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7 March 2014

Online at <https://mpra.ub.uni-muenchen.de/64926/>
MPRA Paper No. 64926, posted 09 Jun 2015 16:45 UTC

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

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May 2015

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 on 4,407 Spanish firms during the period 2002-2005, we estimate a multivariate probit to analyse the determinants of firms' 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. With respect to innovation outputs, apart from the indirect effect of public support by stimulating R&D intensity, we also find evidence of a direct effect of participation in the CDTI credit system and in the European subsidy programme on the probability of obtaining innovations and applying for patents.

Keywords: Soft loans, 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. The authors benefited from presentations at XVII Applied Economics Meeting (Las Palmas de Gran Canarias, 2014), 41th EARIE Annual Conference (Milan, 2014), XXIX Jornadas de Economía Industrial, (Barcelona, 2014), the seminar at the Department of Economy (Universitat Rovira i Virgili, Reus, 2014), the Economic & Finance Seminar Series (Universita Cattolica del Sacro Cuore, Milano, 2015) and especially from suggestions by Miguel Manjón, Oscar Martínez, Pierre Mohnen and Gabriele Pellegrino.

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1. INTRODUCTION

There is a great deal of empirical evidence of the impact of public aid on private R&D, with a wide variety of countries analysed and methodologies employed to take into account that 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 only one programme in their analyses and this fact makes it difficult to accurately compare 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 (2014). In both cases, the empirical analysis is based on microdata from the Community Innovation Survey (CIS). The first one compares the impact of public support from the central government and the European Union (EU) on the innovation of Austrian firms, using the third wave of the CIS, which covers 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 sales of new to firm products. However, EU support is never significant once national support is taken into account.

The study by Czarnitzki and Lopes-Bento (2014) 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 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 from only 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 obtained.

The objective of this paper is to compare the effect of 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, which 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 13,546 observations and 4,407 firms for the period 2002 to 2005. Specifically, 2,185 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 from 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 the innovative performance of firms if the CDTI or 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 probit model 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 R&D intensity to be technological input, and product and process innovations and patent applications to be technological outputs. We use Heckman's treatment effect model to face selectivity and endogeneity problems.

Our results confirm that the three instruments are effective in enhancing firms' R&D intensities. However, the highest impacts correspond to the CDTI credit system and the European subsidy programme. 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 soft credits and European subsidies on the probability of obtaining technological outputs.

The rest of the paper is organised 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 of 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), where by 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 complementary if the agencies coordinate efficiently to take into account the nature and extent 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, 2014). 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-organised consortia, as often happens in supra-national R&D programmes. The organisation 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 has to do with 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 information flows out of the firm (outgoing spillovers) to appropriate the returns from 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 inflows and outflows is not exogenous to the firm. This element is especially important for our analysis, as projects financed through supra-national programmes usually correspond to Research Joint Ventures (RJVs) that involve partners from different countries. In this case, the technological capabilities of subsidised firms can be affected not only by public aid but also

by spillovers of cooperation among partners. However, most papers that study the impact of public programmes that support 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 public support is a second dimension that could affect our analysis when comparing the effect of subsidies and loans. 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 loans 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 loans also self-enforce more discipline on the recipients, as they assume the commitment to pay back the principal. The monitoring of the project development by the agency is consequently 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 participation within a funding programme agency probably depends on the same firm characteristics that determine innovative performance. That is, it is necessary to take into account both selection and endogeneity problems.

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 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 the Framework Programme of the European Commission.¹ Then, we analyse the impact of this participation on some variables that measure technological inputs or outputs.

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

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

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 a value of 1 on the leading diagonal and correlations $\rho_{jk} = \rho_{kj}$ 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 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 R&D effort id_{it}^* by

¹ We have information only 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.

the intensity of 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:

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

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 public funding programme,² γ_m is the parameter that reflects the impact of the different public aid programmes, z_{1it} is a vector of observable explanatory variables, and 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,

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

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 model, assuming 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 whether the impact of public aid differs across programmes, not only in the decision to undertake innovation activities but also in R&D intensity.

² This predicted value is introduced in percentage in all equations. Therefore, we can interpret estimated γ_{1m} as the increase in the probability of performing R&D when the probability of participating within public funding programme m increases in one percentage point.

After this, we focus on technological outputs that we measure through binary variables for the generation of process and product innovations and for patent application. We formalise the production of technological output as follows:

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

where z_{3it} is a vector of determinants of the technological outputs, which can differ depending on the dependent variable considered, and ε_{3it} is the error term. In some specifications, we include the latent R&D effort, id_{it}^* , or the lagged R&D effort, id_{it-1} , as an element of vector z_{3it} , assuming that the more firms spend on R&D activities, the more likely it is that they will obtain technological outputs. In this case, public support can affect innovation outputs directly (through γ_m) or indirectly by increasing R&D intensity. Given that our measures of technological outputs are 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

3.1. The database

As we mentioned in the introduction, two data sources are used in this paper. The first one is the CDTI database of low-interest loans 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 loan by the CDTI during this period. These data are especially suitable for our analysis as most of the direct R&D support from the Spanish central government is channelled through the CDTI, and the CDTI's main instrument during this period consists of loans at a preferential interest rate.

This information has been completed with a database that was provided by the National Institute of Statistics (INE) and corresponds to a sample of innovative firms from the Spanish

³ In addition, as a robustness test, we estimate equation [4] as a linear probability model using the predicted probability of participation in each programme as the instrumental variable of the participation status.

Technological Innovation Survey. In this survey, we find complementary information about sources of public financial support 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 one of the most generous among OECD countries in terms of the tax subsidy rate (OECD, 2012).⁴

For the estimations we have eliminated 48 observations with a ratio of R&D expenditures over sales bigger than 10 (more than 1000%); these relate mainly to new firms which have initiated their technological activities but have not yet begun to sell their products or services. The final sample consists of an unbalanced panel with 4,407 firms (13,546 observations).

As can be seen in Table 1, around 50% of the firms do not obtain any type of public funding in the period, while less than 3% of firms are supported through the three schemes. In these sense, notice that our sample is slightly biased towards innovative firms, which have a higher propensity to apply for public funding.

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

	Yearly observations	Firms (in period 2002-2005)
No public funding	9,662 (70.1%)	2,222 (50.4%)
Only CDTI loan	1,108 (8.2%)	635 (14.4%)
Only national subsidy	1,451 (10.7%)	483 (11.0%)
Only European subsidy	322 (2.4%)	160 (3.6%)
CDTI loan & national subsidy	587 (4.3%)	624 (14.2%)
CDTI loan & European subsidy	32 (0.2%)	25 (0.6%)
National & European subsidies	324 (2.4%)	144 (3.3%)
All types of public funding	60 (0.4%)	114 (2.6%)
	13,546	4,407

Notes: In column 1, firms are classified according to the year that they are supported or not. In column 2, firms are classified considering the whole 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 firms' participation in public R&D programmes (equation [1]), most papers include measures of the firm's

⁴A nice exercise associating the use of R&D subsidies and tax incentives by Spanish firms with financing constraints can be found in Busom, Corchuelo and Martínez-Ros (2014). They conclude that direct funding and tax credits are not perfect substitutes in terms of their ability to reach firms experiencing barriers associated to market failures.

technological profile, as the chance to apply increases when the propensity to perform R&D projects is higher.⁵ The available information allows us to consider several variables. The first one is internal R&D intensity, which we compute as the ratio of internal R&D expenditures over total employment. We also define total R&D intensity as total (internal plus external) R&D expenditures per employee and the percentage of R&D employment (over 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 superior in these nationally-subsidized firms than in firms with a CDTI loan (see Table 2).

In addition, we introduce an indicator reflecting whether the firm has technological cooperative agreements. We can distinguish between the kinds of partners, which 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 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 participants in national and European R&D programmes than in non-supported firms. Regarding the sectorial dimension, public-funded firms are relatively more present in high and medium-tech service sectors⁶.

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.

⁵ See, for instance, Blanes and Busom (2004), González, Jaumandreu and Pazó (2005), Heijs (2005), Clausen (2008) or Huergo, Trenado and Ubierna (2015).

⁶In Appendix 1, we explain which NACE two-digit industry codes are assigned to each group and present the definitions of the variables. In Table A.1 of Appendix 2 we show their main descriptives for the whole sample.

Statistics in Table 2 show that firms awarded by the CDTI and firms supported by national subsidies are smaller than non-supported companies. However, firms supported by European subsidies are bigger than non-participants in public systems. Most observations of the sample refer to firms which have between 10 and 50 employees (33,8%) and large firms, with more than 200 workers (33,9%).

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-ups is higher among firms supported by national and international agencies, especially by the CDTI.

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 programmes? 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 compared to non-exporters (Takalo, Tanayama and Toivanen, 2013). In our sample, the presence of firms with foreign activity is higher among supported firms, especially by the CDTI (see Table 2). The export intensity is also bigger for participants supported by the three systems 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' budgets. 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 in Table 2, there are no significant differences between non-funded firms and participants supported by the soft loan system.

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 loan (2)	National subsidy (3)	European subsidy (4)	(1) vs (2)	(1) vs (3)	(1) vs (4)
<i>Technological characteristics</i>								
- Internal R&D intensity (K€ per employee)	6.7	3.2	12.8	16.6	25.9	0.000	0.000	0.000
- Internal R&D performer (0/1)	0.592	0.450	0.879	1.000	1.000	0.000	0.000	0.000
- Patent application (0/1)	0.170	0.129	0.284	0.304	0.292	0.000	0.000	0.000
- Percentage of R&D employees (%)	43.1	32.0	66.4	73.4	79.4	0.000	0.000	0.000
- Process Innovation (0/1)	0.444	0.396	0.575	0.600	0.507	0.000	0.000	0.000
- Product Innovation (0/1)	0.493	0.421	0.674	0.730	0.609	0.000	0.000	0.000
- R&D performer (Internal or external) (0/1)	0.625	0.492	0.901	1.000	1.000	0.000	0.000	0.000
- Technological cooperation (0/1)	0.340	0.245	0.495	0.650	0.690	0.000	0.000	0.000
- Total R&D intensity (K€ per employee)	8.2	4.3	15.2	19.8	28.9	0.000	0.000	0.000
- High and medium-tech manuf. sector (0/1)	0.235	0.193	0.412	0.330	0.249	0.000	0.000	0.000
- High and medium-tech service sector (0/1)	0.096	0.073	0.103	0.175	0.247	0.000	0.000	0.000
<i>Other firm characteristics</i>								
- Belonging to a group (0/1)	0.399	0.392	0.467	0.429	0.436	0.000	0.000	0.017
- Export intensity (Export over sales)	0.171	0.149	0.260	0.229	0.204	0.000	0.000	0.000
- Exporter (0/1)	0.548	0.511	0.714	0.656	0.569	0.000	0.000	0.002
- Foreign capital (0/1)	0.115	0.122	0.113	0.095	0.091	0.281	0.000	0.013
- Public firm (0/1)	0.020	0.019	0.008	0.024	0.045	0.001	0.162	0.000
- Size (Number of employees)	358.2	375.0	268.0	329.9	587.3	0.000	0.053	0.000
- Start-up (0/1)	0.032	0.021	0.060	0.055	0.033	0.000	0.000	0.049
Number of observations	13,546	9,662	1,764	2,422	738			

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.

For the same reason, an indicator of business group membership for each firm is considered. Agencies might be less willing to finance firms which belong to a group because it is expected that these firms benefit from the group in terms of having fewer financial restrictions. And a dummy variable that represents 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 in R&D investment and the determinants of the intensity of the R&D (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 studies for the Spanish economy point out that, since 2000, the investment effort has been superior in firms that won public support than in those which 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.⁷ 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 European innovation subsidies schemes. These public aid instruments could increase the chances of performing R&D, as tools that reduce a firm's financial constraints.

⁷The 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 that hamper innovation. However, this information was not provided in the selection of variables that the INE gave us to do this research.

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 approximate sectorial technological opportunities and appropriability conditions (Beneito, 2003; Ortega-Argilés, Moreno and Suriñach-Caralt, 2005). Specifically, we included the dummies for firms that belong 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' organisational aspects: belonging to a group, foreign capital, public capital and technological cooperation.

With respect to the technological output equation [4], we try three different specifications. In the first, we consider almost the same explanatory variables as in the technological input equation [3]. In the other two specifications, besides the variables that reflect participation in public programmes and time, size and sectorial dummies, some measure of the R&D intensity is added as an explanatory variable. This allows us to discuss 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 participation in public aid programmes. Later, we analyse how participation in 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 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).⁸ Some of the explanatory variables are included with one lag in the estimates to prevent endogeneity problems.

As expected, the correlation coefficients ρ_{21} and ρ_{32} are significantly different from zero and positive. In accordance with Busom and Fernández-Ribas (2007) and Czarnitzki and Lopes-Bento (2014), national support and European funding are positively linked to each other. The same happens with soft loans and national subsidies, indicating the presence of common unobserved factors that affect the probability of participating in both programmes. A positive shock on the likelihood of being awarded an EU grant and a CDTI loan would also translate into a positive shock in the probability of getting a national subsidy. However, ρ_{31} is non-significant, implying that there are no common unobserved factors affecting the probabilities of participating in the national soft loan system and the scheme of European subsidies. At this respect, in our very short panel most of non-supported firms in one year remain in the same status the following year, while awarded firms tend to change the specific type of public aid they achieve from one period to the next (see Table A.2 of Appendix 2).⁹

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 coefficients 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 kinds 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 loan system.

⁸ See Cappellari and Jenkins (2003).

⁹ In particular, among firms awarded both an EU grant and a CDTI loan in year t , about 48% get a national subsidy in year $t+1$ (with or without other type of aid).

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

	CDTI loan programme		National subsidy programme		European subsidy programme	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
<i>Technological characteristics</i>						
- Internal R&D intensity (in logs.) (t-1)	0.081 ***	0.006	0.144 ***	0.007	0.107 ***	0.011
- Patent application (t-1)	0.151 **	0.045	0.081 *	0.043	0.081	0.061
- Technological cooperation with:						
• clients (t-1)	-0.040	0.067	0.176 **	0.059	0.230 **	0.075
• competitors (t-1)	-0.231 **	0.080	0.214 ***	0.066	0.371 ***	0.078
• other firms from the group (t-1)	-0.047	0.070	-0.076	0.067	0.157 *	0.085
• providers (t-1)	0.014	0.059	-0.138 **	0.054	-0.090	0.073
• consultants & laboratories (t-1)	0.014	0.071	-0.063	0.066	0.007	0.086
• universities, PRCs and technological centres (t-1)	0.129 **	0.046	0.609 ***	0.042	0.535 ***	0.061
- High and medium-tech manufacturing sector	0.282 ***	0.043	0.090 **	0.043	-0.148 **	0.066
- High and medium-tech service sector	-0.038	0.070	0.429 ***	0.057	0.481 ***	0.073
<i>Other firm characteristics</i>						
- Belonging to a group	0.109 **	0.045	0.098 **	0.044	0.055	0.066
- Exporter (t-1)	0.313 ***	0.045	0.040	0.042	0.040	0.061
- Foreign capital	-0.212 **	0.061	-0.228 ***	0.062	-0.135	0.090
- Public firm	-0.081	0.166	0.332 **	0.128	0.634 ***	0.145
- Size (in logs.)	0.649 ***	0.068	0.154 **	0.050	-0.118 *	0.065
- Size squared	-0.059 ***	0.007	-0.010 *	0.005	0.019 ***	0.006
- Start-up	0.541 ***	0.153	0.230 *	0.136	-0.297	0.200
ρ_{21}			0.256***	(0.000)		
ρ_{31}			-0.005	(0.885)		
ρ_{32}			0.313***	(0.000)		
Test [CDTI loan-National subsidy]			0.000			
Test [CDTI loan-European subsidy]			0.000			
Test [National subsidy-European subsidy]			0.000			
Log of likelihood function			-7187.3			
Number of observations (number of firms)			8716 (3534)			

Notes: S.E.: Standard errors. (t-1) denotes that the variable is included with one lag. All regressions include a constant and time dummies for the years 2003 and 2004. Test reports the p-value of a test of equality of coefficients. ρ_{21} , ρ_{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 cooperation between 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 participation in the national funding programme with the exception of the cooperation with providers. Our results are in accordance with García and Mohnen (2010), who find that Austrian firms which cooperated in innovation were more likely to get help from both national and EU sources during the period 1998-2000. A similar result is obtained by Hottenrott and Lopes-Bento (2014) for Belgian firms but only for small and medium firms which cooperate with foreign firms. However, technological cooperation does not seem to increase the propensity to participate in the soft loan programme. Only cooperation with universities, PRCs and other technological centres has a positive and significant impact, while cooperation with competitors shows a negative effect.

Being a patent applicant in the previous year positively affects the chance of participation in the soft loan and national subsidy systems.¹⁰ It seems that the CDTI is especially sensitive to the previous technological success of candidate firms in order to award a loan. These results are in accordance with the evidence provided by Huergo, Trenado and Ubierna (2015) for the same loan system.

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

As for the rest of the 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 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 reluctant to finance firms that belong to foreign groups than to domestic ones. García and Mohnen (2010) and Czarnitzki and Lopes-Bento (2014) also find a negative effect

¹⁰ In a complementary estimation without distinguish among the partners of technological cooperation, patent application also affects the participation in the European subsidy system.

of this variable on European funding, but in our sample, we do not find this result. Group membership does not have a significant effect on European subsidies.

Another interesting result in Table 3 is the existence of a non-linear effect of size on the probability of participating in low-interest loan and national and European funding systems, but in a different way. As firms are larger, they have a higher probability of being awarded by the CDTI and national subsidies, but the increase in size affects the probability of obtaining financing marginally less. This result, which is in accordance with Huergo, Trenado and Ubierna (2015), 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 participating, although as a certain amount of resources is obtained, the size effect is smaller. However, in line with Czarnitzki and Lopes-Bento (2014), the estimated curve describes a U-shaped relationship between the European subsidy receipt and firm size.

Finally, being a start-up positively affects the chance of participation in soft loan and national subsidy programmes. Although more experienced firms are more likely to know and use public aid programmes, younger firms are usually more financially constrained, having more incentives to apply for and receive them. It seems that the second effect exceeds the first one. In the case of European public aid it is seems that both effects compensate each other.

4.2. 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. All explanatory variables in the first equation are also considered as explanatory variables in the second equation.

In order to analyse whether 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 ρ is significant in both estimations, pointing out the necessity of estimating a selection model for the observed intensity.

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)		Internal R&D intensity		Propensity to engage in R&D (0/1)		Total R&D intensity	
	(1)		(2)		(3)		(4)	
	<i>dy/dx</i>	S.E.	<i>dy/dx</i>	S.E.	<i>dy/dx</i>	S.E.	<i>dy/dx</i>	S.E.
Participation in CDTI loan programme ^{a)}	0.022 ***	0.003	0.034 ***	0.004	0.022 ***	0.002	0.034 ***	0.004
Participation in national subsidy programme ^{a)}	0.006 **	0.002	0.022 ***	0.003	0.006 ***	0.002	0.020 ***	0.004
Participation in European subsidy programme ^{a)}	0.017 ***	0.005	0.035 ***	0.004	0.017 ***	0.004	0.039 ***	0.006
<i>Technological characteristics</i>								
- Percentage of R&D employees (t-1)	0.004 ***	0.000	0.002 ***	0.001	0.004 ***	0.000	0.002 **	0.001
- Technological cooperation (t-1)	0.059 ***	0.016	-0.379 ***	0.048	0.059 ***	0.022	-0.309 ***	0.044
- High and medium-tech manufacturing sectors			0.141 ***	0.055			0.167 ***	0.036
- High and medium-tech service sectors			0.091	0.077			0.092	0.076
<i>Other firm characteristics</i>								
- Belonging to a group	-0.028	0.017	0.069 **	0.034	-0.028 **	0.013	0.141 ***	0.031
- Exporter (t-1)	0.059 **	0.021	-0.272 ***	0.048	0.055 **	0.020	-0.298 ***	0.040
- Foreign capital	0.055 **	0.019	0.396 ***	0.057	0.053 **	0.021	0.398 ***	0.057
- Public firm			-0.449 **	0.167			-0.503 **	0.182
- Size (in logs.)	-0.029 ***	0.005	-0.559 ***	0.012	-0.029 ***	0.004	-0.558 ***	0.014
- Start-up			-0.018	0.102			0.006	0.099
Selection term, rho			0.160 ***	0.024			0.166 ***	0.030
Log of Likelihood Function			-10,501.5				-10,675.8	
Number of observations (number of firms)			8,716 (3,534)				8,716 (3,534)	

Notes: ^{a)} The prediction of the probability of participating in each programme is obtained from Table 3. S.E.: Bootstrapped standard errors. 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 the 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, 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 any type of public support clearly increases the probability of conducting R&D activities. Participation in the three kinds of public funding systems raises the probability of self-financing internal R&D activities. The highest impact corresponds to soft loans and the lowest to the national subsidies. The impact is quite similar when we consider total R&D expenditures.¹¹

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 5.9 percentage points more likely to self-finance internal R&D activities, stressing the complementarity between internationalisation 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 another Spanish database, also find a positive impact of human capital approximated by the proportion of engineers and graduates on firms' innovation behaviour.

A positive sign is also obtained for technological cooperation, which can also be considered a proxy of the firm's technological capability. Unexpectedly, we find a negative effect of the firm's size on the decision to carry out R&D. Belonging to a group also has a negative impact on the probability, but only when total R&D expenditure is considered.

With respect to magnitude of R&D expenditures, as can be seen in columns (2) and (4), once the firm has decided to invest, again the three kinds of public aid stimulate the intensity of

¹¹ If instead of introducing the three variables denoting the participation in public programmes simultaneously in the equation, we consider a separate equation for the participation in each programme, estimated impacts are higher. This evidence points out that, when we do not take into account the correlation in the participation in the three programmes, the impacts of this participation could be over-estimated.

R&D investment, although the lowest impact corresponds to national subsidies. The effects are quite similar when we consider total R&D expenditures. Our results are in line with García and Mohnen (2010) and Czarnitzki and Lopes-Bento (2014), who define R&D intensity as the ratio of R&D expenditures over sales. Notice also that European subsidies have a higher impact on total R&D intensity than on internal R&D intensity. This suggests that international funding is more effective for fostering external R&D activities.

Belonging to a group and being partly owned by foreign capital 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 with higher percentage of R&D employment and firms operating in high and medium-tech manufacturing sectors also present greater R&D activity. However, there are not differences in the R&D effort of firms operating in high and medium-tech service sectors. The rest of explanatory variables negatively affect the R&D intensity.

4.3. The production of technological outputs

Tables 5, 6 and 7 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 three alternative specifications to analyse the impact of public support on the probability of obtaining technological results. In the first one, we consider the same control variables as in the previous equation to be explanatory variables and we do not take into account that the technological effort of the firm can increase its chance of obtaining a process or product innovation.

In the other two specifications, R&D intensity is included as an explanatory variable. Notice that the innovation effort is presumably endogenous for achieving innovation outputs – that is, there can be unobservable (to the econometrician) firm characteristics that incentivise 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, in the second specification 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 an explanatory variable in equation [4]. However, as the prediction of the probability of participation in public programmes and the prediction of the R&D intensity are generated from the same set of explanatory variables, there can exist correlation problems. For this reason, in the third specification we substitute the prediction of the R&D intensity by the lagged observed R&D intensity.

When the R&D intensity is not included in the estimates (column (1) of Tables 5, 6 and 7), being supported by public programmes clearly increases the probability of obtaining product innovations. Again, the highest impact is associated with participation in the CDTI loan system. Participation in this programme and in the national subsidy system also raises the probability of obtaining process innovations, while European funding does not seem to have any effect.¹²

Table 5: Product innovation. Probit model

	(1)		(2)		(3)	
	<i>dy/dx</i>	S.E.	<i>dy/dx</i>	S.E.	<i>dy/dx</i>	S.E.
Participation in CDTI loan programme ^{a)}	0.016 ***	0.001	0.014 ***	0.002	0.010 ***	0.001
Participation in national subsidy programme ^{a)}	0.003 **	0.001	0.002 **	0.001	-0.004 ***	0.001
Participation in European subsidy programme ^{a)}	0.006 ***	0.002	0.005 *	0.003	0.009 ***	0.002
Total R&D intensity ^{b)}			0.034	0.038		
Total R&D intensity (t-1)					0.037 ***	0.002
High and medium-tech manufacturing sector	0.012	0.016	0.008	0.013	0.048 ***	0.013
High and medium-tech service sector	0.017	0.019	0.010	0.020	0.040 **	0.020
Belonging to a group	-0.020	0.013	-0.023 *	0.013	-0.007	0.011
Exporter (t-1)	0.039 **	0.013	0.051 **	0.018	0.061 ***	0.013
Foreign capital	0.085 ***	0.015	0.070 ***	0.019	0.038 **	0.017
Public firm	-0.072 *	0.037	-0.056	0.048	-0.074 **	0.035
Size (in logs.)	-0.023 **	0.003	-0.003	0.022	-0.003	0.004
Start-up	0.263 **	0.112	0.264 **	0.091	0.322 **	0.087
Log of Likelihood Function	-4,817.4		-4,633.2		-4,817.0	
Number of observations	8,716		8,716		8,716	

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.E.: Bootstrapped standard errors. 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 the years 2003 and 2004. Coefficients significant at 1%***, 5%***, 10%*.

¹² The results are quite similar when we compute average marginal effects (AME) instead of evaluating the marginal effect as sample means.

Table 6: Process innovation. Probit model

	(1)		(2)		(3)	
	<i>dy/dx</i>	S.D.	<i>dy/dx</i>	S.D.	<i>dy/dx</i>	S.D.
Participation in CDTI loan programme ^{a)}	0.008 ***	0.001	0.019 ***	0.002	0.003 **	0.001
Participation in national subsidy programme ^{a)}	0.005 ***	0.001	0.008 ***	0.001	-0.001	0.001
Participation in European subsidy programme ^{a)}	0.002	0.002	0.010 ***	0.002	0.004 ***	0.002
Total R&D intensity ^{b)}			-0.210 ***	0.038		
Total R&D intensity (t-1)					0.035 ***	0.002
High and medium-tech manufacturing sector	-0.051 ***	0.017	-0.022	0.018	-0.017	0.015
High and medium-tech service sector	-0.102 ***	0.026	-0.060 **	0.021	-0.079 ***	0.020
Belonging to a group	0.008	0.010	0.031 **	0.013	0.019	0.013
Exporter (t-1)	0.062 ***	0.015	-0.007	0.020	0.079 ***	0.013
Foreign capital	0.035 *	0.019	0.129 ***	0.025	-0.009	0.020
Public firm	-0.007	0.043	-0.106 **	0.045	-0.010	0.039
Size (in logs.)	0.009 **	0.003	-0.112 ***	0.022	0.033 ***	0.003
Start-up	0.111 **	0.050	0.108 *	0.056	0.177 ***	0.051
Log of Likelihood Function	-5,407.4		-5,391.4		-5,271.6	
Number of observations	8,716		8,716		8,716	

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.E.: Bootstrapped standard errors. 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 the years 2003 and 2004. Coefficients significant at 1%***, 5%***, 10%*.

Table 7: Patents application. Probit model

	(1)		(2)		(3)	
	<i>dy/dx</i>	S.D.	<i>dy/dx</i>	S.D.	<i>dy/dx</i>	S.D.
Participation in CDTI loan programme ^{a)}	0.018 ***	0.001	0.014 ***	0.001	0.017 ***	0.001
Participation in national subsidy programme ^{a)}	-0.005 ***	0.001	-0.006 ***	0.001	-0.006 ***	0.001
Participation in European subsidy programme ^{a)}	0.014 ***	0.001	0.011 ***	0.001	0.014 ***	0.001
Total R&D intensity ^{b)}			0.067 **	0.023		
Total R&D intensity (t-1)					0.008 ***	0.002
High and medium-tech manufacturing sector	-0.036 ***	0.011	-0.046 **	0.011	-0.030 **	0.011
High and medium-tech service sector	-0.020	0.015	-0.036 **	0.015	-0.017	0.015
Belonging to a group	-0.044 ***	0.009	-0.052 ***	0.009	-0.042 ***	0.009
Exporter (t-1)	-0.053 ***	0.010	-0.030 **	0.010	-0.049 ***	0.010
Foreign capital	0.084 ***	0.011	0.054 ***	0.015	0.074 ***	0.012
Public firm	-0.145 ***	0.036	-0.115 **	0.042	-0.147 ***	0.035
Size (in logs.)	-0.024 ***	0.003	0.015	0.014	-0.018 ***	0.004
Start-up	0.019	0.032	0.019	0.033	0.031	0.028
Log of Likelihood Function	-3,294.1		-3,290.9		-3,284.1	
Number of observations	8,716		8,716		8,716	

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.E.: Bootstrapped standard errors. 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 the years 2003 and 2004. Coefficients significant at 1%***, 5%***, 10%*.

In addition, 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 (see Table 7). In this line, Czarnitzki and Lopes-Bento (2014) 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).¹³

As we expected, when the prediction of the R&D intensity is added to the specification, the impacts of participating in public programmes are lower, and eventually become non-significant. R&D intensity has a significant positive impact on the generation of patents applications, while appears to be no relevant in the case of product innovations and to have a negative impact on process innovations. However, these counterintuitive results can be explained by the correlations among the prediction of the R&D intensity and the predictions of the probabilities of participation in the three public programmes, which are generated from the same set of explanatory variables. In fact, when the probabilities of participation in public programmes are excluded from the specification (see Table A.3 of Appendix 2), the R&D intensity has a positive impact on the three technological outputs. The highest effect corresponds to product innovation and the lowest to patents. In this sense, public support has an indirect effect by stimulating R&D intensity.

As an alternative way to control for the potential endogeneity of innovation effort, in the third specification we include the observed R&D intensity lagged one period. Now this variable shows a positive impact on the generation of the three technological outputs. The results also suggest that participating in the CDTI loan programme and in the European subsidy programme have a direct positive effect on the probability of obtaining the three technological outputs. On the contrary, national subsidies seem to have a negative direct impact. However, this last result could be explained by the correlation in the participation among the programmes.

With respect to the control variables, being partly owned by foreign capital increases the probability of obtaining technological outputs. The rest of the explanatory variables present a

¹³ Again, the results corresponding to separate estimates for the impact of each programme suggest the relevance of controlling for the correlation in the participation in the three programmes.

different impact depending on the measure of technological output. For example, as in previous empirical evidence, the 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.

Finally, as a robustness test, we estimate equation [4] as a linear probability model using the predicted probability of participation in each programme as the instrumental variable of the participation status (see Table A.4 of Appendix 2). The results remain almost unchanged.

5. CONCLUSIONS

The objective of this paper is to compare the effect of participating 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 the design of 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 which finances firms' R&D projects; the national scheme of R&D subsidies; and the European system of R&D grants.

To face the typical selectivity and endogeneity problems that are present in this kind of analysis, we use Heckman's treatment effect model, following a two-stage procedure. Firstly, we estimate a multivariate probit model to study the determinants of 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 R&D intensity to be technological input, and product and process innovations and patent applications technological outputs.

The results obtained for a sample of 4,407 Spanish firms during the period 2002-2005 can be summarised as follows:

Firstly, participation in national subsidy programmes and participation in European subsidy programmes are positively linked to each other. The same happens with CDTI soft loans and

national subsidies schemes, indicating the presence of common unobserved factors that affect the probability of participating in both programmes.

Secondly, being awarded public aid clearly increases the probability of conducting R&D activities. The highest impact corresponds to CDTI soft loans.

Thirdly, once the firm has decided to invest in R&D, the three kinds of public aid also stimulate the intensity of R&D investment, with national subsidies having the smallest impact. In addition, EU grants seem to be the most effective for fostering external R&D activities.

As for innovation outputs, public support has an indirect effect by stimulating R&D intensity, which has a positive impact on innovations and patent applications. In addition, we also find that participation in the CDTI loan system and in the European subsidy programme have direct positive effects on the generation of technological outputs.

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 Estudios Fiscales, 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 (2014), "Tax incentives... or subsidies for business R&D?" *Small Business Economics*, 43(3), 571-96.
- 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 a 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 (2014), “Innovation subsidies: Does the funding source matter for innovation intensity and performance? Empirical evidence from Germany,” *Industry and Innovation*, 21(5), 380-409.
- 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 (2015), "The impact of public support on firm propensity to engage in R&D: Spanish experience," *Technological Forecasting and Social Change*, forthcoming. <http://dx.doi.org/10.1016/j.techfore.2015.05.011>
- Hottenrott, H. and C. Lopes-Bento (2014), "(International) R&D collaboration and SMEs: The effectiveness of targeted public R&D support schemes," *Research Policy*, 41, 1055-1066.
- 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, 562-583.
- Lach, S. (2002), "Do R&D subsidies stimulate or displace private R&D? Evidence from Israel," *Journal of Industrial Economics* 50(4), 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), 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.
- 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.
- Wallsten, S.J. (2000), "The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research Program," *RAND Journal of Economics*, 31(1), 82-100.

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 by 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 or 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 high-tech services (NACE2 codes 64, 72, 73, 92)

Participation in CDTI loan 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 1 if the firm has obtained a process innovation during the last three years.

Product innovation: Dummy variable which takes the value 1 if the firm has obtained a product innovation during the last three years.

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 on R&D during the year.

Internal R&D intensity: Ratio of internal expenditures on 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 technological cooperation agreements during the last three years with other partners.

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

Appendix 2

Table A.1: Statistics of main variables

	Mean	S.D.	Min	Max	Median
R&D funding (1/0)					
With own funding	0.563	0.496	0	1	1
Participation in CDTI loan programme	0.132	0.238	0	1	0
Participation in national subsidy programme	0.177	0.381	0	1	0
Participation in European subsidy programme	0.054	0.227	0	1	0
Percentage of funding (%)					
Own funding	50.5	47.1	0	100	63.0
Funded with a national subsidy	5.6	17.1	0	100	0
Funded with a European subsidy	1.9	11.6	0	100	0
Other firm characteristics (1/0)					
Belonging to a group	0.399	0.490	0	1	0
Exporter	0.548	0.498	0	1	1
Foreign capital	0.115	0.319	0	1	0
High and medium-tech manufacturing sector	0.235	0.424	0	1	0
High and medium-tech service sector	0.096	0.295	0	1	0
Internal R&D performer	0.592	0.491	0	1	1
Patent application	0.171	0.377	0	1	0
Process Innovation	0.444	0.497	0	1	0
Product Innovation	0.494	0.500	0	1	0
Public firm	0.020	0.139	0	1	0
R&D performer (Internal and external)	0.625	0.484	0	1	1
Start-up	0.032	0.172	0	1	0
Technological cooperation with:	0.340	0.474	0	1	0
- clients	0.088	0.283	0	1	0
- competitors	0.062	0.242	0	1	0
- consultants & laboratories	0.081	0.273	0	1	0
- PRCs	0.081	0.273	0	1	0
- other firms of the group	0.078	0.269	0	1	0
- providers	0.126	0.332	0	1	0
- technological centres	0.128	0.334	0	1	0
- universities	0.168	0.374	0	1	0
Other firm characteristics (quantitative):					
Export intensity (Export over sales)	0.171	0.263	0	1	0.011
External R&D Expenditures (K€)	235.7	2,239.1	0	54,800	0
Internal R&D Expenditures	719.5	3,910.4	0	72,300.0	53.6
Percentage of R&D employees (%)	43.1	42.0	0	100	38.3
R&D intensity (K€ per employee)	7.0	27.8	0	1,268.4	0.8
Size (Number of employees)	358.2	1,096.8	1	13,023	69
Total R&D intensity (K€ per employee)	8.7	34.9	0	1,441.2	1.1
Number of observations (firms)			13,546 (4,407)		

Table A.2: Transition rates across participation status

Status in t-1	Number of observations	Status in t								
		No public funding	Only CDTI loan	Only national subsidy	Only European subsidy	CDTI loan & national subsidy	CDTI loan & European subsidy	National & European subsidies	All types of public funding	
No public funding	6,124	84.7	6.7	5.0	0.7	2.1	0.2	0.6	0.1	100
Only CDTI loan	677	65.7	12.4	15.1	1.0	4.7	0.0	1.0	0.0	100
Only national subsidy	1,009	45.3	9.2	28.1	1.4	12.7	0.3	2.9	0.2	100
Only European subsidy	233	54.1	3.4	7.3	21.0	2.2	2.6	8.2	1.3	100
CDTI loan & national subsidy	403	34.2	8.7	38.0	0.7	14.1	0.5	2.2	1.5	100
CDTI loan & European subsidy	21	33.3	4.8	4.8	14.3	9.5	0.0	19.1	14.3	100
National & European subsidies	218	13.8	3.2	15.6	10.6	4.6	0.9	47.7	3.7	100
All types of public funding	48	10.4	4.2	14.6	8.3	2.1	2.1	31.3	27.1	100
Total	8,733	73.2	7.3	10.4	1.7	4.2	0.3	2.5	0.5	100

Table A.3: Product innovation, process innovation and patents application.
Probit model

	Product innovation		Process innovation		Patents application	
	<i>dy/dx</i>	S.E.	<i>dy/dx</i>	S.E.	<i>dy/dx</i>	S.E.
Total R&D intensity ^{a)}	0.219 ***	0.006	0.154 ***	0.007	0.136 ***	0.006
High and medium-tech manufacturing sector	0.030 **	0.012	-0.044 **	0.017	0.007	0.009
High and medium-tech service sector	-0.053 **	0.022	-0.138 ***	0.020	-0.090 ***	0.017
Belonging to a group	-0.034 **	0.012	-0.004	0.013	-0.037 ***	0.009
Exporter (t-1)	0.147 ***	0.011	0.125 ***	0.010	0.065 ***	0.010
Foreign capital	-0.034 **	0.017	-0.045 **	0.015	-0.011	0.011
Public firm	-0.012	0.041	0.040	0.037	-0.082 **	0.037
Size (in logs.)	0.108 ***	0.004	0.097 ***	0.005	0.072 ***	0.005
Start-up	0.299 **	0.099	0.158 ***	0.043	0.034	0.027
Log of Likelihood Function	-4,852.5		-5,447.8		-3,373.2	
Number of observations	8,716		8,716		8,716	

Notes: ^{a)} The prediction of the total R&D intensity is obtained from estimations (3) and (4) in Table 4. S.E.: Bootstrapped standard errors. 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 the years 2003 and 2004. Coefficients significant at 1%***, 5%***, 10%*.

Table A.4: Product innovation, process innovation and patents application.
IV Linear probability model

	Product innovation		Process innovation		Patents application	
	<i>dy/dx</i>	S.E.	<i>dy/dx</i>	S.E.	<i>dy/dx</i>	S.E.
Participation in CDTI loan programme ^{a)}	0.015 ***	0.002	0.009 ***	0.002	0.022 ***	0.003
Participation in national subsidy programme ^{a)}	0.004 **	0.001	0.004 ***	0.001	-0.007 ***	0.002
Participation in European subsidy programme ^{a)}	0.004 *	0.002	0.002	0.002	0.017 ***	0.004
High and medium-tech manufacturing sector	0.020	0.026	-0.049 **	0.019	-0.031	0.025
High and medium-tech service sector	0.028	0.034	-0.094 ***	0.019	0.002	0.037
Belonging to a group	-0.022	0.017	0.006	0.015	-0.042 **	0.021
Exporter (t-1)	0.058 **	0.018	0.064 ***	0.017	-0.078 ***	0.023
Foreign capital	0.094 ***	0.023	0.041 **	0.021	0.085 **	0.026
Public firm	-0.059	0.054	-0.003	0.041	-0.093 *	0.052
Size (in logs.)	-0.027 ***	0.004	0.007 *	0.004	-0.020 ***	0.005
Start-up	0.127	0.079	0.099	0.067	0.079	0.111
Number of observations	8,716		8,716		8,716	

Notes: ^{a)} The instrumental variables are the prediction of the probability of participating in each programme obtained from Table 3 and the prediction of the total R&D intensity obtained from estimations (3) and (4) in Table 4. S.E.: Bootstrapped standard errors. All regressions include a constant and time dummies for the years 2003 and 2004. Coefficients significant at 1%***, 5%***, 10%*