National or international public funding? Subsidies or loans? Evaluating the innovation impact of R&D support programmes

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February 2014

Abstract

The objective of this study is to compare the effect of different types of public support for R&D projects on firms' technological capabilities. We distinguish between low-interest loans and subsidies and between national and European support. Using data of 2,319 Spanish firms during the period 2002-2005, we estimate a multivariate Probit to analyse the determinants of the firm's participation in public R&D programmes and, later, the impact of this participation on firms' technological capabilities using different indicators. The results provide evidence of the effectiveness of all treatments for improving firms' innovative performance although their impacts differ. Specifically, although the three kinds of public aid stimulate the intensity of R&D investment, the highest impact corresponds to soft credits. In addition, national subsidies have a higher impact on internal R&D intensity than EU grants, but the opposite relation is found as regards total R&D intensity. With respect to the innovation outputs, apart form the indirect effect of public support by stimulating R&D intensity we also find evidence of a direct effect of the participation in the CDTI credit system and in the European subsidy programme on the probability of obtaining product innovations and applying for patents.

***Keywords*:** Soft credits, R&D subsidies, impact assessment

J.E.L. Classification: H81, L2, O3, L52

This research has been partially funded by the Seventh Framework Programme (Ref.: 290597) and by a research grant from the Spanish Ministry of Science and Innovation (Ref.: ECO2010-19847).The authors thank the CDTI for the transfer of the data to carry out this research.

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1. INTRODUCTION

There is a huge empirical evidence about the impact of public aid on private R&D with a wide variety of countries analysed and methodologies employed to take into account that the public support can be endogenous (Wallsten, 2000; Busom, 2000; Lach, 2002; Duguet, 2004; González, Jaumandreu and Pazó, 2005; González and Pazó, 2008; Czarnitzki and Licht, 2006; OECD, 2006; Clausen, 2008; Takalo, Tanayama and Toivanen, 2013). Most papers consider a unique programme in their analyses and this fact makes difficult an accurate comparison of the impacts among funding systems, which can differ in their objectives, the national or supranational character of the supporting entity and the funding scheme (Blanes and Busom, 2004). In this sense, it seems reasonable that their evaluation also provides different results.

Two exceptions are the papers by García and Mohnen (2010) and Czarnitzki and Lopes-Bento (2011). In both cases, the empirical analysis is based on the micro data from the Community Innovation Survey (CIS). The first one compares the impact of public support from the central government and from the European Union (EU) on the innovation of Austrian firms, using the third wave of the CIS covering the years 1998-2000. To measure the effectiveness of these programmes, the authors propose a structural model of the endogeneity of innovation and of public support for it. The estimation of this model by the method of asymptotic least squares suggests that receiving central government support increases the intensity of R&D by 2.3 percentage points and yields a 2.5 percentage point increase in the share of new to firm innovative sales. However, EU support is never significant once national support is taken into account.

The study by Czarnitzki and Lopes-Bento (2011) also offers a comparison of the impact of national and European funding on innovation intensity and performance. The empirical analysis is based on the German part of the CIS for seven waves but, as the data can only be used as pooled cross-sections, to face the endogeneity problem they apply a variant of a non-parametric matching estimator. In terms of the innovation input, their results provide evidence that getting funding from both sources displays the highest impact, while EU subsidies have higher effects when the firm receives funding only from one source. As for innovation performance, funding from both sources again yields higher sales of market novelties and patent applications, but in this case the impact of national funding is superior when only one type of grant is achieved.

The objective of this paper is to compare the effect of the participation within different public funding programmes on the technological performance of Spanish firms. This will allow us to analyse the relative relevance of two features of public programmes: the national or supranational character of the financing agency, that is usually associated with the national or international character of the R&D project, and the magnitude of reimbursement implied in design of the public support. Specifically, we consider public programmes based on low-interest loans versus national and European innovation subsidies.

For this purpose we integrate two data sets. The first one is provided by the Centre for the Development for Industrial Technology (CDTI). This public organism grants financial help of its own to companies and facilitates access to third-party funds for the execution of both national and international research and development projects. The second database is provided by the National Institute of Statistics (INE) and corresponds to a sample of innovative firms from the Spanish Technological Innovation Survey (the Spanish version of the CIS). Overall, we compile a homogeneous sample that consists of an unbalanced panel of 7,007 observations and 2,319 firms for the period 2002 to 2005. Specifically, 1,850 of them have received some type of public support for their R&D projects during the period.

The factors taken into account to apply for a low-interest loan by the CDTI or for a national or European subsidy can differ. However, some of them may be the same as those that affect the firm's R&D decision. This fact can generate a bias in the impact of these funding instruments on innovative performance of firms if the CDTI or the other public domestic and foreign organisms award firms with a better technological profile.

To deal with this selection problem, in this paper we follow a two-stage procedure. Firstly, we estimate a multivariate Probitmodel to study the determinants of each of the three schemes of public support. Then, in a second stage, we analyse how this participation affects the technological capability of the firms. Specifically, we consider the R&D intensity as technological input, and product and process innovations and patent applications as technological outputs. We use a Heckman's treatment effect model to face selectivity and endogeneity problems.

Our results confirm that the three instruments are effective to enhance firms' R&D intensities. However, the highest impacts correspond to soft credits. As for innovation outputs, there is an indirect effect of public support by stimulating R&D intensity that has a positive impact on the generation of innovations and the application for patents. In addition, we find evidence of a direct effect of the participation in the CDTI credit system and in the European subsidy programme on the probability of obtaining product innovations and applying for patents. However, this direct effect is not present in the case of process innovations.

The rest of the paper is organized as follows. In section 2 we highlight how some characteristics of support programmes can justify their different impact on firms' innovation. In section 3, we describe the empirical model and the data. Section 4 shows the estimates and discusses the results. Finally, we present key conclusions in Section 5.

2. THE LINK BETWEEN INNOVATION IMPACT AND PROGRAMME FEATURES

Assessing the impact of public support to firms' R&D projects on innovation inputs or outputs requires a clear understanding of the design of public programmes. Although the general design of an R&D programme is likely to have an impact on innovation, it is difficult to clearly associate certain design features of R&D programmes with (not directly intended) innovation (European Commission, 2009).

In this paper we investigate the role of two specific dimensions of supporting schemes: the national versus supranational level of the programme and the reimbursable character of the aid. As for the first aspect, why should we expect a different impact of R&D subsidies depending on the government level of the supporting organism? There are at least three reasons:

First of all, the design of R&D programmes can differ between public agencies of different levels of governance, especially when they have specific objectives. These aims can consist of stimulating specific groups such as R&D champions (picking-the-winners strategy), SMEs with major financial constraints to undertake R&D projects, or companies in sectors with large knowledge externalities. In the case of national agencies, the objective could also be the technological updating of firms in traditional or declining sectors (see, Blanes and Busom, 2004), whereby the agencies try to increase the probability of survival and avoid employment losses. And depending on the final objective, selected projects can be more or less market-oriented or focused on core technologies of participants. For instance, the Framework Programme (FP) of the European Union is characterised by the participation of universities and research institutes in consortia and the relevance of pre-competitive research, while the Eureka Programme is more market-oriented (Benfratello and Sembenelli (2002).

Alternatively, as Busom and Fernández-Ribas (2007) point out, programmes implemented by different jurisdictions could be complement if the agencies coordinate efficiently to take into account the nature and extend of spillovers and other relevant market failures. In fact, most supra-national policies are justified by the existence of cross-border spillovers and economies of scale. In this line, Busom and Fernández-Ribas (2007) test whether the Spanish government and the European Commission have different selection criteria for awarding R&D subsidies to firms. They conclude that the determinants of firm participation in each programme are different, suggesting that these programmes do not systematically overlap ex-post, as intended ex-ante by policy makers.

A second argument is related to the different costs of application in each programme (Czarnitzki and Lopes-Bento, 2011). These application costs are mainly related to bureaucratic and administrative requirements that are enlarged when the procedure of granting implies a negotiation phase. Firms usually perceive this negotiation phase as resource-consuming, delaying the timing of the R&D project (Barajas and Huergo, 2010).

In addition, application costs increase with coordination costs in the case of programmes that imply the existence of self-organized consortia, as it often happens in supra-national R&D programmes. The organization of the network of partners, the formulation of the proposal and the daily monitoring of the project usually entail higher overhead costs in time and human resources than in the case of individual R&D projects.

And a third reason for having different impacts among programmes refers to the size of expected knowledge spillovers. These spillovers refer both to the company's ability to capture information flows from the public pool of knowledge (incoming spillovers) and to the ability to control the information flows out of the firm (outgoing spillovers) to appropriate the returns from own innovation.

The measurement of these spillovers is especially complex in cooperative R&D agreements. In fact, as Cassiman and Veugelers (2002) find out, there is a significant relation between external information flows and the decision to cooperate in R&D; and the level of knowledge in- and outflows is not exogenous to the firm. This element is especially important for our analysis, as projects financed through supra-national programmes correspond usually to Research Joint Ventures (RJVs) that involve partners from different countries. In this case, the technological capabilities of subsidized firms can be affected not only by public aid but also for the spillovers of cooperation among partners. However, most papers that study the impact of public programmes supporting RJVs consider R&D collaboration and R&D public support to be an integrated treatment (Benfratello and Sembenelli, 2002; Bayona-Sáez and García-Marco, 2010; Kaiser and Kuhn, 2012; Barajas, Huergo and Moreno, forthcoming). An exception is the paper by Czarnitzki, Ebersberger and Fier (2007), who interpret RJVs and subsidies as heterogeneous treatments for a sample of German and Finnish firms. Although, they find that the combination of both treatments has a positive impact on the firm's R&D expenditures or the number of patents, when cooperation and public support are separately analysed, subsidies for individual research do not significantly affect R&D or patenting by German firms.

The reimbursable character of the public support is a second dimension that could affect our analysis when comparing the effect of subsidies and credits. In this sense, as perceived by programme managers, the existence of private co-funding is highly relevant for innovation impact (European Commission, 2009). Preferential(below market) or low-interest credits in fact imply a hidden subsidy in terms of interest savings. However, they are fully compatible with fiscal incentives, while subsidies in many cases imply that firms cannot benefit from tax cuts that are related to R&D investments. The credits also self-enforce more discipline on the recipients, as they acquire the compromise to pay back the principal. The monitoring of the project development by the agency is in consequence also higher. In addition, the percentage of the firm's budget that is allocated to the project is higher than usual, and it may be easier to obtain private financing outside the company (Huergo and Trenado, 2010).

3. THE EMPIRICAL MODEL AND THE DATA

Following the literature on impact assessment of R&D policies, the implicit question to answer is what the behaviour of a supported firm would have been if it had not received this public aid. The problem is that each firm can only be observed either in the status of receiving the support or not. Therefore, to measure the effect of public aid on technological capability, we have to take into account that the participation within a funding programme agency probably depends on the same firm characteristics that determine innovative performance. That is, it is necessary taking into account both selection and endogeneity problems.

The econometric literature has developed several methods in order to solve these difficulties (Heckman, 1979; Cerulli and Potì, 2012; Aerts, Czarnitzki and Fier, 2006; Guo and Fraser, 2010). In this paper we follow the Heckman's treatment effect model: Initially, a selection equation for the participation status is estimated for each of the three programmes considered in our analysis: the CDTI' programme of low-interest credits, the Spanish programme of R&D subsidies and Framework Programme of the European Commission.[1] Then, we analyse the impact of this participation on some variables measuring technological inputs or outputs.

Specifically, our first equation is devoted to the participation of firm $i\,(i=1\cdots N)$ in a funding public programme $m\,(m=1,2,3)$ during year $t\,(t=1\cdots T)$ and is formalized in terms of a multi-variate model given by:

$$y_{mit}=\begin{cases}1 & \text{if } y^{*}_{mit}=x_{mit}\beta_m+u_{mit}>0\\ 0 & \text{otherwise}\end{cases} \qquad [1]$$

, where y^{*}_{mit} is a latent dependent variable, x_{mit} is the set of explanatory variables that can differ across equations, β_{m} is the vector of coefficients and u_{mit} are the error terms distributed as multivariate normal, each with a mean of zero, and variance–covariance matrix *V*, where *V* has value of 1 on the leading diagonal and correlations $\rho_{\mathrm{jk}}=\rho_{\mathrm{kj}}$ as off-diagonal elements:

$$\begin{pmatrix}u_{1it}\\ u_{2it}\\ u_{3it}\end{pmatrix}\approx N_M\left[\begin{pmatrix}0\\0\\0\end{pmatrix},\begin{pmatrix}1 & \rho_{12} & \rho_{13}\\ \rho_{12} & 1 & \rho_{23}\\ \rho_{13} & \rho_{23} & 1\end{pmatrix}\right]$$

In the second step, we analyse how the participation of the firm in these programmes affects its technological profile, distinguishing between innovation inputs and outputs.

Initially, we deal with the R&D intensity as a measure of technological inputs. Following the approach of Griffith et al. (2006), we believe that, to some extent, all firms make some innovative effort. However, below a certain threshold, the firm is not capable of picking up explicit information about this effort and will not report on it. Thus, we estimate a selection model for the observed R&D intensity. In particular, we think that we can measure the R&D effort

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[1] We have only information about financed projects and therefore we cannot distinguish between the firm's decision to apply for the aid and the agency selection among the proposals. The main disadvantage of this lack of information is that the selectivity problem is not fully considered.

id_{it}^{*} by the intensity of the R&D expenditure id_{it} only if the firm makes and reports that expenditure. To represent this decision to perform and report R&D expenditures, we assume the following selection equation:

$$r_{it} = \begin{cases} 1 & \text{if} \quad r_{it}^{*} = \sum_{m=1}^{3} p_{mit}\gamma_m + z_{1it}'\delta_1 + \varepsilon_{1it} > 0 \\ 0 & \text{otherwise} \end{cases} \qquad [2]$$

, where r_{it} is a binary variable that takes the value 1 when the firm invests in (and reports) R&D, and 0 otherwise. If the latent variable r_{it}^{*} is bigger than a constant threshold (which can be zero), we then observe that the firm engages in (and reports) R&D activities. In this equation, p_{mit} denotes the predicted value for the probability of participating within a funding public programme, γ_m is the parameter reflecting the impact of the different programme of public aid, z_{1it} is a vector of observable explanatory variables. Finally, ε_{1it} is an idiosyncratic error.

Conditional on the performance (and reporting) of R&D activities, we can observe the quantity of resources allocated to this purpose; that is,

$$id_{it} = \begin{cases} id_{it}^{*} = \sum_{m=1}^{3} p_{mit}\gamma_m + z_{2it}'\delta_2 + \varepsilon_{2it} & \text{if} \quad r_{it} = 1 \\ 0 & \text{if} \quad r_{it} = 0 \end{cases} \qquad [3]$$

, where z_{2it} is a vector of determinants of the innovative effort, which can differ from those determinants that explain the decision to perform and report R&D expenditures and ε_{2it} is the error term.

Therefore, we estimate a Heckman modelassuming that the error terms ε_{1i} and ε_{2i} follow a bivariate normal distribution with a mean equal to 0, variances $\sigma_1^2 = 1$ and σ_2^2, and correlation coefficient ρ_{12}. This structure allows us to analyse if the impact of public aid differs across programme not only in the decision to engage innovation activities but also in the R&D intensity.

After this, we focus on technologicaloutputs that we measure through binary variables for the generation of process and productinnovations and for patent application. We formalize the production of technological output as follows:

$$w_{it} = \sum_{m=1}^{3} p_{mit}\gamma_m + z_{3it}'\delta_3 + \varepsilon_{3it} \qquad [4]$$

, where z_{3it} is a vector of determinants of the technological outputs, which can differ depending on the dependentvariable considered, and ε_{3it} is the error term. In some specifications, we include the latent R&D effort, id_{it}^{*}, as an element ofvector z_{3it}, assuming that the more the firms spend on R&D activities, the higher their probabilitywill be to obtain technological outputs. In this case, public support can affect innovation outputs directly (through γ_m) or indirectlyby increasing R&D intensity. Given that our measures of technologicaloutputsare binary variables,this equation is estimated as a Probit model.

Notice that, in equations [2] to [4], to deal with the selection (and endogeneity) problem, the predicted probability of participation in each public programme is considered instead of the observed participation status.

3.1. The database

As we have mentioned at the introduction, two data sources are used in this paper. The first one is the CDTI database of low-interest credits for R&D projects. During the period 2002-2005, the CDTI financed three types of projects through soft loans: Technological Development Projects (TDP), Technological Innovation Projects (TIP) and Joint Industrial Research Projects (JIRP). Specifically, we consider 1,787 projects which were granted a low-interest credit by the CDTI during this period.These data are especially suitable for our analysis as most of the direct R&D support of the Spanish Central Government is channelled through the CDTI, and the main CDTI's instrument during this period consists of credits at a preferential interest rate.

This information has been completed with a database provided by the National Institute of Statistics (INE) that corresponds to a sample of innovative firms from the Spanish Technological Innovation Survey. In this survey we find complementary information about the sources of public financialsupport for innovation activities from the different levels of government. Unfortunately, we do not have access to information related to R&D tax credits. This can limit the results of our analysis as, nowadays, the Spanish tax system is considered as one of the most generous among OECD countries in terms of the tax subsidy rate (OECD, 2012).[2]

For the estimations we have eliminated 42 observations with a ratio of R&D expenditures over sales bigger than 10 (more that 1000%), that mainly relate to new firms which have initiated their technological activities but have not yet begun to sale their products or services.The final sample consists of an unbalanced panel with 2,319 firms (7,007 observations).

As can be seen in Table 1, around half of the observations correspond to firms that do not achieve any type of public funding that specific year, while less than 5% of firms are supported through the three schemes in the period.

Table 1: Distribution of the sample by type of public funding. 2002-2005

	Yearly observations	Firms (in period 2002-2005)
Not public funding	3,675 (52.4%)	469 (20.2%)
Only CDTI credit	1,108 (15.8%)	635 (27.4%)
Only national subsidy	1,014 (14.5%)	209 (9.0%)
Only European subsidy	268 (3.8%)	139 (6.0%)
CDTI credit & national subsidy	587 (8.4%)	624(26.9%)
CDTI credit & European subsidy	32 (0.5%)	25(1.1%)
National & European subsidies	263 (3.8%)	104 (4.5%)
CDTI credit & national & European subsidies	60 (0.9%)	114 (4.9%)
	7,007	2,319

Notes: In column one, firms are classified according to the year that they are supported or not. In column 2,the firms are classified considering all the period.

The selection of explanatory variables in the model is based on previous empirical literature and is also determined by the availability of information in our databases. As for the firms' participation in public R&D programmes (equation [1]), most papers include measures of the firm's technological profile, as the chance to apply increases when the propensity to perform R&D projects is higher.[3]The available information allows us to consider several variables. The first one is the internal R&D intensity that we compute as the ratio of internal R&D expenditures over total employment. We also define the total R&D intensity as total (internal plus external) R&D expenditures per employee and the percentage of R&D employment (over

[2] A nice exercise associating the use of R&D subsidies and tax incentivesby Spanish firms with financing constrains and appropriabilitycan be found in Busom, Corchuelo and Martínez-Ros (2012).They conclude that, from apolicyperspective, these tools may be complements rather than substitutes.

[3] See, for instance, Blanes and Busom (2004), González, Jaumandreu and Pazó (2005), Heijs (2005), Clausen (2008) or Huergo, Trenado and Ubierna (2013).

total employment), as a proxy of skilled labour. In our sample, the means of these variables are greater in firms that have been awarded a European subsidy than in firms with a national subsidy, and also superior in these later than in firms with a CDTI credit (see Table 2).

In addition, we introduce an indicator reflecting whether the firm has technological cooperative agreements. We can distinguish between the kind of partners, that can be clients, providers, competitors, consultants and laboratories, other firms of the group, universities, public research centres (PRCs) and technological centres. As can be seen in Table 2, the sample mean of these indicators is higher for the participants in public R&D programmes than for non-awarded firms.

We also consider the generation of process and product innovations and the application for patents as proxies of technological outputs that can reflect the firm's innovative intensity and technological and commercial success. Again, the sample mean of these variables is higher for participantsin national R&D programmes than in non-supported firms. However, although companies with European funding present a higher probabilityof applying for patents, they do not show any significant differences in declaring product or process innovations with respect to non-public funded firms.

Regarding the sectorial dimension, while firms financed with national and European subsides are relatively more present in high and medium-tech services sectors[4], the proportionof firms supported by the CDTI seems to be higher among manufacturing firms.

In addition to the variables that reflect technological features, we also consider in our specification other firms' characteristics that can affect their participation in public R&D programmes. In this sense, the firm's size is a usual determinant in most papers which deal with the impact of public funding. However its effect on participation is not clear. SMEs are usually more affected by innovation- related market failures, so their benefits from public aid could be higher. However, large firms usually have more resources with which to undertake R&D projects and apply for the aid. In addition, public agencies can be too risk averse to finance R&D of small firms.

[4]In Appendix 1 we explain which NACE two-digit industry codes are assigned to each group. In this appendix we also present the definitions of the variables used in our estimates, and in Table A.1 of Appendix 2 we show their main descriptives for the whole sample.

Table 2: Means of main variables by type of public funding

	All firms	Non-supported firms (1)	Supported firms			Difference of means test[a)]		
			CDTI Credit (2)	National subsidy (3)	European subsidy (4)	(1) vs (2)	(1) vs (3)	(1) vs (4)
Technological characteristics								
- Internal R&D intensity (K€ per employee)	10.6	5.5	12.8	16.3	26.4	0.000	0.000	0.000
- Internal R&D performer (0/1)	0.785	0.649	0.879	1.000	1.000	0.000	0.000	0.000
- Patent application (0/1)	0.249	0.210	0.284	0.336	0.316	0.000	0.000	0.000
- Percentage of R&D employees (%)	58.7	47.4	66.4	74.8	80.7	0.000	0.000	0.000
- Process Innovation (0/1)	0.541	0.518	0.575	0.614	0.490	0.000	0.000	0.209
- Product Innovation (0/1)	0.632	0.585	0.674	0.756	0.613	0.000	0.000	0.197
- R&D performer (Internal or external) (0/1)	0.814	0.693	0.901	1.000	1.000	0.000	0.000	0.000
- Technological cooperation (0/1)	0.468	0.382	0.494	0.654	0.657	0.000	0.000	0.000
- Total R&D intensity (K€ per employee)	12.2	7.0	15.2	19.7	29.3	0.000	0.000	0.000
- High and medium-tech manuf. sector (0/1)	0.361	0.350	0.412	0.376	0.268	0.000	0.058	0.000
- High and medium-tech services sector (0/1)	0.126	0.099	0.103	0.187	0.255	0.352	0.000	0.000
Other firms characteristics								
- Belonging to a group (0/1)	0.428	0.418	0.467	0.468	0.440	0.001	0.000	0.307
- Export intensity (Export over sales)	0.232	0.223	0.263	0.257	0.216	0.000	0.000	0.537
- Exporter (0/1)	0.687	0.700	0.714	0.709	0.581	0.646	0.467	0.000
- Foreign capital (0/1)	0.106	0.109	0.113	0.098	0.085	0.710	0.187	0.071
- Public firm (0/1)	0.015	0.014	0.008	0.018	0.040	0.059	0.350	0.000
- Size (Number of employees)	313.3	299.1	268.0	365.3	581.5	0.153	0.025	0.000
- Start-up (0/1)	0.047	0.033	0.060	0.059	0.030	0.000	0.000	0.701
Number of observations	7,007	3,675	1,764	1,924	623			

Notes: The symbol (0/1) means dummy variable. [a)]: p-value of a two-sample difference of means test. This test is a t-test for continuous variables and a two-sample z-test of proportions in case of dummy variables.

Statistics in Table 2 show that firms awarded by the CDTI are smaller than companies financed through other public schemes, although the difference is not statistically significant with respect to non-awarded firms. However, firms supported by national or European subsidies are bigger than non-participants in public systems. Most observations of the sample refer to firms between 10 and 50 employees (33%), but more than 25% correspond to large firms, with more than 200 workers.

A second dimension frequently considered in the literature is the age of the firm. Again, its expected effect on participation is ambiguous. More experienced firms (older firms) are more likely to use public aid. However, young firms tend to be more financially constrained and, as a consequence, they could apply for and receive public aid more frequently. The information in our databases allows us to know whether the firm was born during the last three years. If this is the case, we consider the firm to be a start-up. Table 2 shows that the percentage of start-upsis higher among firms supported by national agencies, especially by the CDTI. Nevertheless, there are not significant differences in the percentage of firms supported by the EU and non-participants: about the 3% in both cases.

Another aspect that should be taken into account is the firm's competitive position in the reference market, which could be captured by its market share, the evolution of sales or the exporting activity. The key question here is what to expect. Will firms with more market power participate more in public programs? Regarding international competition, the expected answer for exporters would be affirmative, for at least two reasons. Their position in international markets could be a signal of their ability to transform innovations into successful products (Czarnitzki and Licht, 2006). Also, they could be facing lower application costs as they are more experienced in dealing with bureaucracy when compared with non-exporters (Takalo, Tanayama and Toivanen, 2013). However, in our sample, the presence of firms with foreign activity is clearly smaller among EU funded companies (see Table 2), while in terms of the export intensity participants supported by the soft credit system or national subsidies do not present differences in their foreign activity with respect to non-participants.

Finally, additional control variables are introduced. Time dummy variables are included, allowing for business cycle effects or changes in national and European agencies budget. As an indicator of the ease of access to external capital markets, possibly meaning better knowledge of the public aid system, a dummy variable representing the presence of foreign capital among shareholders is incorporated. As can be seen on Table 2, there are not significant differences between non funded firms and domestic supported ones.

For the same reason, an indicator of business group membership for each firm is considered. Agencies might be less willing to finance firms belonging to a group because it is expected that these firms benefit from the group in terms of having less financial restrictions. And a dummy variable representing the presence of public capital is incorporated. Notice that a higher proportion of public firms are supported by the European agency.

With respect to the decision to engage R&D investment and the determinants of the R&D intensity (equations [2] and [3]), the theoretical literature suggests including variables related basically to technological environment, market conditions, financial constraints, appropriability of technological returns and size (reflecting R&D economies of scale) as determinants (see, for example, Arvanitis and Hollenstein, 1994; Klepper, 1996).

To capture environmental and demand conditions, we have considered one indicator of the firm's export character, the export intensity and time dummies. We expect that firms operating in competitive international markets have more incentives to innovate and therefore to invest in R&D.

As for financial restrictions, the high level of risk of R&D projects and the existence of information asymmetries between firms and suppliers of external finance increase the firms' dependence on internal funds (Hall, 2002). Therefore, firms with liquidity constraints are expected to have more difficulties undertaking R&D projects. The evidence about the impact of financial restrictions on investment effort is mixed. Previous works for the Spanish economy point out that,since 2000, the investment effort has been superior in firms that won public support than in those who applied for it without success, and greater in the latter than in firms that did not apply for it. Unfortunately, we do not have information about firms' financial conditions in our database.[5]However, given the aim of this paper, special attention is devoted to a firm's participation in the CDTI low-interest loan programme and national and Euro-

[5]The Spanish Technological Innovation Survey includes information about the relative importance assigned by firms to the lack of funds in the firm or group, the lack of external financing or the existence of high innovation costs as factors hampering innovation. However, this information was not provided in the selection of variables that the INE gave us to do this research.

peaninnovation subsidies schemes. These public aid instruments could increase the chances to perform R&D, as tools that reduce a firm's financial constraints.

To indicate appropriability conditions, we use the proportion of R&D employees in the firm as a measure of human capital. We think that those firms with more qualified personnel are more capable of assimilating new knowledge, whether it is developed internally or externally. Piva and Vivarelli (2009) provide evidence that supports this hypothesis for a panel of Italian firms. As expected, and as can be seen in Table 2, supported firms present a higher percentage of R&D employment than non-financed firms. In addition, following previous papers for the Spanish economy, we introduce industry dummies that can also approach sectoral technological opportunities and appropriability conditions (Beneito, 2003; Ortega-Argilés, Moreno and Suriñach-Caralt, 2005). Specifically, we included the dummies for firms belonging to high and medium-tech sectors defined previously.

Along with the above variables, the specification includes indicators to capture differences in the firms' investment behaviour in terms of the time of permanence in the market.In particular, an indicator of newly born firms (start-ups) is included. Empirical evidence suggests that start-ups are usually among the most innovative firms; their survival probability as well as their growth rate depends strongly on their innovative behaviour (Audretsch, 1995; Huergo and Jaumandreu, 2004). Finally, as in equation [1], we include as control variables some factors related to firms' organizational aspects: belonging to a group, foreign capital, public capital andtechnological cooperation.

With respect the technological output equation [4], we try two different specifications. In the first, we consider almost the same explanatory variables than in the technological input equation [3]. In the second, besides the variables reflecting the participation in public programmes and time, size and sectoral dummies, only the prediction of the R&D intensity is added as explanatory variable. This allows us to discuss about the existence of direct and indirect effects of public funding.

4. RESULTS

In this section, we present the results of the estimation of equations [1] - [4] depicted in Section 3. We begin with the explanation of the participation in public aid programmes. Later we analyse how the participationin these programmes affects the technological performance of the firms, distinguishing between innovation inputs and outputs.

4.1. The determinants of participation in public R&D programmes

Table 3 shows the estimation of the determinants of the firms' participation in public aid programmes. Considering that we have information about three systems of public aid, we use a multivariate Probit model (seemingly unrelated Probit model).[6] Some of the explanatory variables are included with one lag in the estimates to prevent endogeneity problems.

As expected, the correlation coefficients $\rho_{21}$and ρ_{32} are significantly different from zero and positive. In accordance with Busom and FernándezRibas (2007) and Czarnitzki and Lopes-Bento (2011), national support and European funding are positive linked to each other. The same happens with soft credits and national subsidies, indicating the presence of common unobserved factors that affect the probability of participating in both programmes. A positive shock in the probability of getting a national subsidy would also translate into a positive shock on the likelihood of being awarded an EU grant and a CDTI credit. However, ρ_{31} is non-significant, implying that there are not common unobserved factors affecting the probabilities of participating in the national soft credit system and the scheme of European subsidies.

As for the explanatory variables, most of them are statistically significant and their coefficients have the same sign in all columns. However, the joint chi-square test clearly rejects the equality of coefficient across equations (p-value=0.000).

The first fact that can be highlighted from Table 3 is the positive effect of having a higher technological profile on the probability of participation in all public aid programmes. The internal R&D intensity of the previous year has a statistically positive impact for all kind of funding. Looking at the magnitude of the coefficients, the participation in subsidy programmes reacts more sensitively to prior innovation experience than in the CDTI credit system.

[6] See Cappellari and Jenkins (2003).

Table 3: Participation in public R&D programmes. Multivariate Probit model

	CDTI credit programme (1)		National subsidy programme (2)		European subsidy programme (3)	
	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Technological characteristics						
- Internal R&D intensity (in logs.) (t-1)	0.030 ***	0.007	0.108 ***	0.008	0.081 ***	0.013
- Patent application (t-1)	0.157 **	0.049	0.080	0.049	0.106	0.067
- Technological cooperation with:						
• clients (t-1)	-0.019	0.072	0.171 **	0.068	0.185 **	0.085
• competitors (t-1)	-0.228 **	0.086	0.232 ***	0.077	0.425 ***	0.089
• other firms from the group (t-1)	-0.062	0.076	-0.073	0.075	0.194 **	0.094
• providers (t-1)	-0.021	0.064	-0.205 **	0.063	-0.086	0.083
• consultants & laboratories (t-1)	0.013	0.067	-0.097	0.075	-0.022	0.096
• universities, PRCs and technological centres (t-1)	0.006	0.050	0.487 ***	0.049	0.413 ***	0.069
- High and medium-tech manufacturing sector	0.105 **	0.047	-0.016	0.048	-0.224 **	0.072
- High and medium-tech services sector	-0.224 **	0.077	0.342 ***	0.069	0.410 ***	0.086
Other firms characteristics						
- Belonging to a group	0.056	0.051	0.116 **	0.052	0.035	0.075
- Exporter (t-1)	0.160 **	0.052	-0.012	0.052	0.012	0.072
- Foreign capital	-0.087	0.070	-0.193 **	0.072	-0.137	0.104
- Public firm	-0.200	0.192	0.261	0.171	0.686 ***	0.184
- Size (in logs.)	0.438 ***	0.078	0.011	0.068	-0.278 ***	0.086
- Size squared	-0.038 ***	0.008	0.006	0.007	0.034 ***	0.008
- Start-up	0.360 **	0.161	0.126	0.149	-0.595 **	0.229
ρ_{21}			0.173*** (0.000)			
ρ_{31}			-0.056 (0.040)			
ρ_{32}			0.302*** (0.000)			
Test [CDTI credit-National subsidy]			0.000			
Test [CDTI credit-European subsidy]			0.000			
Test [National subsidy-European subsidy]			0.000			
Log of likelihood function			-5619.5			
Number of observations (number of firms)			4333 (1867)			

Notes: S.D.: Standard deviation. (t-1) denotes that the variable is included with one lag. All regressions include a constant and time dummies for years 2003 and 2004. Test reports the p-value of a test of equality of coefficients. ρ_{21}, $\rho_{31}$and ρ_{32}(p-values in parentheses) are the correlation coefficients across equations. Coefficients significant at 1%***, 5%**, 10%*.

In addition, having technological agreements in general increases the probability of obtaining European funding. This result is coherent with the objectives of the Framework Programme which promotes the cooperation across firms of different countries. The European agency is especially sensitive to cooperation with competitors and with universities, PRCs and other technological centres. A similar effect is obtained for the participation in the national funding programme with the exception of the cooperation with providers. Our results are in accordance with Garcia and Monhen (2010) that find that Austrian firms which cooperate in innovation are more likely to get help from both national and EU sources during 1998-2000. A similar result is obtained by Hottenrott and Lopes-Bento (2013) for Belgium firms but only for small and medium firms which cooperate with foreign firms. However, the technological cooperation does not seem to increase the propensity to participate in the soft credit programme. Only the cooperation with competitors has a significant but negative impact.

Being a patent applicant in the previous year only affects positively the chance of participation in the soft credit system.[7] It seems that the CDTI is especially sensitive to the previous technological success of candidate firms in order to give a credit. These results are in accordance with the evidence provided by Huergo, Trenado and Ubierna (2013) for the same credit system.

Regarding the belonging to a high or medium-tech sector, the results confirm what we observed in the descriptives. In fact, high and medium-tech services firms have a higher probability of participation in subsidy programmes, while the low-interest credits by CDTI favour firms which operate in high or medium-tech manufacturing sectors.

As for the rest of firms' characteristics, being an exporter in the previous year increases the probability of participating in the CDTI low-interest loan system but does not affect the participation in national and European subsidy systems. The presence of foreign capital has a negative effect for obtaining national funding. This result suggests that the national government is more reticent to finance firms belonging to foreign groups than to domestic ones. Garcia and Monhen (2010) and Czarnitzki and Lopes-Bento (2011) also find a negative effect of this variable on European funding but in our sample we do not find this result. The group membership neither has a significant effect on low interest loans and European subsidies.

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[7] In a complementary estimation without distinguish among the partners of technological cooperation, patent application is also significant in the national and European public subsidies.

Another interesting result in Table 3 is the existence of a non-linear effect of size on the probability of participating in the low-interest credit and European funding systems, but in a different way.As firms are larger, they have a higher probability of being awarded by the CDTI, but the increase in size affects the probability of obtaining financing marginally less. This result, which is in accordance with Huergo, Trenado and Ubierna (2013), suggests that applying for CDTI loans has some costs in terms of time and searching for information, so larger firms have a higher probability of participation, although as a certain amount of resources is obtained, the size effect is smaller. However, in line with Czarnitzki and Lopes-Bento (2011), the estimated curve describes a U-shaped relationship between the European subsidy receipt and firm size. Unexpectedly, size does not appear to be significant for National subsidies.

Finally, being a start-up affects positively and negatively the chance of participation in soft credit and European subsidy programmes, respectively. Although more experienced firms are more likely to know and use public aid programs, younger firms are usually more financially constrained, having more incentives to apply for and receive them. It seems that the first effect exceeds the second one in the case of European public aid. The opposite happens with low interest credit systems.

4.2. The R&D intensity

Table 4 shows the results of the estimation associated with equations [2] and [3] explained in Section 3. Specifically, we present the marginal effects of the Generalized Tobit model where the participation and the intensity equations are estimated consistently by maximum likelihood.

In order to analyse if the determinants of internal R&D expenditures differ from the determinants of total R&D expenditures, we present the results of the Heckman model for both internal and total R&D intensity. Notice that the correlation term rho is significant in both estimations, pointing out the necessity of estimating a selection model for the observed intensity. Initially, we tried the same set of explanatory variables for both equations ($z_{1it} = z_{2it}$), but eventually we finally include only those variables that turn out to be statistically significant in each specification.

Table 4: R&D intensity (in logarithms). Generalized Tobit model

	Internal R&D				Total R&D			
	Propensity to engage in internal R&D (0/1) (1)		Internal R&D intensity (2)		Propensity to engage in R&D (0/1) (3)		Total R&D intensity (4)	
	dy/dx	**S.D.**	***dy/dx***	**S.D.**	***dy/dx***	**S.D.**	***dy/dx***	**S.D.**
Participation in CDTI credit programme[a)]	0.808 ***	0.127	2.941 ***	0.405	0.807 ***	0.127	2.825 ***	0.411
Participation in national subsidy programme[a)]	0.759 ***	0.097	2.608 ***	0.271	0.752 ***	0.097	2.483 ***	0.276
Participation in European subsidyprogramme[a)]	0.067	0.184	2.456 ***	0.449	0.075	0.184	2.723 ***	0.457
Technological characteristics								
- Percentage of R&D employees (t-1)	0.001 ***	0.000			0.001 ***	0.000		
- Technological cooperation			-0.107 **	0.037			-0.037	0.037
- Technological cooperation (t-1)	0.040 ***	0.012			0.040 ***	0.012		
- High and medium-tech manufacturing sectors			0.366 ***	0.042			0.369 ***	0.042
- High and medium-tech services sectors			0.532 ***	0.067			0.491 ***	0.068
Other firms characteristics								
- Belonging to a group	-0.037 ***	0.011	0.099 **	0.041	-0.137 **	0.011	0.134 ***	0.041
- Exporter (t-1)	0.044 ***	0.015			0.045 **	0.015		
- Export intensity (t-1)			0.295 ***	0.089			0.309 ***	0.090
- Foreign capital	0.057 ***	0.012	0.221 ***	0.058	0.056 **	0.012	0.232 ***	0.058
- Public firm			-0.475 **	0.154			-0.564 **	0.157
- Size (in logs.)	0.001	0.004	-0.600 ***	0.017	0.001	0.004	-0.600 ***	0.016
- Start-up			0.302 **	0.130			0.314 **	0.132
Selection term, rho			0.389 ***	0.054			0.414 ***	0.053
Log of Likelihood Function	-6,385.0				-6,436.1			
Number of observations (number of firms)	4,326 (1867)				4,326 (1867)			

Notes:[a)] The prediction of the probability of participating in each programme is obtained from Table 3. S.D.: Standard deviation. Coefficients significant at 1%***, 5%**, 10%*. Marginal effects (*dy/dx*) are computed at sample means. For dummy variables, the marginal effect corresponds to change from 0 to 1. All regressions include a constant and time dummies for years 2003 and 2004.

Although it is possible to assume that most variables are exogenous, the indicators for being an exporter, technological cooperation and the percentage of R&D employees are again introduced with a lag in the decision equation. For the same reason, the export intensity is also included with a lag in the R&D intensity equation.

With respect to the decision to engage in R&D, the estimations in columns (1) and (3) show that being awarded a soft credit or a national subsidy clearly increases the probability of conducting R&D activities. The participation in the soft credit and national subsidy funding systems raises the probability of self-financing internal R&D activities 81.8 and 76.0 percentage points, respectively. The impact is quite similar when we consider total R&D expenditures. However, the participation in European subsidy programmes does not seem to affect the decision to undertake technological activities.

Table 4 also shows that most explanatory variables increase the probability of carrying out R&D expenditures. Firms which operate in international markets (exporters and firms with foreign capital) present a higher probability of engaging in R&D activities. Specifically, firms involved in exporting activities during the last year are 4.4 percentage points more likely to self-finance internal R&D activities, stressing the complementarity between internationalization and R&D investment strategies.

In addition, the coefficient for the percentage of R&D employment confirms the relevance of having qualified workers to more easily assimilate new knowledge. This result is in line with Huergo and Moreno (2011) who, with other Spanish database, also find a positive impact of human capital approached by the proportion of engineers and graduates on the firms' innovation behaviour.

A positive sign is also obtained for technological cooperation that can also be considered as a proxy of the firms'technological capability of the firm. Unexpectedly, we do not find any significant effect of the firms' size on the decision to carry out R&D. The only variable which has a negative impact on the probability is belonging to a group.

With respect to magnitude of R&D expenditures, as can be seen in columns (2) and (4), once the firm has decided to invest, the three kinds of public aid stimulate the intensity of R&D investment, although the highest impact corresponds to soft credits. The effects are quite similar when we consider Total R&D expenditures. Our results are in line with García and Monhen (2010) and Czarnitzki and Lopes-Bento (2011) that define R&D intensity as the ratio of R&D expenditures over sales. However, our coefficients are larger. This difference can be explained by the fact than in our sample there is a relevant percentage of start-ups that present very high R&D intensities.

The export intensity, belonging to a group, being participated by foreign capital or beinga start-up also increase the intensity of R&D investment. These results are in accordance with Ortega-Argilés, Moreno and Suriñach-Caralt (2005), Griffith et al. (2006) and Hall, Lotti and Mairesse (2009). As expected, firms operating in high and medium-tech sectors also present a higher R&D activity. The only variables with a negative impact on R&D intensity are the firm's size and being a public firm.

4.3. The production of technological outputs

Tables 5 and 6 show the results of the estimation of equation [4] for three alternative measures of innovation outputs: product innovation, process innovation and patent application.Given the binary character of our innovation outputs, the equation is estimated as a Probit model. As we have explained in section 3, we consider two alternative specifications to analyse the impact of public support on the probability of obtaining technological results.[8]

In the first one (columns (1) and (3) of Table 5 and column (1) of Table 6) we consider as explanatory variables the same control variables than in the previous equation and we do not take into account that the technological effort of the firm can increase its chance to obtain a process or product innovation. In the second one (columns (2) and (4) of Table 5 and column (2) of Table 6), the R&D intensity is included as an explanatory variable. Notice that the innovation effort is presumably endogenous for achieving of innovation outputs – that is, there can be unobservable (to the econometrician) firm characteristics that incentivize firms to invest more in R&D and, at the same time, make them more productive in the use of this effort. This could generate spurious correlation and upward bias in the coefficient of R&D intensity. To face this problem, we interpret the R&D intensity equation [3] as an instrumental variables equation, and use the predicted R&D intensity obtained from this equation instead of the observed intensity as explanatory variable in equation [4].

[8] In Tables A.3 and A.4 of Appendix 2, we present the coefficients of these estimations.

Table 5: Product and process innovation.Probit model

	Product innovation				Process innovation			
	(1)		(2)		(3)		(4)	
	dy/dx	**S.D.**	***dy/dx***	**S.D.**	***dy/dx***	**S.D.**	***dy/dx***	**S.D.**
Participation in CDTI credit programme[a)]	1.779 ***	0.202	1.445 ***	0.248	0.669 ***	0.207	0.308	0.265
Participation in national subsidy programme[a)]	0.247 **	0.122	-0.013	0.181	0.329 **	0.125	-0.104	0.191
Participation in European subsidyprogramme[a)]	0.848 ***	0.223	0.375 *	0.223	0.334	0.223	-0.200	0.233
Total R&D intensity[b)]			0.105 **	0.047			0.151 ***	0.050
High and medium-tech manufacturing sector	0.061 ***	0.017	0.027	0.024	-0.060 ***	0.019	-0.121 ***	0.026
High and medium-tech services sector	0.095 ***	0.024	0.065 *	0.034	-0.150 ***	0.031	-0.207 ***	0.041
Belonging to a group	-0.061 ***	0.017			-0.006	0.018		
Exporter (t-1)	0.033	0.020			0.044 **	0.022		
Foreign capital (>50%)	0.095 ***	0.022			0.044 *	0.025		
Public firm	-0.201 **	0.071			-0.281 ***	0.063		
Size (in logs.)	-0.018 **	0.007	0.036	0.028	0.038 ***	0.007	0.121 ***	0.030
Start-up	0.210 ***	0.035			0.124 **	0.052		
Log of Likelihood Function	-2,354.7		-2,371.8		-2,690.9		-2,695.9	
Number of observations	4,333		4,325		4,333		4,325	

Notes: [a)]The prediction of the probability of participating in each programme is obtained from Table 3.[b)]The prediction of the Total R&D intensity is obtained from estimations (3) and (4) in Table 4. S.D.: Standard deviation. Marginal effects (*dy/dx*) are computed at sample means. For dummy variables, the marginal effect corresponds to change from 0 to 1. All regressions include a constant and time dummies for years 2003 and 2004. Coefficients significant at 1%***, 5%**, 10%*.

Table 6: Patents Application. Probit model

	(1)		(2)	
	dy/dx	S.D.	*dy/dx*	S.D.
Participation in CDTI credit programme[a)]	4.498 ***	0.197	2.752 ***	0.236
Participation in national subsidy programme[a)]	-1.046 ***	0.112	-0.974 ***	0.174
Participation in European subsidyprogramme[a)]	3.246 ***	0.198	1.952 ***	0.202
Total R&D intensity[b)]			0.127 ***	0.046
High and medium-tech manufacturing sector	-0.015	0.016	-0.030	0.023
High and medium-tech services sector	0.128 ***	0.033	0.054	0.040
Belonging to a group	-0.077 ***	0.016		
Exporter (t-1)	-0.240 ***	0.023		
Foreign capital	0.196 ***	0.029		
Public firm	-0.188 ***	0.023		
Size (in logs.)	-0.083 ***	0.007	0.006	0.027
Start-up	0.084	0.057		
Log of Likelihood Function	-1,994.1		-2,073.2	
Number of observations	4,333		4,325	

Notes: [a)]The prediction of the probability of participating in each programme is obtained from Table 3. [b)]The prediction of the Total R&D intensity is obtained from estimations (3) and (4) in Table 4. S.D.: Standard deviation. Coefficients significant at 1%***, 5%**, 10%*. Marginal effects (*dy/dx*) are computed at sample means. For dummy variables, the marginal effect corresponds to change from 0 to 1. All regressions include a constant and time dummies for years 2003 and 2004.

When the prediction of the R&D intensity is not included in the estimates, being supported by public programmes clearly increases the probability of obtaining product innovations. Again, the highest impact is associated with the participation in the CDTI credit system. The participation in this last programme and in the national subsidy system also raise the probability of obtaining process innovations, while the European funding does not seem to have any effect. Note, however, that more than 25% of firms in our sample receive both national and European support during the period.

In addtion, the probability of applying for patents is higher for firms awarded a CDTI credit or a European grant, but national subsidies negatively affect this probability. In this line, Czarnitzki and Lopes-Bento (2011) find that German firms that receive combined support from national and European administrations increase their patent applications, while this effect disappears when companies are only financed by EU programmes. However, Spanish firms rarely use patents to protect their technological results (Barajas, Huergo and Moreno, 2011).

As we expected, when the R&D intensity is added to the specification, the impacts of the participation in the public programmes are lower, and eventually become non-significant. The R&D intensity has a significant positive impact on the generation of the three technological outputs. The quantitative effect of this variable is quite similar on them, being the biggest the one on process innovation. In this sense, there is an indirect effect of the public support by stimulating R&D intensity. The results also suggest that there is a direct positive effect of the participation in the CDTI credit programme and in the European subsidy programme on the probability of obtaining product innovations.

With respect to the control variables, being participated by foreign capital increases the probability of obtaining technological outputs. The opposite happens with public firms: they are less likely to be successful. The rest of explanatory variables present a different impact depending on the measure of technological output. For example, as in previous empirical evidence, youngest firms have a higher probability of innovating but they do not present any difference with respect to the other firms in terms of patent applications. Belonging to a group reduces product innovations and patent applications but has not effect on process innovations.

With respect to the size, larger firms show a higher probability of obtaining process innovations and a lower probability of applying for patents and obtaining product innovations. However, when we including the R&D intensity in the specification, the size turns to be non-significant for patents and product innovations. And, it seems that the activity sector also affects firms' technological results. Specifically, companies operatingin high and medium-tech sectors are more innovative in terms of product innovations. The opposite happens in the case of process innovations.

5. CONCLUSIONS

The objective of this paper is to compare the effect of the participation within different public R&D funding programmes on firms' technological performance. This will allow us to analyse the relative relevance of two features of public programmes: the national or supranational character of the financing agency and the magnitude of reimbursement implied in design of the public support.

Specifically, for the empirical analysis, we consider three types of instruments used by public administrations to support Spanish firms: The programme of low-interest loans provided by the CDTI, the main national agency financing firms' R&D projects; the national scheme of R&D subsidies; and the European system of R&D grants.

To face with the typical selectivity and endogeneity problems that are present in this kind of analysis, we use a Heckman's treatment effect model following a two-stage procedure. Firstly, we estimate a multivariate Probitmodel to study the determinants of the participation in each of the three public programmes. Afterwards, in a second stage, we analyse how this participation affects the technological capability of the firms. Specifically, we consider the R&D intensity as technological input, and product and process innovations and patent applications as technological outputs.

The results obtained for a sample of 2,319 Spanish firms during the period 2002-2005 can be summarized as follows:

Firstly, the participation in national subsidy programmes and the participation in European subsidy programmes are positive linked to each other. The same happens with CDTI soft credits and national subsidies schemes, indicating the presence of common unobserved factors that affect the probability of participating in both programmes.

Secondly, being awarded a CDTI soft credit or a national subsidy clearly increases the probability of conducting R&D activities. However, the participation in European subsidy programmes does not seem to affect the decision to undertake these activities.

Thirdly, once the firm has decided to invest in R&D, the three kinds of public aid stimulate the intensity of R&D investment, corresponding the highest impact to soft credits. National subsidies have a higher impact on internal R&D intensity than EU grants, but the opposite relation is found as regards total R&D intensity. This suggests that international funding is more effective to foster external R&D activities.

As for innovation outputs, there is an indirect effect of public support by stimulating R&D intensity that has a positive impact on innovations and patent applications. In addition, we find also direct positive effects of the participation in the CDTI credit system and in the European subsidy programme on the probability of obtaining product innovations and applying for patents. However, this direct effect is absent in what relates to process innovations.

REFERENCES

Aerts, K., D. Czarnitzki and F. Andreas (2006), "Evaluación econométrica de la política pública de I+D: estado del arte," in Heijs and Buesa (eds.): *La cooperación en innovación en España, el papel del estado.*Instituto de EstudiosFiscales, España.

Arvanitis, S. and H. Hollenstein (1994), "Demand and supply factors in explaining the innovative activity of Swiss manufacturing firms," *Economics of Innovation and New Technology*, 3, 15-30.

Audretsch, D. (1995), *Innovation and Industry Evolution*, MIT Press: Cambridge, MA.

Barajas, A. and E. Huergo (2010), "International R&D cooperation within the EU Framework Programme: empirical evidence for Spanish firms," *Economics of Innovation and New Technology*, 19(1–2), 87–111.

Barajas, A., E, Huergo and L. Moreno (2011), "Las empresas españolas que patentan en la oficina europea," *Economía industrial,* 382, 53-62.

Barajas, A., E. Huergo and L. Moreno (forthcoming), "SME performance and public support for international RJVs," *Journal of Small Business Management*.

Bayona-Sáez, C. and T. García-Marco (2010), "Assessing the effectiveness of the Eureka program," *Research Policy,* 39, 1375–1386.

Beneito, P. (2003),"Choosing among alternative technological strategies: An empirical analysis of formal sources of innovation," *Research Policy*, 32, 693-713.

Benfratello, L. and A. Sembenelli (2002), "Research joint ventures and firm level performance," *Research Policy,* 31, 493-507.

Blanes, J. V. and I. Busom (2004), "Who participates in R&D subsidy programs?The case of Spanish manufacturing firms," *Research policy*, 33(10), 1459-1476.

Busom, I. (2000), "An empirical evaluation of the effects of R&D subsidies," *Economics of Innovation and New Technology*, 9(2), 111-148.

Busom, I. and A. Fernández-Ribas (2007), "Do R&D Programs of different government levels overlap in the European Union?" *Science, Technology and Innovation Policy*, Atlanta Conference, 1-5.

Busom, I. M. B. Corchuelo and E. Martínez-Ros (2012), "Tax incentives or subsidies for R&D," UNIT-MERIT WP Series 056, United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology.

Cappellari, L. and S.P. Jenkins (2003), "Multivariate probit regression using simulated maximum likelihood," *The Stata Journal,* 3(3), 278-294.

Cassiman B. and R. Veugelers (2002), "R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium," *American Economic Review*, 92(4), 1169-1184.

Cerulli, G. and B. Potì (2012), “Evaluating the robustness of the effect of public subsidies on firm’s R&D: An application to Italy”, *Journal of Applied Economics* 15(2), 287-320.

Clausen, T. H. (2008), “Do subsidies have positive impacts on R&D and innovations activities at the firm level?” TIK Working papers on Innovation Studies No. 20070615. Oslo.

Czarnitzki, D. and G. Licht (2006), “Additionality of Public R&D grants in a transition economy: the case of Eastern Germany,” *The Economics of Transition* 14(1), 101-131.

Czarnitzki D., B. Ebersberger and A. Fier (2007), “The relationship between R&D Collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany,” *Journal of Applied Econometrics* 22(7), 1347-1366.

Czarnitzki, D. and C. Lopes-Bento (2011), “Innovation subsidies: Does the funding source matter for innovation intensity and performance? Empirical evidence from Germany,” CEPS/INSTEAD Working Paper Series 2011-42, CEPS/INSTEAD.

Duguet, E. (2004), “Are R&D subsidies a substitute or a complement to privately funded R&D? Evidence from France using propensity score methods for non-experimental data,” *Revue d’Economie Politique*, 114(2), 263-292.

European Commission (2009), *Analysing and Evaluating the Impact on Innovation of Publicly Funded Research Programmes: Lot 2 – Benchmarking Strategies and Methodologies of National, European and International R&D Programmes to Assess and Increase their Impact on Innovation*, Final Report, European Commission, DG Enterprise.

García, A. and P. Mohnen (2010), “Impact of government support on R&D and innovation”, UNU-MERIT Working Paper Series 2010-034, United Nations University, Maastricht Economic and social Research and training centre on Innovation and Technology.

González, X., Jaumandreu, J. and C. Pazó (2005), “Barriers to innovation and subsidy effectiveness,” *The Rand Journal of Economics*, 36(4), 930-949.

González, X. and C. Pazó (2008), “Do public subsidies stimulate private R&D spending?” *Research Policy,* 37(3), 371-389.

Griffith, R., E. Huergo, J. Mairesse and B. Peters (2006), “Innovation and productivity across four European countries,” *Oxford Review of Economic Policy,* 22(4), 483-498.

Guo, S. and M. W. Fraser (2010), *Propensity Score Analysis: Statistical Methods and Applications*, SAGE publications, Inc.

Hall, B. H., (2002), “The financing of research and development,” NBER Working Papers 8773, National Bureau of Economic Research, Inc.

Hall, B., F. Lotti and J. Mairesse (2009), “Innovation and productivity in SMEs.Empirical evidence for Italy,” *Small Business Economics*, 33, 13-33.

Heckman, J. J. (1979), “Sample selection bias as a specification error,” *Econometrica*, 47, 153–162.

Heijs, J. (2005), “Identification of firms supported by technology policies: the case of Spanish low interest credits,” *Science and Public Policy,* 32(3), 219-230.

Huergo, E. and J. Jaumandreu (2004),“Firms’ age, process innovation and productivity growth,” *International Journal of Industrial Organization*, 22, 541– 559.

Huergo, E. and L. Moreno (2011), “Does history matter for the relationship between R&D, innovation and productivity?” *Industrial and Corporate Change*, 20(5), 1335–1368.

Huergo, E. and M. Trenado (2010), “The Application for and the Awarding of Low-Interest Credits to Finance R&D Projects,” *Review of Industrial Organization* 37(3), 237-259.

Huergo, E., M. Trenado and A. Ubierna (2013), “Impact of low-interest credits on business R&D expenditures: Spanish firms and CDTI loans for R&D projects,” MPRA Paper 44221. Online at http://mpra.ub.uni-muenchen.de/44221/

Hottenrott, H. and C. Lopes-Bento (2013), “(International) R&D collaboration and SMEs: The effectiveness of targeted public R&D support schemes,” DICE Discussion Papers 121, Heinrich-Heine-Universität Düsseldorf, Düsseldorf Institute for Competition Economics (DICE).

Kaiser, U. and J. M. Kuhn (2012), “Long-run effects of public-private joint ventures: The case of the Danish Innovation Consortia support scheme,” *Research Policy,* 41, 913-927.

Klepper, S. (1996), “Entry, exit, and innovation over the product life-cycle,” *American Economic Review*, 86, pp. 562-583.

Lach, S. (2002), “Do R&D subsidies stimulate or Displace private R&D? Evidence from Israel,” *Journal of Industrial Economics* 50(4), pp. 369-390.

OECD (2006), *Government R&D funding and company behaviour.Measuring behavioural additionality*. OECD report.

OECD (2012), *OECD Science, Technology and Industry Outlook 2012*, OECD Publishing.

Ortega-Argilés, R., R. Moreno and J. Suriñach-Caralt (2005),“Ownership structure and innovation: is there a real link?” *The Annals of Regional Science*, 39(4), pp. 637-662.

Piva, M. and M. Vivarelli (2009), “The role of skills as a major driver of corporate R&D,” *International Journal of Manpower*, 30(8), 835-852.

Wallsten S.J. (2000), “The effects of government-industry R&D programs on private R&D: the case Small Business Innovation Research Program,” *RAND Journal of Economics,*31(1), 82-100.

Takalo, T., Tanayama, T. and O. Toivanen (2013), “Estimating the benefits of targeted R&D subsidies,” *The Review of Economics and Statistics*, 95(1), 255-272.

Appendix 1

DEFINITIONS OF VARIABLES

Belonging to a group: dummy variable which takes the value 1 if the firm belongs to a group.

Exporter: Dummy variable, which takes the value 1 if the company exported during the period.

Foreign capital: Dummy variable which takes the value 1 when the firm is partly owned for a foreign firm (more than 50% of foreign capital during the period).

High and medium-tech manufacturing: Dummy variable which takes the value 1 if the company belongs to any high and medium-tech manufacturing sectors (NACE2 codes 24, 29, 30, 31, 32, 33, 34, 35).

High and medium-tech services: Dummy variable which takes the value 1 if the company belongs to the high-tech services (NACE2 codes 64, 72, 73, 92)

Participation in CDTI credit programme: dummy variable which takes the value 1 if the firm has been awarded a CDTI soft loan during the year.

Participation in national subsidy programme: dummy variable which takes the value 1 if the firm has been awarded a national subsidy during the year.

Participation in European subsidy programme: dummy variable which takes the value 1 if the firm has been awarded a European subsidy during the year.

Patent application: dummy variable which takes the value 1 if the firm applied for patents during the period.

Process innovation: Dummy variable which takes the value one if the firm has obtained a process innovation during the year.

Product innovation: Dummy variable which takes the value one if the firm has obtained a product innovation during the year.

Public firm: Dummy variable which takes the value 1 when the firm is partly publicly owned (more than 50% of public capital during the period).

R&D performer: Dummy variable which takes the value 1 if the firm has positive expenditures in R&D during the year.

Internal R&D intensity: Ratio of internal expenditures in R&D over total employment.

Size: number of employees during the current year.

Start-up: dummy variable which takes the value 1 if the firm was created during the last three years.

Technological cooperation: Dummy variable which takes the value 1 if the company established technologicalcooperation agreements during the last three years with other partners.

Total R&D intensity: Ratio of total expenditures in R&D (including technology imports) over total employment.

Appendix 2

Table A.1: Statistics of main variables

	Mean	SD	Min	Max	Median
R&D funding (1/0)					
With own funding	0.742	0.438	0	1	1
Participation in CDTI credit programme	0.255	0.436	0	1	0
Participation in national subsidy programme	0.275	0.446	0	1	0
Participation in European subsidy programme	0.089	0.284	0	1	0
Percentage of funding (%)					
Own funding	65.5	42.7	0	100	93.5
Funded with a national subsidy	8.1	19.8	0	100	0
Funded with a European subsidy	3.2	15.2	0	100	0
Other firm characteristics (1/0)					
Belonging to a group	0.428	0.495	0	1	0
Exporter	0.687	0.464	0	1	1
Foreign capital	0.106	0.307	0	1	0
High and medium-tech manufacturing sector	0.361	0.480	0	1	0
High and medium-tech services sector	0.126	0.332	0	1	0
Internal R&D performer	0.785	0.411	0	1	1
Patent application	0.248	0.432	0	1	0
Process Innovation	0.541	0.498	0	1	1
Product Innovation	0.631	0.482	0	1	1
Public firm	0.015	0.120	0	1	0
R&D performer (Internal and external)	0.814	0.389	0	1	1
Start-up	0.047	0.211	0	1	0
Technological cooperation with:	0.468	0.499	0	1	0
- clients	0.128	0.335	0	1	0
- competitors	0.088	0.283	0	1	0
- consultants & laboratories	0.116	0.321	0	1	0
- PRCs	0.123	0.329	0	1	0
- other firms of the group	0.111	0.315	0	1	0
- providers	0.174	0.379	0	1	0
- technological centres	0.195	0.396	0	1	0
- universities	0.249	0.432	0	1	0
Other firm characteristics (quantitative):					
Export intensity (Export over sales)	0.232	0.283	0	1	0.100
External R&D Expenditures (K€)	329.5	2,562.0	0	54,800	0
Internal R&D Expenditures	1,154.4	5,103.1	0	72,300.0	214.1
Percentage of R&D employees (%)	58.7	39.2	0	100	66
R&D intensity (K€ per employee)	10.1	32.7	0	1,268.4	2.7
Size (Number of employees)	313.3	1,009.9	1	13,023	71
Total R&D intensity (K€ per employee)	12.2	38.9	0	1,268.4	3.4
Number of observations (firms)			7,007 (2,319)		