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

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Abstract

Research and innovation partnerships involving firms or firms and public research organizations (PROs) have been increasing over the last twenty years in OECD countries. In this paper we present empirical evidence about the impact of government sponsored R&D programs on firms' partnership strategies related to R&D. Using a sample of Spanish manufacturing firms we estimate the effects of receiving public support on the probability that firms set up an R&D partnership with a PRO or a partnerhsip with other firms that are suppliers or customers. Controling for the endogeneity of participation in R&D support programs, we find that (i) the choice of private-private and of public-private partnerships is associated with different firm characteristics, and (ii) public support encourages directly or indirectly both types of cooperation, but the impact on public-private partnerships is larger. Results suggest that R&D cooperation is affected by market failures, and that public programs subsidizing industry-science links trigger a behavioral change in firms' R&D strategic partnerships.

JEL CODES: O31, O38, H32, C25, C35.
KEYWORDS: R&D, vertical cooperation, public-private partnerships, innovation policy.

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1. Introduction.

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) countries, provides additional evidence on R&D partnerships and on their diverse importance 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 1998-2000[2]. 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.

Significant and large cross-country differences are observed, however: 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 varying rates of innovative firms, even within this subset differences are large, as Figure 1 shows.[3]

At the same time public support programs have been implemented in the US, Japan and the EU with the purpose of encouraging private R&D effort as well as research partnerships between private firms and public research organizations. The Advanced Technology Program in the US and the EU's successive European Framework Programs are significant illustrations of these policies.

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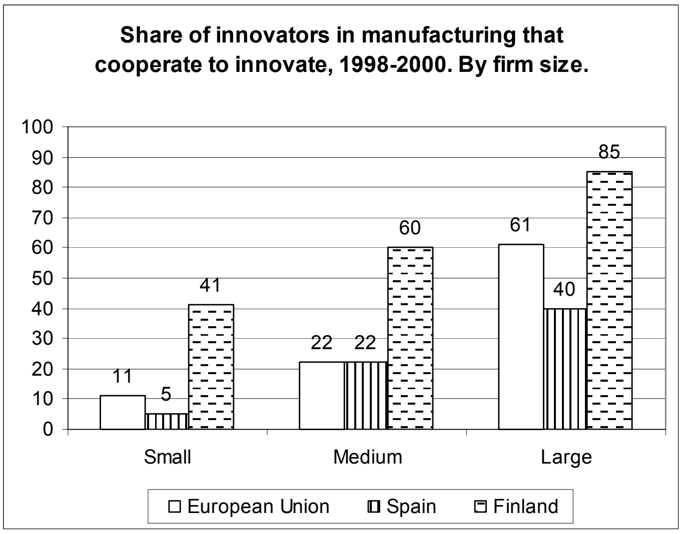
[1] The Community Innovation Survey (CIS) is a European-wide firm level survey focusing on innovation and R&D decisions. It has been conducted three times (1992, 1996 and 2001) in all European Union member countries. There is a set of common core questions for all countries. Definitions and survey methodology 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).

Figure 1



Note: Size is measured by the number of employees. Small refers to firms with 10 to 49 employees; Medium to those with 50 to 249 employees, and Large to 250 or more. Source: European Commission (2004).

These observations raise a number of questions of interest from a policy perspective. Some deal with the need to understand the determinants of private and social costs and benefits of research partnerships and how they vary across types of partners, in order to provide a solid ground for policy design. Another set of questions deals with the ex-post evaluation of these policies, and involves analyzing how public support for R&D and for R&D partnerships affect firm behavior and innovation performance. The main issue is whether without support outcomes would have or not been the same.

While there is a quite extensive body of empirical research on the determinants of research partnerships, evidence on the ability of public support to effectively increase them is relatively limited. The evaluation literature has focused on the impact that public support has on private R&D expenditure (testing for substitution effects), on patenting or on other measures of

[3] See European Commission (2003a and 2004).

innovation performance, but not on its effects on firm behavior regarding how these activites are organized.[4]

In our contribution we explicitly address this issue and investigate whether public support for private research and innovation activities changes firms' research cooperation strategies and increases the likelihood to cooperate with particular types of partners.[5] To that end we use a large sample of manufacturing firms in Spain and obtain estimates of the effect of program participation on the probability that a firm will establish vertical (with customers or suppliers) and/or public-private partnerships. 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 previous firm-level 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 likely to be affected by market failures that public programs help overcoming.

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.

[4] See for instance Darby et al. (2004) on the ATP Program and Czarnitzki et al (2004) on German and Finish Programs.

[5] 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 addtioality is measured by the increase in private R&D expenditure triggered by public support. Output addtionality 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.

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

The analysis of R&D cooperation has been approached from a variety of perspectives, producing an extensive stock of literature. Both within the business and the industrial organization fields several not mutually exclusive hypotheses have been proposed in order to explain which factors affect the incentives that firms have to cooperate with other firms or with public research organizations. They can be broadly classified in four types.[6] One strand of the literature emphasizes that to develop an innovation firms need 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 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 hyptothesis predicts R&D cooperation may occur when it enables partners to increase market power in the product market (Martin (1995)).

The choice of different types of partners (customers or suppliers, competitors, public research organizations) will presumably be affected by the importance of each of these factors for firms in different industries and by the nature of their R&D projects (whether their purpose is using

[6] For recent surveys see Sena (2004) or Caloghirou, Ioannides and Vonortas (2003). Detailed references are given in these surveys.

science to develop new commercial applications or solve complex problems, developing or adapting complementary innovations, setting standards), and to 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.[7] 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 partnerhips are possibly more likely (horizontal cooperation with (potential) competitors).[8]

While there is quite an extensive empirical literature studying the determinants of R&D cooperation and its effects on performance, evidence on how motivations and firm characteristics affect partner choice is more limited. Recently the availability of European firm-level data has made possible to test some hypotheses related to partner choice with a comparative perspective.[9] Cassiman and Veugelers (2002)[10] provide interesting insights in that direction. Using Belgian data on manufacturing firms, they find that incoming spillovers, outgoing spillovers, firm size, cost and risk of research affect partner choice.[11] In particular, incoming spillovers (proxied 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

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[7] Several dimensions of heterogeneity are possible: firm size, knowledge assets, market scope or location, or product space.
[8] See Röller, Siebert, Tombak (2004).
[9] 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. Few data sets have this type of information. Some examples are those used by Navaretti et al (2002), Bizan (2003) and Röller et al. (2004).
[10]Kaiser (2002), Fritsch and Lukas (2001) and Tether (2002) have also investigated whether different types of partnerships have different determinants using cross-section data.

a vertical partnership.[12] In contrast, lack of tecnological 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 of the types of partnership, they have a larger impact on the probability of cooperating with public research organizations.

Overall these results suggest that the nature of the projects involving public partners differs from those involving private partners. Collaborations with public research organizations are presumably 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 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 directions for expanding Cassiman and Veugeler's work. One involves the addition of objective explanatory variables some of which are usually available in this type of data set, such as the firm's affiliation to a foreign company. As is well known in the literature,

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[11] They find that a model for horizontal cooperation cannot be estimated because only a small number of firms declare having this type of partnership.

[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.

[14] There is an expanding literature, theoretical and empirical, on public-private collaborations. Specialized journals have devoted special issues to this topic. For our purposes as well as for brevity we highlight in the text a small number of empirical contributions that focus on the comparison between private-public and private-private partnerships 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), who analyze projects funded by the Advanced Technology Program in the US. One of their findings is that property rights are indeed an issue in public-private partnerships, preventing sometimes their formation.

foreign direct investment may be a channel of technology transfer, through mechanisms such as labor mobility or directly through technological alliances with local companies that are either customers or suppliers. On the other hand, depending on the country's scientific base, foreign owned firms might also source knowledge from local public research organizations. It is therefore interesing to test whether this type of firms are more likely to engage in one type of partnership or the other.

A second factor that may affect the choice of partner is whether the firm receives public funding for research activities. Public support for private research is usually based on the belief that private incentives to perform R&D and to set up partnerships in particular might not be high enough to reach the socially desirable level. This is more likely to be the case when 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.[15]

A first step to evaluate whether programs contribute to mitigate market failures associated to private R&D activities is to test whether they induce behavioral change, or behavioral additionality. 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 might fall. On the other hand, when the aim is to measure output additionality, data for several periods might be needed, since research projects can take some time to produce results, and these take place over a number of years. Unless the data used covers a wide period, including observations before, during and after receiving support, the overall impact of public funding might be underestimated. Hence behavioral additionality can provide a better measure of short run policy impact.

Behavioral additionality means in our case that we should observe 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 is not a random outcome, but 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 by estimation methods.

Out of four studies that estimate the effect of public programs on cooperation using data from the European Community Innovation Survey only one explores the issue of endogeneity. Belderbos et al. (2003) use a panel data set of Dutch firms to obtain estimates of the impact that some factors have on three types of partnerships: horizontal (involving competitors), vertical and private-public, including the effect of public support.[16] The authors find that two factors increase significantly the probability of cooperating with any type of partner: firm size and firms' perceptions of universities and public research and innovation centers as important sources of knowledge. An indicator of the speed of technological change seems to be what

[15] An interesting reference in that respect is Klette and Moen (1999).
[16] Two waves of the Dutch CIS survey (for periods 1994-1996 and 1996-1998) provide a set of variables including measures of incoming and outgoing spillovers, firm characteristics and firms' perceptions of

distinctively leads firms to cooperate with research centers, while being part of a group and lack of organizational capabilities positively affect vertical partnerships. The effect of receiving R&D subsidies is not conclusive, however, as results vary with the empirical strategy used to control for subsidy endogeneity.[17]

Remaining studies have looked into the relationship between partner choice and program participation without addressing the endogeneity problem. 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), who study the determinants of collaboration between firms and national universities or government labs by European firms from several countries, find that receiving subsidies is the most influential factor affecting the probability that a firm will set up this type of collaboration.[18] Finally, Bayona, García and Huerta (2003) study the determinants of horizontal and vertical cooperation in Spain. Their results confirm that the drivers of each type of cooperation are not the same, that relatively small firms are more likely to engage in vertical cooperation, and that participation in international R&D programs increases horizontal cooperation but not vertical cooperation.[19]

The common result from these studies is that firm characteristics affect the choice of partners suggesting that different types of cooperation tend to benefit different types of firms. The effects of particular characteristics and, most importantly from a policy perspective, participation in public R&D programs do not seem to be robust across samples, however. A possible

main obstacles for R&D activities as in Cassiman and Veugelers (2002). The samples consist of innovative firms, that is, those that introduced a product or process innovation during the surveyed period.

[17] 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.

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

explanation for these differences is the treatment of endogeneity of R&D subsidies. An addtional shortcoming is that a distinction between national and EU programs is often not made when it should because programs have different eligibility conditions, suggesting that public agencies use different selection rules.[20] 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 conducted by the Spanish Statistical Institute (INE) in 1999. We use a sub-sample of 737 manufacturing firms that reported positive expenditures in R&D in 1998.[21] 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: European, other international, national and regional level. Most firms participated in only one program, mainly at the national level.

Table 1 shows the distribution of firms by cooperation and program participation status.[22] 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

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[19] They use the Spanish Innovation Survey for 1994-1996. In this and a companion paper, Bayona et al (2001) find that the probability of engaging in any type of cooperation increases with firm size and in-house R&D experience.

[20] See Blanes and Busom (2004) on patterns of participation across industries and agencies.

[21] The questionnaire includes questions 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 expenditures by category (wages, equipment), R&D personnel and innovation expenditures in 1998, participation in public R&D programs, cooperation to innovate (in R&D), and patent applications within the period 1996-1998. Cooperating 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, an autonomous region in northeastern Spain. It produces about 19% of Spain's GDP, 22% of the Spanish Gross Domestic Expenditure on R&D, and 28% of business innovation expenditures in manufacturing industries.

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, but the data suggest that national agencies may have a preference for funding R&D partnerships.

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	

Note: The whole sample of 716 firms is used in this table, after public utilities and a small number of firms with missing information have been eliminated.

When distinguishing according to partner type: customers and/or suppliers (vertical cooperation) and Universities or public labs (public-private cooperation) we observe that about 20% of firms in the sample collaborate with Universities and 19% cooperate with customers or with suppliers.[23] Table 2 shows the frequency of cooperation by type of partner and participation status in our sample.[24] Among participants in national programs, the share of collaborations with public labs and Universities is sensibly higher than for non-participants. The

[22]A number of firms (41) participate in regional level programs but almost all of them also participate in national level programs. Similarly, the number of firms participating in other international programs is very small, so the description focuses basically on national and EU programs.
[23] 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.
[24] These categories are not mutually exclusive, and some firms have several types of partners at the same time. However almost half of the partnerships involve only one additional partner; less than 20% of the number of firms that cooperate do it with customers and suppliers and with universities at the same time.

pattern is different for participants in EU programs, where collaboration with other firms seems to be more prevalent.

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

		Participation in National R&D Programs				Participaion in EU or International R&D Programs			
Type of Cooperation		Non-participants		Participants		Non-participants		Participants	
	Total	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	

Note: The number of firms with R&D partnerships is 308.

Other characteristics of our sample are the following. In terms of firm size distribution, about 26% are large firms, 45% are medium-sized firms, and 26% are small firms. Table 3 shows the pattern of cooperation by type of partner and firm size interval. 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]

[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).

Table 3
Frequency of Cooperation by Size

Firm size	Number of firms	Percentage of firms cooperating within group size	Of those cooperating	
			% with vertical partnership	% with Public-private partnership
Small 10-49 employees	194	29%	42%	49%
Medium 50-249 employees	325	44%	41%	55%
Large 250 or more employees	185	56%	51%	59%
Total	716	43%	45%	55%

4. Empirical framework: model and hypotheses.

4.1. Empirical model.

An approach to modeling whether a firm will set up R&D and innovation agreements with certain partners, and its participation status in publicly supported R&D programs, consists of specifying a structural model with a recursive system of equations where participation status is allowed to affect the choice of cooperation partners, but not vice versa.[27] The system would be as follows, where the first two equations determine participation status, and the last two refer to establishing a vertical or a public-private R&D partnership:

$$P^{*}_{E} = Z_{E}\, b_{E} + v_{E} \quad [1]$$

$$P^{*}_{N} = Z_{N}\, b_{N} + v_{N} \quad [2]$$

$$Y^{*}_{v} = X_{v}\, b_{v} + P_{N}\, d_{vN} + P_{E}\, d_{vE} + w_{v} \quad [3]$$

$$Y^{*}_{pp} = X_{pp}\, b_{pp} + P_{N}\, d_{ppN} + P_{E}\, d_{vE} + w_{pp} \quad [4]$$

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

P^*_E and P^*_N are the unobserved propensity to be a participant in a European and a national level program, respectively. A binary participation status indicator is observed in each case. Z_E and Z_N are vectors of exogenous variables. Firms may participate in both programs at the same time. Analogously, $Y^*_{.j}$ is an unobserved variable capturing the net benefit of including a particular type of partner, X is a vector of individual firm characteristics, P_E and P_N are the participation status binary indicators, and w_j are normally distributed random error with zero mean. We observe the indicator variables $Y_j = \mathbf{1}(X_j b_j + P_N d_j + P_E d_{vE} + w_j > 0)$. Vectors X and Z can share some variables, but identification requires exclusion restrictions.

There are two problems with this model, however. The first is that participation in EU programs means that firms necessarily cooperate, so participating in those programs and cooperating are not different choices. Including an EU participation indicator in a cooperation equation is very likely to produce a perfect predictor problem. A different setting is required to evaluate the effects of EU programs on R&D partnerships.[28] National-level programs instead allow firms to apply for different types of R&D subsidies. Cooperation is not a requirement for all of them, although it is for a subset that provide more generous funding when firms set up a partnership with universities or other public research organizations. Consequently, equations [2] and a modified version of [3] and [4] can be estimated using the appropriate sample provided that the model is identified.[29]

The second problem is that the effect of participating, d_j, on R&D partnerships will be overstated if omitted variables contained in w are correlated with P, participation status. Both firm behavior and public agency selection rules may account for such correlation. Some likely

[28] 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 problem we face in practice is that we do not have a sufficient number of cases where we observe international cooperation and non-participation in EU programs, hence we do not have a control group.
[29] Participation status in EU programs would be dropped as an explanatory variable, and the sample should exclude those firms that received EU funding.

common omitted variables are those related to project characteristics. In addition, participation and cooperation may be simultaneously determined. Therefore endogeneity tests must be conducted, and provided that identification conditions are satisfied, structural parameters in [3] and [4] can be consistently estimated through instrumental variables.

If identification conditions do not hold the structural parameters cannot be estimated, hence the effect of participation on the establishment of partnerships. However, a non-parametric estimator of the impact of program participation can still be obtained under certain conditions. 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.[30] In the spirit of controlled experiments, the idea is to compare the *treated* sample of firms, those that participate, with an appropriate control group consisting of non-participants, using field data and controlling for the fact that assignment to each group is non-random. 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. In addition it 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 observed variables X, the observed outcome under treatment and the potential outcome under no treatment are independent of treatment. That means that conditioning on X unobservables do not affect assignment, so that assignment to treatment can be considered random.[31]

[30] See Heckman, Ichimura, Smith and Todd (1998).
[31] See for instance Dehejia and Wahba (2002).

The first step of the matching method consists of finding in the sample an appropriate control group of non-participants using all information used in X. Since X is usually multidimensional, one way to simplify the matching is using *propensity score,* the 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. Matching estimators, however, do not deal with an additional source of potential selection bias, that caused by correlation between participation status and unobserved characteristics of cooperating firms, because zero correlation is a maintained assumption.[32]

We use both approaches because as we explain below the data set does not provide instrumental variables to estimate a structural model for public-private partnerships, although a reduced form can be estimated. We first discuss the variables used and their relationship with partner choice.

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.

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[32] 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).

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 opposite effects on each type of partnership.[33]

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 be quite different 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

[33] Table A1 in the Appendix contains the precise definition of each variable.

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 partnership member 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 bee 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*).[34]

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

[34] We approximate follow the standard OECD classification. Ideally we would like to distinguish between different high tech indutries, because many studies find that science as a source of innovations plays a different role in the pharmaceutical than in the IT industries. Our data base does not allow us to make this distinction, so we just single out the chemical/pharmaceutical industry. Table A2 details industry definition.

4.3. Hypotheses about variables affecting participation in national R&D programs.[35]

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.[36] 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.

Obtention of 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.[37]

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

[35]We focus on national level programs because the number of participants in EU programs is small, and when distinguishing by type of partner the number of observations becomes smaller. A participation model can be estimated though.
[36] See the annual report of the Ministry of Industry and Energy, MINER (1998).
[37] 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.

negative. Which effect dominates is an empirical question. We expect national agencies to have a preference for domestic 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.[38]

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. 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.[39] 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

[38] We do not have data on rejected applicants, but just on whether o 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.

[39] See Wooldridge (2002).

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 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 a middle income country as 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 of utmost importance 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.[40]

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.

[40] We have estimated several different specifications, using size, size squared, researchers and researchers squared, as explanatory variables, as well as interaction terms between size and industry indicators. Results are similar. We also estimate a bivariate probit model for both cooperation types, and find that the

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.

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

correlation estimates is positive and significant. Equality of coefficients across equations is rejected in all 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 cannot reject the null for vertical partnerships, but we do reject exogeneity in the case of public-private partnerships.

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.

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 the 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

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cases.

explain them. 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.[41] 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.[42]

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 each block we are able to find comparable controls, that is, firms a set of firms with a similar probability to participate but who have not. Thirty-seven observations are discarded for lack of match.[43] 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.

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[41]This 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.

[42] 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.

[43] 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. Observations outside this range are discarded.

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 one of the variables, international patent application. Therefore, we estimate treatment effects for the sub-sample of treated and controls that have applied for international patents, and then for the sub-sample that have not.

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.

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

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 interntational patents.
c) Sub-sample of treated and controls that have not applied for international patents.

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 progams on this decision. We extend previous work by taking into account the nature of public support as well as the endogeneity of participation, and by focusing explicitly on estimating the behavioral change induced by public support, or behavioral additionality. 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 by Belderbos et al. (2004) for Dutch firms. We interpret these results as suggesting that vertical cooperation is used as a mechanism for technology transfer in Spain, where a there is higher proportion of firms whose R&D activities are oriented towards technology adoption than in the Netherlands.

Cooperation with universities or public labs is substantially more likely when firms have in-house research capacity, apply for international patents, and are in the chemical and pharmaceutical industry. Firm size has here 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, increasing its human capital as well as 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; 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 knowledge assets. This is evidence, therefore, of behavioral additionality, indicating that there are indeed barriers to partnerships, which affect in particular those between firms and PROs, and that public support helps to overcome them. The change in behavior may have permanent effects to the extent that it contributes to raising a firm's absorptive capacity, in addition to increasing short term innovativeness performance.

Before drawing any policy implications from these results, however, we should note some limitations this research. First, our estimates are based on cross sectional data, limiting our ability to use alternative procedures to deal with endogeneity and heterogeneity issues. Second, an important proportion of variation in cooperation and in participation remains unexplained. Third, matching methods provide unbiased estimates when unobservables affecting cooperation and participation are not correlated, which may be a strong assumption in our case. The available data set however does not allow for estimating the magnitude of the bias. These considerations have implications for data collection. In particular, evaluation research would benefit from some enhancements to CIS type surveys: they should collect information on managers' abilities as well as on R&D project and partner characteristics. Finally, the need to provide good instruments for endogenous variables and to estimate dynamic effects should also be taken into account.

6. References.

Almus, M. and D. Czarnitzki (2003), "The Effects of Public R&D Subsidies on Firms' Innovation Activities: The Case of Eastern Germany", Journal of Business and Economic Statistics 21 (2), pp. 226-236.

Bayona, C., T. García-Marco and E. Huerta (2001), "Firms' Motivations for Cooperative R&D: An Empirical analysis of Spanish Firms", Research Policy 30, 1289-1307.

Bayona, C., T. García Marco, E. Huerta Arribas (2003), "¿Cooperar en I+D? Con quién y para qué", Revista de Economía Aplicada, Núm. 31 (Vol. XI), pp. 103-134.

Belderbos, R., M. Carree, B. Diederen, B. Lokshin and R. Veugelers (2004), "Heterogeneity in R&D Cooperation Strategies", International Journal of Industrial Organization, forthcoming.

Bizan, O. (2003), "The determinants of success of R&D projects: evidence from American-Israeli research alliances", Research Policy 32, pp. 1619-1640.

Blanes, J.V. and I. Busom (2004), "Participation in R&D programs: Who gets the Money?", Research Policy

Buisseret, T.J., Cameron, H. and L. Georghiou (1995), "What difference does it make? Additionality in the public support of R&D in large firms", International Journal of Technology Management 10, pp. 587-600.

Caloghirou, Y., S. Ioannides, N.S. Vonortas (2003), "Research Joint Ventures", Journal of Economic Surveys Vol 17, No. 4, pp. 541-570.

Carayol, N. (2003), "Objectives, agreements and matching in science-industry collaborations: reassembling the pieces of the puzzle", Research Policy 32, pp. 887-908.

Cassiman, B. y Veugelers, R. (2002): "R&D cooperation and spillovers: some empirical evidence from Belgium" American Economic Review, 92 (4), pp. 1169-1184.

Czarnitzki, D. B. Ebersberger and A. Fier (2004), "The relationship between R&D collaboration, subsidies and patenting activity: empirical evidence form Finland and Germany", ZEW Discussion Paper 04-37. Available at http://www.zew.de

Darby, M.R., L.G. Zucker and A. Wang (2004), "Universities, Joint Ventures and Success in the Advanced Technology Program", Contemporary Economic Policy 22(2).

Dehejia, R.H. and S. Wahba (2002), "Propensity score matching methods for nonexperimental causal studies", Review of Economics and Statistics 84, pp. 151-161.

D'Aspremont, C. and A. Jacquemin (1988), "Cooperative and non cooperative R&D in duopoly with spillovers", American Economic Review 78, pp. 1133-1137.

De Bondt, R. (1996), "Spillovers and innovative activities", International Journal of Industrial Organization 15, pp. 1-28.

European Communities (2004), "Sources and resources for EU innovation", Statistics in Focus, Science and Technology, Theme 9-5/2004, Eurostat.

European Commission (2003a), 2003 European Innovation Scoreboard, Inovation/SMEs Programme, Enterprise Directorate General.

European Commission (2003b), Indinews, Newsletter on Science and Technology and Innovation Indictors, Nº 10/October 2003.

Fernández-Ribas, A. (2003), "Cooperación en innovación e intervención pública", Tesis Doctoral, Departament d'Economia Aplicada, Universitat Autònoma de Barcelona.

Fritsch, M. and R. Lukas (2001), "Who cooperates on R&D", Research Policy 30, pp. 297-312.

Hagedoorn, J. (1993): "Understanding the rationale of strategic technology partnering: Inter-organizational modes of cooperation and sectoral differences" Strategic Management Journal 14(5), pp. 371-385.

Hagedoorn, J., A.N. Link and N.S. Vonortas (2000), "Research partnerships", Research Policy 29, pp. 567-586.

Hagedoorn, J. (2002) "Inter-firm R&D partnerships: An Overview of Major Trends and Patterns since 1960", Research Policy 31, 477-492.

Hall, B. H., A.N. Link and J.T. Scott (2001), "Barriers inhibiting industry from partnering with Universities: Evidence from the Advanced Technology Program", Journal of Technology Transfer 26, pp. 87-98.

Hall, B. H., A.N. Link and J.T. Scott (2003), "Universities as research partners", The Review of Economics and Statistics 85(2), pp. 485-491.

Heckman, J.J., H. Ichimura, J. Smith, P. Todd (1998), "Characterizing Selection Bias Using Experimental Data", Econometrica, Vol. 66, pp. 1017-98.

Hernán, R., P.L. Marín, G. Siotis (2003), "An Empirical Evaluation of the Determinants of Research Joint Venture Formation", The Journal of Industrial Economics, Vol LI, No. 1.

Katsoulakos, Y, and D.Ulph (1998), "Endogenous Spillovers and the Performance of Reserach Joint Ventures", The Journal of Industrial Economics, 46, pp. 333-354.

Kaiser, U. (2002), "An empirical test of models explaining research expenditures and research cooperation: evidence for the German service sector", International Journal of Industrial Organization 20, pp. 747-74.

Klette, T.J. and J. Moen (1999), "From growth theory to technology policy. Coordination problems in theory and practice", Nordic Journal of Political Economy 25(1), pp. 53-74.

Martin, S. (1994), "R&D Joint Ventures and Tacit product market collusion", European Journal of Political Economy 11, pp. 733-741.

MINER (1998), "Informe sobre la Industria Española 1997-98", Vol I., Ministerio de Industria y Energía, Madrid.

Miotti, L. and F. Sachwald (2003), "Cooperative R&D: why and with whom? An integrated framework analysis", Research Policy 32, pp.

Mohnen, P. and C. Hoareau (2003), What Type of Enterprise forges close links with Universities and Government Labs? Evidence from CIS2", Managerial and Decision Economics 24, pp. 133-145.

OECD (2002), Science, Technology and Industry Outlook 2002, Paris.

Röller, L:H, R. Siebert and M.M. Tombak (2004), "RJVs and firm heterogeneities", mimeo.

Sakakibara, M. (2003), "Knowledge Sharing in Cooperative Research and Development", Managerial and Decision Economics 24, pp. 117-132.

Sena, V. (2004), "The return of the prince of Denmark: A survey on recent developments in the economics of innovation", The Economic Journal 114, pp. F312-F332.

Sinha, D. K. and M.A. Cusumano (1991), "Complementary resources and cooperative research: A model of research joint ventures among competitors", Management Science 37 (9), pp. 1091-1106.

Tether, B. (2002), "Who cooperates for innovation, and why: an empirical analysis", Research Policy 31, pp. 947-67.

Wooldridge, J.M. (2002), Econometric Analysis of Cross Section and Panel Data, The MIT Press, Cambridge, Massachusetts.

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

Explanatory variables	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 Pseudo-R2 N Y=1	-374.72 0.07 716 180	-374.36 0.07 716 180

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.

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