line of business implies that firms have more difficulties investing in specific technology and assets. Positive sign of this variable could be interpreted as follows: firms with more specifics process and assets invest a bigger proportion of their total R&D expenditure in internal R&D activities.

Variable capturing the impact of R&D subsidies report positive influence of public funds for firms performing external and mixed R&D activities, and negative sign for firms carrying out only internal activities. In order to analyze these effect in deep, treatment effect is shown in the next section.

Subsidy Impact on R&D Expenditure

Once endogeneity bias is controlled; it is possible to calculate predicted R&D expenditures for firms with different innovations' strategy depending on its exposition to the subsidy. The differences in expected R&D expenditures between subsidized and non subsidized are estimated using the following equation (3):





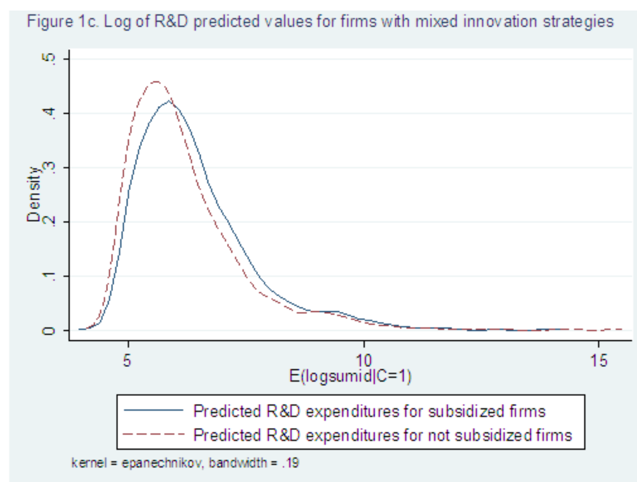


Figure 1a,b,c. Expected R&D expenditures in subsidized and not subsidized firms

Figure 1 show a graphical representation of expected R&D expenditures for subsidized and not subsidized firms. Figure 1a, for firms with only internal R&D, shows that most of the non-subsidized firms are concentrated at lower levels of expenditure while, if we move from the left to the right, there is a major proportion of subsidized firms with higher levels of R&D expenditure. This show that firms spending higher levels of internal R&D receive in average more subsidies, however it cannot be inferred from it, that this higher level of R&D expenditures are an effect of R&D subsidies. In fact, results in table 4 indicate that R&D subsidies' coefficient is not statically significant.

Firms performing only external R&D exhibit a different performance. In this case, lower levels of R&D expenditure correspond to subsidized firms. For higher levels of R&D expenditures, there are a few differences between subsidized and non-subsidized firms. Estimation from table 4 reports non significant effects of R&D subsidies on the level of R&D expenditures in firms performing only external R&D. The figure 1b, confirm in some extent this results showing little difference in subsidized and non subsidized firms.

Finally, in firms with mixed strategy of innovation, R&D expenditures of subsidized and non subsidized firms, is similar to firms with only internal R&D. Subsidized firms perform higher levels of expenditure in R&D. In contrast with two previous results, estimation report positive and significant effect of subsidies on the log of R&D expenditures.

Conclusions

This work identifies main determinants of R&D innovation strategies and its connection with concession of R&D subsidies. Endogeneity problems are tackled by fitting a treatment effect model. Results confirm that this econometric specification is adequate in order to prevent endogeneity bias.

First stage of the model allows identification of the determinants of public subsidies. These results are consistent with previous works, remarking the influence of technological cooperation, R&D effort in previous years, recruitment of qualified personnel, and percentage of foreign capital and exports.

Determinants of the different types of R&D are shown in the second stage of the model. In general, main differences are present in technological cooperation variables. Cooperation with external partners increases internal R&D expenditures and is negative in the case of external R&D expenditures. An interesting question rising from this fact is about the relation between technological cooperation and external R&D. If innovation policy gives priority to projects developed in collaboration with other firms or public institutions, why is this not translated in more external R&D expenditure? Has the type of cooperation some influence in this fact? These questions constitute issues for future research.

The average treatment effects of subsidies suggest that the impact of public funds on R&D expenditures is at some extent related with the innovation strategy performed by firms. R&D subsidies have a positive and significant effect only in firms performing internal and external activities of R&D. Empirical literature report internal and external R&D as complementary and in some cases also associated to better innovative and firm performance. This result is also consistent with previous analysis suggesting that highly innovative firms constitute a frequent target of public agencies seeking high technology contributions and "picking the winners" strategy.

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ISSN: 0718-2724. (http://www.jotmi.org)