

The Impact of Firm Participation in R&D Programs on R&D partnerships*

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Abstract

Encouraging innovation has become one of the main policy goals in many countries, with the final purpose of promoting growth and job creation. Subsidies to the firms' R&D projects are among the set of tools used to that end; some of them intended to establish stronger links between universities, research institutes and firms. We present empirical evidence on the impact that R&D subsidies have on firms' R&D partnership strategies. Using a sample of Spanish manufacturing firms we estimate the effect that receiving public support has on the probability that firms will set up an R&D partnership with a public research organization or with other firms. We find that (i) the choice of partner is associated, on average, with different firm characteristics, (ii) public support encourages both private-public and private-private cooperation, but the impact on public-private partnerships is larger (iii) the effect of public support on private partnerships is larger when firms have intangible knowledge assets. The main policy implication that public-private R&D cooperation seems indeed to be affected by market failures and that public programs subsidizing industry-science links can trigger a behavioral change in firms' R&D strategic partnerships.

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1. Introduction.

Empirical evidence shows that cooperative agreements to perform R&D activities have been increasing over the last twenty years in OECD countries. The share of patent co-applications in triad patent families has almost doubled since 1980, and the number of strategic technology alliances has, on average, almost tripled (Hagedoorn (2002), OECD (2002)). The Community Innovation Survey (CIS), a wide firm level survey conducted in European Union (EU) member countries, provides additional evidence on R&D partnerships and their weight across firms and industries.¹ On average, 17% of manufacturing firms with innovative activities had R&D cooperation agreements with other firms or organizations in 1998-2000². The share was significantly higher for large firms (61%) than for medium and small size firms. Partnerships with suppliers or customers were as frequent as partnerships with universities or public research labs.

Cross-country differences are significant and large. In Finland 22% of SMEs in the manufacturing industries declared being involved in cooperative agreements in order to innovate, while in Spain or Italy barely 3 % did. While part of these differences can be attributed to a lower rate of innovative firms, even within this subset of firms differences are large, as Figure 1 shows.³

[Insert Figure 1]

At the same time public support programs to encourage private R&D effort as well as research partnerships between private firms and public research organizations have been implemented in the US, Japan and the European Union. Some examples are the Advanced Technology Program in the US and the EU successive European Framework Programs. Public support for private research is usually based on the belief that private incentives to conduct R&D and to establish partnerships are insufficient to yield the socially optimal level of R&D output. This is more likely to happen when

¹ The Community Innovation Survey (CIS) is a European-wide firm level survey focusing on innovation and R&D decisions. It has been conducted three times (1992, 1996 and 2001) in all European Union member countries. There is a set of common core questions for all countries. Definitions and survey methodology are also common, making results across countries quite comparable. More information about the CIS can be found at the specialized European Union web page www.cordis.lu.

² See European Communities (2004).

potential new technologies are generic and would require many partners to cooperate; when a project's complexity, risk or appropriability problems limit private funding or when handling the partnership is difficult because partners have different global objectives or time horizons. Therefore, in some cases subsidizing R&D partnerships could reduce collaboration costs and mitigate coordination failures.⁴

These observations raise a number of questions of interest from a policy perspective. Some are related to the need to understand the determinants of private and social costs and benefits of research partnerships. Another set of questions deals with the ex-post evaluation of these policies, and involves analyzing how public support for R&D and R&D partnerships affect firm behavior and innovation performance. The main question is whether outcomes would have been the same without support, and therefore whether this particular type of policy intervention should be maintained.

While there is quite an extensive body of empirical research on the determinants of research partnerships, evidence on the ability of public support to effectively increase their number is limited. The evaluation literature has focused on the impact that public support has on private R&D expenditure, on patenting or on other measures of innovation performance, but not on its effects on firm behavior regarding how these activities are organized.⁵

In this contribution we explicitly investigate whether public support for private research and innovation activities changes firms' R&D cooperation strategies and increases the likelihood to cooperate with particular types of partners, that is, whether there is behavioral additionality.⁶ To that end we analyze a large sample of manufacturing firms in Spain and estimate the change in the

³ See European Commission (2003a and 2004).

⁴ An interesting reference in that respect is Klette and Moen (1999).

⁵ On the impact on outcomes, see for instance Feldman and Kelley (2003) and Darby et al. (2004) on the ATP Program, and Czarnitzki et al (2004) on German and Finish Programs.

⁶ In the program evaluation literature additionality in broad sense means that a program contributes to create additional welfare that would not have been produced otherwise (Buisseret et al. (1995)). Because welfare effects are difficult to measure, other indicators of additionality are used. These are input, output and behavioral additionality. In the case of R&D programs input additionality is measured by the increase in private R&D expenditure triggered by public support. Output additionality is measured as the increase in patents and new products obtained by a supported firm. Behavioral additionality refers to changes in collaboration or management strategies, and has been less explored empirically.

probability that a firm will establish an R&D partnership with customers or suppliers (private vertical partnerships) and/or with a public research organization that can be attributed to program participation. We use two methodological approaches (parametric and non-parametric methods) in order to take into account the endogeneity of program participation. According to our findings, (i) vertical and public-private cooperation are associated with firms with different characteristics, as found in existing studies, and (ii) national R&D programs have a positive effect on both types of cooperation, but especially on public-private partnerships, suggesting that the latter are affected by market failures and that public programs help overcome them to some extent. Finally, we find that the effect of public support on private partnerships is larger when firms have intangible assets in the form of patents.

The paper is structured as follows. In section 2 we provide a short review of closely related work. We describe our data in section 3. In section 4 we outline the empirical framework as well as the hypotheses that will be tested. We discuss results in section 5, and conclude in section 6.

2. Research partnerships and public support for R&D: previous evidence.

Several hypotheses have been proposed to explain the incentives that firms have to cooperate with other firms or with public research organizations. They can be broadly classified into four categories.⁷ One strand of the literature emphasizes that in order to develop an innovation firms require complementary intangible assets, basically tacit knowledge and know-how, which cannot be easily contracted and monitored through market based transactions. Cooperation agreements may provide mechanisms to minimize these problems (Sinha and Cusumano (1991), Katsoulakos and Ulph (1998)). A second hypothesis views research partnerships as a mechanism to share risks and costs, as well as to exploit economies of scale and scope in research and development. The third hypothesis stresses the role played by incoming and outgoing knowledge spillovers. Incoming spillovers relate to the usefulness for the firm to assimilate and exploit knowledge generated by others. A partnership may allow improved learning efficiency (Sakakibara (2003)). On the other hand, outgoing spillovers occur

when knowledge that is generated by the firm leaks out and benefits other firms. These spillovers may be a serious concern when a firm's appropriability mechanisms are weak, therefore reducing, as is well known, the incentives to carry out some R&D projects. In that case, R&D partnerships may provide a mechanism to internalize them (Katz 1986). Finally, a fourth hypothesis predicts R&D cooperation may occur when it enables partners to increase market power in the product market (Martin (1994)).

The choice of different types of partners (customers or suppliers, competitors, public research organizations) by firms will presumably be affected by the importance of each of these factors in different industries, by the nature of R&D projects (whether their purpose is using science to develop new commercial applications or solve complex problems, developing or adapting complementary innovations, setting standards), and by the cost of setting up a particular partnership. We can conjecture that if a firm's objective is to find complementary assets and skills it will tend to form asymmetric partnerships, where partners are heterogeneous.⁸ In some cases partners may be all private, such as in partnerships established with customers or suppliers (vertical partnerships) or they may include a public research organization (public-private partnerships). On the other hand, when the motivation for cooperation is strongly based on internalizing outgoing spillovers or on increasing market power, symmetric partnerships are possibly more likely (horizontal cooperation with (potential) competitors).⁹

Empirical research has focused on the determinants of R&D cooperation and its effects on performance. The issue of partner choice has been recently addressed, as appropriate data are being developed.¹⁰ In particular, the availability of European firm-level data has made possible to test some

⁷ Some hypotheses have been generated in the business literature, some in the industrial organization literature. For recent surveys see Sena (2004) or Caloghirou, Ioannides and Vonortas (2003), where detailed references to the literature are provided.

⁸ Several dimensions of heterogeneity are possible: firm size, knowledge assets, market scope or location, product range.

⁹ See Röller, Siebert, Tombak (2004).

¹⁰ Ideally, to study R&D cooperation decisions data on partnership members would be needed. Few data sets have this type of information. Some examples are those used by Navaretti et al (2002), Bizan (2003) and Röller

hypotheses about partner choice.¹¹ Cassiman and Veugelers (2002) provide interesting insights using the Belgian edition of the survey. They find that incoming spillovers, outgoing spillovers, firm size, cost and risk of research affect partner choice. In particular, incoming spillovers (measured through proxies such as the importance given by managers to patent information, publications, meetings, conferences and trade fairs) have a positive and significant effect on the probability that a firm will establish a public-private partnership, but not on that of establishing a vertical partnership.¹² In contrast, lack of technological information to produce an innovation significantly affects the likelihood of establishing a vertical partnership, but not a public-private one. Another interesting finding is that although firm size and innovation cost sharing increase the likelihood of any type of partnership, they seem to have a larger impact on the probability of cooperating with public research organizations. López (2006) performs a similar analysis with Spanish data. These authors do not consider the effect that participating in public R&D programs may have on partnership choice.

These results suggest that the nature of the projects involving public partners differs from those involving private partners. In particular, collaborations with public research organizations are more likely to have an exploratory and risky character, taking usually more time to mature, with the firm aiming at learning from public research in order to produce a product or process with a high degree of novelty, hence increasing the likelihood of being granted a patent.¹³ In addition, collaboration with public research organizations may face specific barriers, some related to different approaches to

et al. (2004). The association between firm characteristics and cooperation has also been explored by Firtsch and Lukas (2001), Kaiser (2002) and Tether (2002).

¹¹ We refer to the Community Innovation Survey. Many questions in the CIS are qualitative, but they allow the construction of indicators of incoming spillovers, of appropriability (outgoing spillovers) and of obstacles for innovation according to managers' beliefs. A limitation concerning cooperation decisions, however, is that no information is collected on characteristics of partnership members.

¹² Their index of incoming spillovers used as an explanatory variable is in turn found to be highly correlated to the importance that managers give to universities and technical or public research institutes as information sources relative to the importance of suppliers or customers.

¹³ This is not to mean that all public-private partnerships develop only this type of projects. Carayol (2003) studies 46 collaborations in five European countries in the IT and pharmaceutical industries, and finds five types of collaborations according to the risk and length of the projects, academic partner characteristics, and relationship characteristics.

property rights by firms and the PROs, some to a possible gap between a firm's absorptive capacity or knowledge capital and that of the PRO.¹⁴

There are several paths for expanding the empirical analysis of R&D partnerships with this type of data. One is to address the role of multinational companies and their affiliates in R&D cooperation. As is well known, foreign direct investment may be a channel of technology transfer, and a particular mechanism is technological alliances with local companies that are either customers or suppliers. On the other hand, foreign owned firms might also source knowledge from local public research organizations. Thus, it is interesting to test whether this type of firm is more likely to engage in one type of partnership or the other, which we do in this paper.

A second direction consists of explicitly addressing the impact of public funding for private R&D on partner choice. As mentioned above, in the program evaluation literature additionality in broad sense means that a program contributes to create additional welfare that would not have been produced otherwise. As welfare effects are difficult to measure, some indicators of additionality are used: input, output and behavioral additionality. Input additionality is defined as the increase in private R&D expenditure triggered by public support. Output additionality is defined as the increase in patents and/or new products obtained by a supported firm. Behavioral additionality refers to changes in collaboration or management strategies, and has been less explored empirically.

There are some advantages in analyzing behavioral relative to input or output additionality. Inference based on input additionality can be misleading in some cases. An example would be when an R&D project involves strong economies of scale or scope; if it is carried out in cooperation with other firms, each member's private R&D expenditure may be smaller. On the other hand, when the aim is to

¹⁴ There is an expanding literature, theoretical and empirical, on public-private collaborations. For brevity we focus on small number of empirical contributions that compare private-public and private-private partnerships

measure output additionality, data for several periods might be needed, since R&D projects can take some time to produce results, and these may take place over a number of years. Unless the data used covers a long period, including observations before, during and after receiving support, the overall impact of public funding might be underestimated. Hence behavioral additionality can provide a complementary measure of short run policy impact.

In our case, behavioral additionality implies that public R&D funding triggers additional cooperation, beyond the level that the market would have produced in the absence of such support. This hypothesis can be tested through an appropriate econometric framework. Some studies approach this by including a binary indicator of participation in R&D programs as an explanatory variable in collaboration equations. The problem that arises is that participation status is the result of the firm and a public agency's decisions to apply for and grant support respectively. Some factors that determine the likelihood of cooperating are very likely to affect participation as well. To the extent that some of these are not observed, the participation indicator and the error term of a cooperation equation will be correlated, generating biased and inconsistent estimates unless this is not properly taken into account.

Some existing studies on R&D partnerships using the CIS have included participation status as an exogenous explanatory variable. Miotti and Sachwald (2003) find that R&D subsidies in particular do encourage public/private and horizontal cooperation among French firms; Mohnen and Hoareau (2003), find that receiving subsidies is the most influential factor affecting the probability that a firm will set up a public-private partnership.¹⁵ Finally, Bayona, García and Huerta (2003) find that participation in international R&D programs increases horizontal cooperation but not vertical cooperation.¹⁶ A recent attempt to explicitly address the endogeneity of participation status is found in

and use European firm-level data. Other relevant work on the characteristics and barriers to public-private partnership includes Hall, Link and Scott (2001 and 2003) on the Advanced Technology Program in the US.

¹⁵The sample includes firms from France (about 45% of the sample), Germany (10%), Ireland (4%) and Spain (42%).

¹⁶They use the Spanish Innovation Survey 1994-1996.

Belderbos et al. (2004), who use two waves of the Dutch innovation survey.¹⁷ The authors find that the effect of receiving R&D subsidies is not conclusive, as results vary with the empirical strategy used to control for subsidy endogeneity.¹⁸

The main conclusion of existing evidence is thus, that careful attention has to be paid to the treatment of endogeneity of R&D subsidies. An additional limitation of existing studies is that a distinction between national and EU R&D support programs is often not made when it should because programs have different eligibility conditions, suggesting that public agencies use different selection rules.¹⁹ That is, there may be substantial program heterogeneity, explaining part of the differences in program impact. We will take this heterogeneity into account in our empirical model.

3. Data.

The source of our data is the Spanish Innovation Survey administered by the Spanish Statistical Institute (INE) in 1999. We use a sub-sample of 716 manufacturing firms that reported positive expenditures in R&D in 1998.²⁰ About 40% of these firms had established some type of cooperation in R&D over the period and almost one third declared receiving public support through some R&D program. Firms could participate in four types of programs: EU-level, other international, national and regional level. Most firms participated in only one program, mainly at the national level.

¹⁷ As in CIS surveys for other countries, the Dutch CIS survey provides information related to incoming and outgoing spillovers, firm characteristics and firms' perceptions of main obstacles for R&D activities. The samples consist of innovative firms, that is, those that introduced a product or process innovation during the surveyed period. However, in this case the authors could use two waves of the survey: 1994-1996 and 1996-1998. This is not the general case for most researchers, as usually each country' survey is not designed as a panel survey.

¹⁸ When using lagged subsidies, they find a positive effect on the likelihood of vertical and public/private cooperation, but not on horizontal cooperation. However, when restricting the sample to include only firms that are new to cooperation, R&D subsidies are not found to have any effect on vertical or public cooperation, and moreover have a negative effect on horizontal cooperation. The authors conclude that the possible endogeneity of R&D subsidies needs further investigation.

¹⁹ See Blanes and Busom (2004) on patterns of firm participation across industries and agencies.

²⁰ The questionnaire collects information on the number of employees (in 1996 and in 1998), sales and export volume in both years, ownership type (domestic or foreign subsidiary), R&D and innovation expenditures in 1998, R&D personnel, participation in public R&D programs, cooperation (in R&D), and patent applications within the period 1996-1998. Cooperation means that the firm is actively involved in joint R&D and/or innovation projects with other organizations. Subcontracting is not regarded as cooperation. The questionnaire did not collect information to construct spillover indices. All firms in the sample are located in Catalonia, a region in north-eastern Spain that produces about 19% of Spain's GDP, and whose manufacturing industries spend about 28% of Spain's business innovation expenditure.

Table 1 shows the distribution of firms by cooperation and program participation status.²¹ Cooperation rates are much higher for participants in either type of program than for non-participants, suggesting that public agencies might tend to fund R&D projects that involve cooperation. The strong association between participating in EU programs and cooperating is not surprising since cooperation among firms or institutions of several member states is required for obtaining EU R&D funds. The association is not as strong in the case of national programs, because not all lines of funding require cooperation.

[Insert Table 1 about here]

When distinguishing according to partner type: customers and/or suppliers (vertical cooperation) and Universities or public labs (public-private cooperation) we observe that about 24% of firms in the sample collaborate with Universities and 19% cooperate with customers or with suppliers.²² Table 2 shows the frequency of cooperation by type of partner and participation status in our sample.²³ Among participants in national programs, the share of collaborations with public labs and Universities is sensibly higher than for non-participants. The pattern is different for participants in EU programs, where collaboration with other firms seems to be more prevalent.

[Insert Table 2]

Table 3 provides some additional information on the size distribution of firms and its association with cooperation. In terms of firm size distribution, about 26% are large firms, 45% are medium-sized firms, and 26% are small firms. Clearly the rate of cooperation increases with firm size. Interestingly, within each size interval partnerships with public research centers are slightly more frequent than with customers or suppliers.²⁴

[Insert Table 3]

²¹A small number of firms (41) participate in regional level programs but almost all of them also participate in national level programs. The number of firms participating in other international programs is even smaller, so the description focuses basically on national and EU programs.

²² Our initial plan was to include cooperation with competitors as a specific category, but the number of observations was too small to allow for a meaningful econometric analysis.

²³ These categories are not mutually exclusive. However, almost half of the partnerships involve only one additional partner. Less than 20% of firms that cooperate do it at the same time with customers and suppliers and with universities.

About one third of firms applied for patents between 1996 and 1998, but only 17% applied for international patents. Foreign owned firms engage in cooperation more frequently than domestic firms (56% versus 38%, respectively).²⁵ Finally, most large firms declare allocating resources to R&D on a regular basis, while small firms report occasional R&D activities more frequently.²⁶

4. Empirical framework: model and hypotheses.

4.1. Empirical approaches.

There are two possible approaches to estimating the effect of program participation on cooperation with a particular partner type. One is to specify a parametric structural model, and the second is to use a quasi-experimental approach, such as a propensity score matching method.

We specify first a structural model for cooperation and participation in national-level R&D programs. We exclude participation in EU programs precisely because cooperation is a requirement for obtaining EU funds, so participating in those programs and cooperating are not different choices. Including an EU participation indicator in a cooperation equation would produce a perfect predictor problem. Hence a different setting is required to evaluate the effects of EU programs on R&D partnerships.²⁷ National-level programs instead allow firms to apply for different types of R&D subsidy programs. Cooperation is not a requirement for all of them, although it is for a subset of programs that provide more generous funding when a firm sets up a partnership with universities or other public research organizations.

²⁴ There were a small number of firms reporting horizontal cooperation, insufficient to perform a statistical analysis.

²⁵ About 27% firms in our sample are foreign owned, where foreign owned means having more than a 50% share in ownership.

²⁶ A discussion of sample representativity as well as an extensive description can be found in Fernández-Ribas (2003).

²⁷ A treatment effects approach, described below, would be adequate. This method involves comparing firms that participate to those that do not participate but have the same likelihood of doing it. The appropriate control group would consist of firms that are involved in international cooperation but do not participate in EU programs. The problem we face in practice is that within this sample we have a very small number of such cases; hence we do not have a control group.

The structural model consists of a recursive system of equations where participation status is allowed to affect the choice of cooperation partners, but not vice versa.²⁸ The first equation determines participation in an R&D program, while the second and third refer to establishing a vertical or a public-private R&D partnership:

$$P^*_N = Z_N b_N + v_N \quad [1]$$

$$Y^*_v = X_v b_v + P_N d_{vN} + w_v \quad [2]$$

$$Y^*_{pp} = X_{pp} b_{pp} + P_N d_{ppN} + w_{pp} \quad [3]$$

P^*_N is the unobserved propensity to be a participant in a national level program. A binary participation status indicator is observed. Z_N is a vector of exogenous variables. Y^*_j is an unobserved variable capturing the net benefit of including a particular type of partner, X is a vector of individual firm characteristics. The parameter of interest is mostly d_{vN} .

The problem is that the effect of participating, d_j , on R&D partnerships will be overstated if omitted variables contained in the error term w are correlated with P , participation status. Some common omitted variables, such as project characteristics, may account for such correlation. In addition, participation and cooperation may be simultaneously determined. Therefore endogeneity tests must be conducted. In case exogeneity is rejected, structural parameters in [2] and [3] can be consistently estimated through instrumental variables provided that identification conditions are satisfied. If the system is not identified, only a reduced form can be estimated, but not the policy parameter of interest. However, a non-parametric estimator of the impact of program participation can still be obtained under certain conditions.

The second empirical approach consists of focusing exclusively on obtaining an estimate of the parameter of interest, d_{vN} , that is, estimating the impact of a “treatment”, which in this case is

²⁸ Ours is a selected sample, since it does not include non-R&D performing firms. Therefore results do not extend to the whole population of firms.

participating in an R&D program, on cooperation with partner type j , without intending to explain other determinants of cooperation. This can be done by using a matching estimator.

Following the methodological debate in evaluation research, mostly in the field of labor market and social policies, a number of estimators of the effects that program participation has on treated individuals have been proposed in order to deal with the selection bias that typically arises when using non-experimental data. Among them are matching methods. In the spirit of controlled experiments, the idea is to compare participants, the *treated* individuals, to an appropriate control group of non-participants, controlling for the fact that assignment to each group is non-random in the available sample. The advantage of this approach is that its aims are more modest than those of structural modeling, in that it focuses exclusively on the policy parameter. It does not intend to explain the behavior of economic agents, hence there is no need of specifying a structural model. This method reduces that part of selection bias caused by correlation between observed characteristics of an individual and its treatment (participation) status. The key maintained assumption is that conditional on the vector of observed variables X , the observed outcome under treatment and the potential outcome under no treatment are independent of treatment. That means that conditioning on this vector, unobservables do not affect assignment, so that assignment to treatment can be considered random.²⁹ A non-zero correlation between participation status and unobserved characteristics of cooperating firms would be a source of selection bias.

The first step of the matching method consists of finding in the sample an appropriate control group of non-participants using all information contained in vector X . Since X is usually multidimensional and contains continuous variables, one way to implement the matching procedure is using the *propensity score*, or probability of being treated. This amounts to estimating the probability of participating, and then, for each participant, choosing among non-participants, only those that have the same estimated probability of participating. The second step consists of testing for differences in mean cooperation rates for participants and non-participants. This provides an estimate of the average treatment effect on

the treated.³⁰ In the next sections we first describe the main hypotheses linked to the structural model, and then discuss the results obtained by using both approaches.

4.2. Hypotheses about variables affecting cooperation partner choice.

The data set includes a number of objective, measurable variables that capture some firm characteristics. Unlike the papers reviewed above, however, we have no information on managers' perceptions about the importance of certain sources of information or of certain obstacles for innovation. Consequently, we cannot build indicators for incoming or outgoing spillovers. However, to the extent that these subjective beliefs may be correlated to objective characteristics of the firm such as size, knowledge capital indicators or industry class, we can expect that the lack of this type of information will have only limited effects in terms of bias. We describe next the variables and state some hypotheses about their relationship with partner choice.

Firm size. Most previous empirical evidence shows that firm size is a key variable for predicting whether a firm will engage in R&D. However, once a firm does R&D, it is not clear why and how size should be relevant regarding cooperation. On the one hand, given a potential R&D project, smaller firms may be more likely to cooperate in order to share associated fixed costs. On the other hand, large firms may also find cooperation beneficial when potential R&D projects are very costly. Without information about the nature and scope of R&D projects, it is not possible to make a conclusive prediction on the effects of firm size. However, if we assume that vertical cooperation involves mostly development of complementary innovations and technology transfer projects, while private-public cooperation tends to involve projects with a heavier and more risky research component, then we would expect SMEs to be more likely to participate in vertical agreements, and large firms more likely to participate in private-public partnerships. We use the number of employees as a measure of firm size, and expect it to have on average opposite effects on each type of partnership.³¹

²⁹ See Heckman, Ichimura, Smith and Todd (1998) and Dehejia and Wahba (2002).

³⁰ An application of this method to evaluate the effects of public R&D subsidies can be found in Almus and Czarnitzki (2003) and Czarnitzki, Ebersberger and Fier (2004).

³¹ Table A1 in the Appendix contains the precise definition of each variable.

Knowledge capital. A firm's knowledge capital is a valuable intangible asset in R&D cooperation partnerships. However, to the extent that some partnerships are established precisely to facilitate technology transfer and product development, partners may differ from each other in this respect. We do not have information about partner characteristics for each cooperative agreement, but it is reasonable to expect vertical cooperation agreements to involve some partners with low levels of knowledge capital. In public-private partnerships, in contrast, we would expect firms to have a high level of knowledge capital, as they need to have absorptive capacity to benefit from university research.

We will use five indicators of the firm's knowledge capital related to innovation experience, knowledge assets and human capital. *Stable RD* is a binary variable taking the value of 1 if the firm allocates at least one time-person to R&D over some years. *PatSp* is binary and equal to 1 if the firm has applied for patents only at the Spanish Patent Office, and *PatInt* is binary and equal to 1 if the firm has applied both in Spain and in some international patent office. The variable *Researchers*, the ratio of R&D researchers to non-R&D employees, approximates human capital intensity. Finally, we use the (log) average *wage of R&D* employees as an indicator of researcher quality. We expect them to increase the likelihood of public-private partnerships. Their effect on vertical partnerships is ambiguous since partners will differ in this dimension.

Foreign ownership. Foreign owners have a majority stake in about one fourth of the firms in our sample. We expect subsidiaries to be more likely to engage in vertical partnerships either with the mother company or with local suppliers or customers (for developing specific complementary innovations or adapting products to local markets). We expect subsidiaries to be less likely, on average, to engage in private-public partnerships because they can access the type of generic knowledge they can provide through the mother company but also because this link may allow them to access international technology markets more easily than domestic firms. We define the variable *Foreign* as binary and equal to 1 if foreign share in ownership was at least 50% in 1998.

Export propensity. The relationship between innovation and exporting has been established in the international trade literature, and empirical evidence supports the existence of a causal link from innovation to export performance. Feedback effects from exporting to innovation behavior have been less explored. There would be two possible reasons for feedback effects. First, exporters, being exposed to international competition, face higher pressure to innovate through all kinds of R&D strategies, including cooperation, than non-exporters. Second, exporting firms gain access to a richer network of customers, suppliers or competitors than non-exporters, making international cooperation more likely. Therefore, we expect exporters to be more likely to cooperate with any partner, and to test this prediction we include the share of exports over total sales in the set of explanatory variables.

Industry effects. Cooperation patterns may vary by industry and type of partner. CIS aggregate data show that 25% of firms in the chemical, electrical and optical equipment industries innovated through cooperation in 1997, while in the wood, paper or textile industries the rate was well below 10%. Cooperation with universities and public labs is probably more beneficial in industries where basic and applied research is an increasingly important source of innovations, i.e., the chemical and pharmaceutical industry. To test for industry effects in the choice of partners we define five industry level binary variables: chemical/pharmaceutical industry (*IndCHF*), high tech industries (*IndHT*), medium-high tech (*IndMHT*), medium-low tech (*IndMLT*) and low tech (*IndLT*).³²

Receiving public support. R&D partnerships involve costs and risks that can deter cooperation. These may be higher when partners have different global objectives and incentives, as is the case of firms and universities, where in addition the nature of potential projects may be relatively open and exploratory. Public funding reduces the cost for firms to experiment with this type of partner, so we expect it to have a positive effect on the likelihood of partnering with a PRO. In private vertical partnerships we expect partnership costs to be smaller on average, because R&D projects are likely to

³² We basically follow the standard OECD classification; we just single out the chemical/pharmaceutical industry. Table A2 details the industry classification.

be well defined, close to market and relatively short-term. There would be less room for market failure in that case, and public funding may not have a significant *additionality* effect.

4.3. Hypotheses about variables affecting participation in national R&D programs.

National level R&D and innovation programs may have several goals at the same time, such as increasing both business R&D expenditure and the number of researchers employed by firms, promoting cooperative research between firms and universities, public research centers or technological centers, and encouraging participation in international programs.³³ Several types of funding are established accordingly, ranging from grants to subsidized loans. Firms decide whether to apply for funding for an individual R&D project or for a joint R&D project with other partners. Application costs usually are not expected to be a significant barrier, unlike those of European level programs. Since all firms in our sample conduct R&D, we assume that most are well informed about the existence of these programs and able to present proposals without incurring in high costs.

The ability to obtain funding, and hence participation status, will most likely be determined by the funding agencies' preferences and budget. Program information obtained from national public agencies in Spain and application forms suggests that when deciding whether to fund an R&D and innovation proposal public agencies weigh technical and commercial feasibility as well as the benefits generated for other firms and consumers. Other than that, program guidelines do not seem to impose additional eligibility conditions.³⁴

Firm size, knowledge capital and R&D experience are likely to be positively associated with technical and commercial feasibility, and hence with participation. However, to the extent that a variety of market failures may affect SMEs in particular, and that public agencies intend to offset this, the relationship between firm size and the probability of participation could be negative. Which effect dominates is an empirical question. We expect national agencies to have a preference for domestic

³³ See the annual report of the Ministry of Industry and Energy, MINER (1998).

relative to foreign owned firms; whether the firm is export oriented or not would not in principle be a matter of concern for the public agency. Finally, we expect agencies to have a preference for high-tech industries.³⁵

5. Results.

5.1. Cooperation and participation in national R&D programs: structural and reduced form estimates.

As explained above, we consider only the effects of national programs and eliminate from the sample those firms that participate in EU programs. We are left with 661 firms, of which 29% have a vertical or a public-private partnership, or both, and 27% receive public funding. We first estimate a set of univariate probit models for cooperation as a whole and then separately for each of the two types of partnerships, including as explanatory variables all those we assume to be exogenous.³⁶ These are reduced form estimates. We then include participation status as an explanatory variable treating it as exogenous. To test for endogeneity of participation, we estimate a cooperation equation for each type of partnership where participation status and residuals from a probit model for participation are included as explanatory variables.³⁷ Finally we also obtain estimates of the correlation between participating and each of cooperation type from two bivariate probit models.

Table 4 shows the results of estimating the univariate probit models for cooperation and for each type of cooperation. Columns (1), (3), and (5) show that the net effect of firm characteristics on cooperation varies with the type of cooperation. We find that vertical cooperation is more likely to be observed among foreign owned, non-exporting firms, and firms that have intangible assets in the form of international patent applications, as well as high human capital. Firms in the chemical and

³⁴ We consider all national programs as a whole. Within national programs there are sectoral sub-programs as well as some specific for public-private partnerships.

³⁵ We do not have data on rejected applicants, but just on whether or not a firm obtains public funding. Consequently we cannot strictly test for the agencies' selection criteria, but only test the net effect of firm characteristics on its participation status.

³⁶ We have jointly estimated both equations as well, but results do not change significantly.

³⁷ See Wooldridge (2002).

pharmaceutical industry are less likely to establish vertical partnerships. We interpret these results as suggesting that technology transfer is likely to be an important motivation for this type of cooperation in Spain.

In contrast, we find that cooperation with public research institutions is mostly driven by research intensity: one percentage point rise in the ratio of researchers over non-R&D employees increases the likelihood of cooperating by 67%. We interpret this as evidence that having absorptive capacity is highly important for establishing this sort of partnership, whereas it seems to be much less important for vertical partnerships. The effect of firm size is positive and significant but small. Firms in the chemical and pharmaceutical industry are more likely to collaborate with public research institutions.³⁸

[Insert Table 4 about here]

When we include participation status in the cooperation models and treat it as an additional exogenous variable, we find that participation has a positive effect on all types of cooperation. Columns (2), (4), and (6) in Table 4 report the estimated marginal effect on the probability of establishing a partnership. Being a participant becomes one of the most important variables to affect the likelihood of cooperation with public research organizations, and it would increase the probability of cooperating by 0.25 points. The impact on vertical cooperation is smaller but positive and significant. Estimates of coefficients for other variables remain practically unchanged.

These estimates above will be inconsistent if the correlation between the error terms of cooperation and participation is non-zero. A Hausman test for endogeneity is performed by estimating each cooperation equation including as explanatory variables both participation status and the residuals obtained in the estimation of participation status. Under the null hypothesis of exogeneity, the coefficients for the residuals should be zero. According to our estimates, reported on Table 5, we

³⁸ We have estimated several specifications, using size, size squared, researchers and researchers squared, as explanatory variables, as well as interaction terms between size and industry indicators. Results are very similar. We also estimate a bivariate probit model for both cooperation types, and find that the correlation estimates is positive and significant. Equality of coefficients across equations is rejected in all cases.

cannot reject the null for vertical partnerships, but we do reject exogeneity in the case of public-private partnerships.

[Insert Table 5]

To obtain an estimate of the effect of participation on the likelihood of establishing a private-public partnership we need a proper instrument for participation, that is, a variable that is correlated with participation but not with cooperation. Among the available variables we do not have a good candidate fulfilling this condition, so in practice we cannot estimate the structural model for public-private partnerships. Hence we turn to a treatment effects approach to estimate the policy effect.

5.2. The effects of participation on cooperation: a treatment effects approach.

As explained above, the purpose of this approach is to compare cooperation rates of participants in national R&D programs to those of an appropriate control group, without attempting to test hypothesis about the determinants of cooperation. The first step involves estimating the propensity score or probability of being a participant and using this estimate to find an appropriate control group. We use the specification shown in column (2) of Table A3 in the Appendix to obtain this estimate.³⁹ Interpretation of the estimated coefficients is of interest. We find that the firm's knowledge assets (percentage of researchers and having international patents) significantly increase the chances of obtaining public funding, while firm size has a positive but rather small impact and foreign ownership tends to reduce them.⁴⁰

Table 6 shows the number of participants and of available comparable non-participants for five intervals of the estimated probability of participating in national R&D programs. For participants in

³⁹This specification provides a slightly better match of treated and controls than the specification in column (1). We have experimented with additional specifications, including interaction effects between industry and firm size. Although they are in some cases significant, the estimate of the policy effect does not vary.

⁴⁰ We have estimated, but do not report here, a model for participation in EU programs. Results show that participants in this type of program have a rather different profile. The variable that has a larger and significant impact on the likelihood of participating is export intensity, while firm's knowledge assets are not significant. This suggests that participation of Catalan firms in European level R&D programs may increase if more firms compete in international markets.

each block we are able to find comparable controls, that is, firms a set of firms that have a similar probability to participate but who do not. Thirty-seven observations are discarded for lack of match.⁴¹ Table A4 in the Appendix shows the means of observed characteristics of the treated and control groups. Differences are not significant except for basically two variables: research intensity and having applied for international patents. Inspection of the distribution of research intensity reveals a higher proportion of firms with very low research intensity among non-participants, but otherwise the distributions are quite similar. As for applications for international patents, 31% of non-participants have applied, relative to 50% of participants. We will take this significant difference into account below.

[Insert Table 6 about here]

The second step consists of calculating the difference in mean cooperation rates for participants and non-participants. This provides an estimate of the average treatment effect on the treated. Table 7 shows the results for each type of partnership using two alternative matching methods, Kernel and Stratification, and three sets of treated and corresponding control groups. The first set uses all 180 treated firms and 444 controls. But as shown on Table A4, treated firms and controls differ significantly in international patent application. Therefore, we split the sample, and we estimate the treatment effect for the sub-sample of treated and controls that have applied for international patents, and then for the sub-sample that have not.

We find that the receiving public support increases the likelihood that firms will cooperate with universities or public labs by about 28%, and that the magnitude of this effect is similar whether firms have applied for patents or not. The effect of public support on the probability of cooperating with customers/suppliers, however, is higher if firms have applied for patents than if they have not. The increase is of 0.17 probability points and of 8% respectively, but the latter barely significant. In both cases the effect of participating on private-private partnerships is smaller than the effect on public-private partnerships. From a policy perspective, this means that subsidizing firms that do not have a

⁴¹ The region of common support is in the range (0.087, 0.909). This means that there are no participants with a predicted probability smaller than 0.087, and no non-participants with a probability higher than 0.9.

certain type of intangible assets (international patent applications) may not lead on average to a significant increase in private-private partnerships.

[Insert Table 7 about here]

As indicated above, we have to keep in mind however that unobserved factors related to project characteristics (extent of novelty and basicness) and to managerial abilities and attitudes might affect simultaneously participation status (treatment) and cooperation partnerships. In that case one of the assumptions of the treatment approach would not be satisfied, and the treatment estimator could be overestimating the true effect of participating. However, with the data available it is not possible to test for the presence and size of this potential source of bias.

6. Conclusions and implications.

In this paper we have analyzed some determinants of firms' choice of type of partner to cooperate in R&D, as well as the impact of participation in public R&D programs on this decision. We extend previous work by focusing explicitly on testing the behavioral change induced by public support, taking into account the source of public support as well as the endogeneity of participation. Our main findings, obtained with a sample of innovative and R&D performing firms from the Spanish innovation survey, are summarized as follows.

First, using a reduced form approach, we find that the choice of cooperation partner is related to firm characteristics and that the impact of these characteristics differs across partner type. This result is in line with those of similar studies that analyze the motivation for partnerships. Our results differ from others, however, in that in our study vertical cooperation is more likely among firms that sell mostly in the domestic market, are foreign subsidiaries and have applied for international patents. Firm size does not play a significant role. These results differ from those obtained for Dutch firms. We interpret these results as suggesting that vertical cooperation is used as a mechanism for technology transfer in Spain,

Observations outside this range are discarded.

where there is higher proportion of firms whose R&D activities are oriented towards technology adoption rather than generation.

The likelihood that firms cooperate with universities or public labs increases substantially when firms have in-house research capacity, apply for international patents, and are in the chemical and pharmaceutical industry. Firm size has a small positive effect on public-private partnerships. Our results are in this case in line with similar studies for advanced countries. The fact that one of the most important variables to affect the likelihood of cooperation with a PRO is the number of researchers in firms suggests that the effectiveness of public funding could be enhanced if complemented with policies that encourage hiring highly qualified labor at the firm level, thereby increasing its human capital and its absorptive capacity.

Second, we find that participation in national R&D programs changes firms' behavior in the intended direction. The probability that a firm will cooperate with a PRO increases by 0.28 points when it receives public support. Vertical partnerships are also increased as a result of participating in national programs, but to a lesser extent and mostly for firms that already have intangible knowledge assets, embodied in international patents (by about 0.18 points).

This is evidence, therefore, of behavioral additionality, indicating that there are indeed barriers to partnerships that affect in particular those between firms and PROs, and that public support helps to overcome them. The change in behavior may have permanent effects if it leads to repeated collaboration.

Before drawing any policy implications from these results, however, we should note the limitations of the data set we use. First, our estimates are based on a cross section of firms, limiting our ability to use alternative procedures to address endogeneity and firm heterogeneity issues, as well as our ability to check the robustness of our results. Second, an important proportion of variation in cooperation and in participation remains unexplained. The data available do not allow us to estimate the magnitude of

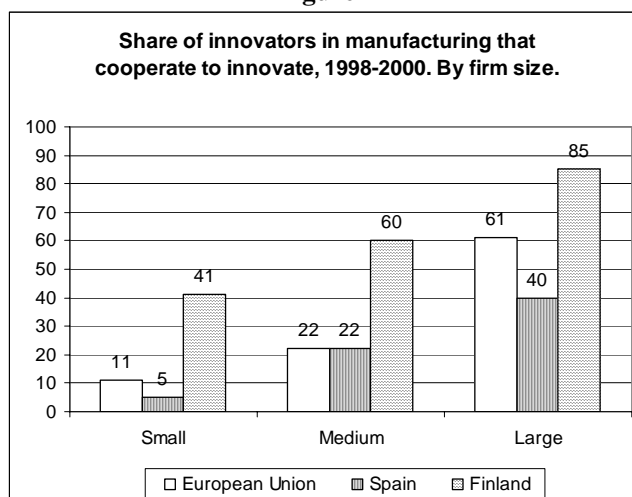
both potential sources of bias. These considerations have implications for data collection. In particular, R&D program evaluation research could benefit from some enhancements to CIS type of survey. One possible enhancement is to design it as a true longitudinal survey. A second enhancement would be considering the addition of key questions related to managers' skills as well as to R&D project and partner characteristics. These may help improve our understanding of innovation decisions, how they change over time, and how alternative policy instruments affect them.

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Figure 1



Note: Size is measured by the number of employees. Small refers to firms with 10 to 49 employees; Medium to firms with 50 to 249 employees, and Large firms with 250 or more employees.

Source: European Commission (2004).

Table 1
Cooperation and participation in different publicly funded R&D programs.

		Cooperate					
		No		Yes		Total	
		Num	Percent	Num.	Percent	Num.	Percent
Participate in National Programs	No	338	63%	198	37%	536	100
	Yes	70	39%	110	61%	180	100
Participate in EU Programs	No	401	61%	260	39%	661	100
	Yes	7	13%	48	87%	55	100
Total		408		308		716	

Table 2
Subsample of firms that cooperate
Type of Partner and Program Participation

Type of Cooperation	Total	Participation in National R&D Programs				Participation in EU or International R&D Programs			
		Non-participants		Participants		Non-participants		Participants	
		N	N/198	N	N/110	N	N/260	N	N/48
Vertical	138	91	46%	47	42%	113	43%	25	52%
Public Research	169	94	47%	75	68%	154	59%	15	31%
Other firms	67	42	21%	25	23%	49	19%	18	37%
Number of firms that cooperate	308	198		110		260		48	

Table 3

Frequency of Cooperation by Size

Firm size	Number of firms	Percentage of firms cooperating within a given group size	Of those cooperating	
			% with vertical partnership	% with Public-private partnership
Small	194	29%	42%	49%
Medium	325	44%	41%	55%
Large	185	56%	51%	59%
Total	716	43%	45%	55%

Table 4
Determinants of R&D partnerships by type
 Estimated Marginal Effects on the Probability

	Cooperate All types (1)	Cooperate All types (2)	Vertical (3)	Vertical (4)	Public- Private (5)	Public- Private (6)
Size	0.07*** (3.55)	0.06*** (2.82)	0.02 (1.57)	0.02 (1.13)	0.05*** (3.44)	0.04*** (2.66)
Stable RD	-0.08 (-1.44)	-0.10* (-1.82)	0.01 (0.24)	0.001 (0.02)	0.03 (0.57)	0.007 (0.16)
RD Wage	0.05 (1.25)	0.05 (1.15)	0.02 (0.74)	0.02 (0.67)	0.02 (0.61)	0.02 (0.47)
Researchers	0.84*** (2.67)	0.64** (1.96)	0.34* (1.87)	0.25 (1.38)	0.67*** (3.01)	0.50*** (2.21)
PatSp	0.01 (0.14)	0.03 (0.47)	0.02 (0.53)	0.03 (0.72)	-0.06 (-1.25)	-0.03 (-0.74)
PatInt	0.13*** (2.45)	0.07 (1.31)	0.10*** (2.65)	0.07** (1.91)	0.16*** (3.90)	0.10*** (2.58)
Foreign	0.11*** (2.27)	0.17*** (3.35)	0.12*** (3.00)	0.14*** (3.61)	-0.04 (-0.99)	0.004 (0.11)
Export	0.03 (0.45)	0.008 (0.10)	-0.14*** (-2.48)	-0.15*** (-2.71)	0.03 (0.49)	0.01 (0.19)
Participation National	-	0.29*** (6.35)	-	0.13*** (3.67)	-	0.25*** (6.78)
IndLT	-0.01 (-0.20)	-0.03 (-0.52)	-0.01 (-0.29)	-0.02 (-0.48)	0.001 (0.03)	-0.02 (-0.41)
IndCHF	0.07 (1.00)	0.04 (0.54)	-0.11*** (-2.63)	-0.12*** (-3.00)	0.12*** (2.11)	0.09* (1.60)
IndMHT	0.03 (0.48)	0.02 (0.33)	0.07 (1.43)	0.06 (1.34)	-0.006 (-0.12)	-0.02 (-0.30)
IndHT	0.01 (0.15)	-0.01 (-0.18)	-0.03 (-0.68)	-0.04 (-0.82)	-0.05 (-0.73)	-0.07 (1.19)
Log L	-414.74	-394.25	-272.25	-265.56	-297.07	-273.91
Pseudo-R2	0.06	0.11	0.10	0.12	0.09	0.16
N	661	661	661	661	661	661
Y=1	39 %	39 %	17 %	17 %	20 %	20 %
% correctly predicted	68 %	68 %	66 %	68 %	63 %	72 %

Note: Single Equation Probit Estimates. z statistics in parentheses. *** stands for significance at the 1% level; ** at the 5% and * at the 10% level. Results are not qualitatively different when vertical and public-private partnerships are jointly estimated through a bivariate probit.

Table 5
Hausman Test for endogeneity of Participation

Equation	Estimated coefficient of residuals ^a (s.e. in parentheses) [z-value in brackets]
Vertical Partnerships	-0.55 (0.85) [-0.64]
Public-private Partnerships	-1.48* (0.83) [-1.77]

^a Cooperation status is regressed on participation, on the residuals from the estimation of the participation equation and on all exogenous variables but one. In these regressions firm size is interacted with industry dummies. Under the null hypothesis of exogeneity the coefficient of the residuals should not be significant. In this case exogeneity is not rejected for vertical cooperation but it is for public-private partnerships.

Table 6
Number of blocks of Treated and Controls for Participation in National Programs

Block	Inferior of Prob(participating)	Number of Controls Non-participants	Number of Treated Participants	Total
1	0.09	171	31	202
2	0.2	214	95	309
3	0.4	54	38	92
4	0.6	4	14	18
5	0.8	1	2	3
Total		444	180	624

Note: The optimal number of blocks is 5. The balancing property of the propensity score is satisfied: the mean propensity score is not different for treated and controls in each block.

Table 7
Estimates of the effect of Participation on Partner Choice
Average Treatment Effect

Sample	Type of matching	Vertical Cooperation	Public Cooperation
180 treated, 444 controls	Kernel	0.13 (0.03) ^(a)	0.28 (0.04)
	Stratification	0.14 (0.03)	0.27 (0.04)
89 treated, 133 controls ^(b)	Kernel	0.17 (0.06)	0.28 (0.06)
	Stratification	0.18 (0.05)	0.26 (0.07)
91 treated, 307 controls ^(c)	Kernel	0.08 (0.04)	0.26 (0.06)
	Stratification	0.09 (0.05)	0.29 (0.05)

Notes:

- a) Standard errors obtained by bootstrapping with 100 replications, are in parentheses.
- b) Sub-sample of treated and controls that have applied for international patents.
- c) Sub-sample of treated and controls that have not applied for international patents.

Appendix.

Table A1. Definition of Variables

Variable	Name in tables	Computed as
Vertical Cooperation	Vertical Cooper.	Binary; =1 if customers or suppliers are partners in firm's R&D or innovation projects
Public Cooperation	Public Cooper.	Binary; =1 if public research organizations are partners in firm's R&D or innovation projects
Cooperation	Cooperation	Binary; =1 if firm cooperates with any other organization.
Firm size	Size	Log employees in 1996
Stable R&D	Stable RD	Binary; =1 if firm does R&D regularly
Average wage of R&D employees	Wage	Log (R&D salaries 1998/number of R&D employees 1998)
Human capital	Researchers	Researchers in 1998/non RD employees, 1998
Patents Spain	PatSp	Binary; =1 if applied for patents only in the Spanish Patent Office during 1996-98
International Patents	PatInt	Binary; = 1 if applied for patents in Spain and international Patent Office during 1996-98
Foreign ownership	Foreign	Binary; =1 if multinational subsidiary in 1998
Export intensity	Export	Ratio of Exports to Sales in 1996
Industry dummies	IndLT IndCHF IndMLT IndMHT IndHT	= 1 if Low tech = 1 if Chemical or pharmaceutical = 1 if Medium-low tech = 1 if Medium-high tech = 1 if High tech

Table A2. Classification of Manufacturing Industries

	ISIC codes
IndLT. Low-technology industries	
Food products and beverages and tobacco	15+16
Textiles, textile products, leather and footwear	17+18+19
Wood, pulp, paper, paper products, printing and publishing,	20+21+22
Furniture and other manufacturing	36
IndCHF. Chemicals and pharmaceuticals	
24	
IndMLT. Medium-low-technology industries	
Coke, refined petroleum products and nuclear fuel	23
Rubber and plastic products	25
Other non-metallic mineral products	26
Basic metals	27
Fabricated metal products, except machinery and equipment	28
IndMHT. Medium-high-technology industries	
Machinery and equipment	29
Electrical machinery and apparatus	31
Motor vehicles, trailers and semi-trailers	34
Railroad equipment and transport equipment	35
IndHT. High-technology industries	
Office, accounting and computing machinery	30
Radio, television and communications equipment	32
Medical, precision and optical instruments	33

Table A3
Participation in public R&D programs
Dependent Variable: Probability of Participating in National level programs

<i>Explanatory variables</i>	Marginal Effects (1)	Marginal Effects (2)
Size (in logs)	0.05*** (2.80)	-
Size (level)	-	0.0002*** (2.41)
Size squared	-	-0.5E-7* (1.85)
Stable RD	0.06 (1.25)	0.06 (1.5)
RD wage	0.01 (0.40)	0.02 (0.59)
Researchers	0.65*** (2.72)	1.16*** (2.64)
Researchers squared	-	-0.93* (-1.74)
PatSp	-0.02 (-0.46)	-0.02 (0.46)
PatInt	0.17*** (4.06)	0.17*** (4.19)
Foreign	-0.14*** (-3.39)	-0.12*** (-2.99)
Export	0.06 (0.97)	0.07 (1.13)
IndLT	0.09 (1.52)	0.08 (1.45)
IndCHF	0.13** (2.08)	0.09 (1.61)
IndMHT	0.03 (0.48)	0.02 (0.28)
IndHT	0.10 (1.26)	0.05 (0.72)
Log L	-374.72	-374.36
Pseudo-R2	0.07	0.07
N	716	716
Y=1	180	180

Note: Single Equation Probit Estimates. z statistics in parentheses. *** stands for significance at the 1% level; ** at the 5% and * at the 10% level.

Table A4
Means of Characteristics of Treated and Controls

Variables	Means after matching		Mean Difference Ho: mean(treated) - mean(control) = 0
	Treated 179 obs.	Controls 444 obs.	
Size (level)	249.21 (430.50)	202.77 (354.26)	-46.44 (33.43)
Size squared	246,399 (1,157,422)	166,334.20 (1,018,253)	-80,065 (93,850)
Stable RD	0.90 (0.30)	0.82 (0.39)	-0.08* (0.03)
RD wage	10.28 (0.44)	10.25 (0.51)	-0.03 (0.04)
Researchers	0.05 (0.10)	0.03 (0.06)	-0.02*** (0.006)
Researchers squared	0.01 (0.08)	0.01 (0.05)	-0.007 (0.005)
PatSp	0.18 (0.39)	0.14 (0.34)	-0.05 (0.03)
PatInt	0.50 (0.50)	0.31 (0.46)	-0.18*** (0.04)
Foreign	0.22 (0.41)	0.26 (0.44)	0.04 (0.04)
Export	0.31 (0.27)	0.27 (0.27)	-0.04* (0.01)
IndLT	0.27 (0.45)	0.29 (0.46)	0.02 (0.04)
IndCHF	0.31 (0.46)	0.27 (0.45)	-0.04 (0.04)
IndMHT	0.22 (0.41)	0.22 (0.42)	0.005 (0.04)
IndHT	0.11 (0.32)	0.09 (0.29)	-0.01 (0.03)

Standard deviations in parentheses.