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The link between public support and private R&D effort: What is the optimal subsidy?

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Abstract The effectiveness of R&D subsidies can vary substantially depending on their characteristics. Specifically, the amount and intensity of such subsidies are crucial issues in the design of public schemes supporting private R&D. Public agencies determine the intensities of R&D subsidies for firms in line with their eligibility criteria, although assessing the effects of R&D projects accurately is far from straightforward. The main aim of this paper is to examine whether there is an optimal intensity for R&D subsidies through an analysis of their impact on private R&D effort. We examine the decisions of a public agency to grant subsidies taking into account not only the characteristics of the firms but also, as few previous studies have done to date, those of the R&D projects. In determining the optimal subsidy we use both parametric and non-parametric techniques. The results show a non-linear relationship between the percentage of subsidy received and the firms' R&D effort. These results have implications for technology policy, particularly for the design of R&D subsidies that ensure enhanced effectiveness.

JEL: O38, H32
Keywords: R&D, public subsidies, evaluation

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1. Introduction

Support for R&D and innovation plays a central role in technology policies and is based on arguments for which a wide consensus exists. Among the justifications for public intervention the most fundamental is market failure, which can result in R&D investment falling below what is socially optimal in the absence of public intervention (Arrow, 1962). Governments, therefore, take different actions to support private technological activities, with R&D subsidies being one of the most frequently adopted tools.

Although the reasons for public support to private R&D are well established, its effectiveness needs to be examined. In recent years, public policy evaluation has acquired growing importance and although the results are not entirely conclusive, recent literature reviews (David *et al*., 2000; García-Quevedo, 2004) indicate that, in the case of R&D subsidies, the existence of an additional effect is the most frequent outcome.

Most studies evaluating R&D subsidies tend to analyze the average effects of these subsidies on recipient firms. Although a number of these papers take into account certain firm characteristics in determining whether the effects are homogenous, very few analyse whether these effects vary depending on the specific characteristics of the R&D subsidies themselves. As Takalo *et al.* (2005) point out, surprisingly, very little is known about the way in which R&D subsidies are allocated by public agencies. The degree of effectiveness of R&D policy can differ substantially depending on the allocation procedure and on the characteristics of R&D subsidies. Among these characteristics, the amount and intensity of the public subsidy (defined as the gross subsidy amount expressed as a percentage of the project's eligible costs) are relevant aspects in the design of public schemes in support of private R&D.

In this respect, firms' R&D projects vary considerably and so the optimal public R&D policy will vary from project to project. This means that, although the rules for allocating R&D subsidies are the same for all firms, the policy should be heterogeneous *ex-post*, i.e., granting different subsidy intensities according to the characteristics of the projects and their expected effects (Toivanen, 2006). Thus, public agencies determine different intensities of R&D subsidies to firms, taking into account EU rules and depending on established eligibility criteria. The European Union, in the Community framework for State aid for Research and Development and Innovation, emphasizes the importance of carefully defining state aid measures so as to avoid distortion and to guarantee their effectiveness. Specifically, it stresses that the amount and intensity of the subsidy should be limited to the minimum required for the R&D activity to take place. Such an allocation faces the difficulty of determining the optimal subsidy intensity, given the complexity of assessing accurately the effects and impact of R&D projects.

As suggested by a number of recent empirical studies (González *et al.*, 2005; Görg and Strobl, 2007; Aschhoff, 2009; Cerulli and Poti, 2010), the effects of subsidies can differ substantially depending on their characteristics. Although these contributions to the literature provide valuable information, our knowledge about the effects that the distribution of the subsidies, in terms of intensity, have on the behaviour of recipient firms and, eventually, on the impact and efficiency of these public programmes is scarce.

The objective of this paper, therefore, is to contribute to this literature by examining whether there is an optimal intensity for public R&D subsidies. In order to do this, we analyse the degree of financial additionality in terms of private R&D effort for the different intensities of subsidy granted to firms' R&D projects. Moreover, we analyse the public agency's decisions to grant the subsidy taking into account not only the characteristics of the firms but also those of the R&D projects themselves. As a few recent papers (Takalo *et al.*, 2008; Huergo and Trenado, 2010) show, the characteristics of the R&D projects are more relevant to these decisions than the specific characteristics of the firms. The availability of a detailed database with information on the characteristics of private R&D projects (including the scores given by the public agency to each R&D project), the applicant firms, and the subsidies granted allows us to estimate the optimal subsidy that firms should receive from the public agency in order to obtain a higher R&D additionality.

For this purpose the empirical strategy proposed here consists in estimating parametrically and non-parametrically the impact of R&D subsidy intensity as a determinant of the firms' R&D effort. In the parametric set-up, and given the possible endogeneity problems of R&D subsidy intensity we make use of a two-step procedure with a Tobit model with instrumental variables in the first stage (see Wallsten, 2000), and a Heckman correction model in the second stage. In the non-parametric set-up, the use of a conditional quantile regression approach allows us to estimate the effect of subsidy intensity for different types of recipient firm. Sorting firms by R&D effort, we obtain the impact of public subsidy intensity conditional on the R&D effort distribution; therefore, we observe the possible existence of an optimal R&D subsidy for each category of firm.

The rest of the paper is organised as follows. Section 2 reviews both the theoretical and the empirical literature and identifies the main hypotheses to be tested. Section 3 deals with the empirical strategy. Section 4 presents in detail the database used. Section 5 is devoted to present and discuss the main results obtained. Finally, section 6 presents the conclusions with some implications for the design of innovation policy.

2. Literature review: Theoretical hypotheses and empirical evidence

A relevant issue on the current empirical research agenda in the economics of technical change is the estimation of the "additionality effect", the change in privately financed R&D expenditures induced by government subsidization of R&D activities. However, to date, there have been few theoretical contributions formulating models of firm decision-making that take into account the mechanism by which this effect can occur (David et al., 2000; Takalo et al., 2008; Lee, 2011).

The arguments justifying why subsidies can stimulate private R&D expenditures are well known. First, upon receiving the agency's approval for its project, the firm commits to match, in a given proportion, the subsidy received, thus inducing subsidized firms, ceteris paribus, to increase their own R&D expenditure. Second, a subsidy to a particular project can lower the fixed costs and, hence, increase the profitability of other current (and future) R&D projects. Finally, learning and know-how spillovers from the subsidized project to other current (and future) R&D projects can increase the probability of success and hence profitability.

What if the firm would have undertaken a particular subsidized R&D project even if the subsidy had not been granted? In this case, from the public agency's point of view the subsidy is superfluous since it would be fully crowding out private R&D expenditures. Consequently, an increase in privately financed R&D can only be guaranteed if the projects approved are those that would not have been undertaken without the subsidy. This vital information is, of course, usually unknown to the agency and constitutes a potential source of inefficiency.

This result is heavily dependent on the strong and unrealistic assumption that the firm will not change its R&D projects' portfolio after receiving a subsidy. For instance, even if the subsidy is superfluous, the private funds released by the subsidy could be used to finance other R&D projects, thus leaving its own R&D expenditures unaffected. Besides, receiving a subsidy may serve as a signal to lower the cost of new funds. In this case, the firm may accelerate existing projects or start new ones, thereby, increasing privately financed R&D expenditures. This could occur even if the subsidy to a particular project is superfluous.

Moreover, even in instances when the subsidized project would not have been undertaken without a subsidy, privately financed R&D expenditures may fall. In cases where a firm lacks enough skilled R&D workers or faces certain liquidity constraints, it may be too costly to implement the non-subsidized projects along with the subsidized project to which it is committed. Therefore, the firm may find it profitable to discontinue some of the non-subsidized projects, thereby contributing to a reduction in privately financed R&D expenditures.

In sum, an R&D subsidy can have a direct and an indirect effect on a firm's performance. The direct effect operates through the increase in total R&D expenditures, holding privately financed R&D constant. The indirect effect operates through the response of privately financed R&D expenditures to the subsidy. If the R&D subsidy displaces a firm's own R&D expenditures, the total effect may be modest or even negative. On the other hand, if it stimulates a firm's own R&D expenditures, then the effects of the subsidy are magnified. Thus, an understanding of the relationship between R&D subsidies and privately financed R&D is necessary for a correct assessment of the role of R&D subsidies in boosting privately financed R&D expenditures.

Firms may react differently to the R&D subsidy depending, essentially, on their own characteristics and on the features of the subsidy. Firms facing better markets or higher probabilities of R&D success, for example, will have larger R&D departments and hence more R&D expenditure. The same is true for firms with lower costs of setting up R&D projects. These firms will be more technologically advanced and, even controlling for the technological level, will be more valuable. According to the classical result of Dasgupta and Stiglitz (1980) (see also Lee, 2002), under certain conditions a firm's R&D spending as a share of its sales revenue (R&D effort) depends positively on the R&D elasticity of demand and inversely on the price elasticity of demand. In this context, several firm and industry characteristics would shape different relationships between these variables.

Furthermore, the characteristics of a subsidy may also have an impact on its specific effects on privately funded R&D expenditures. In this case, both the amount of the subsidy as well as the intensity may have different effects depending on the features of the recipient firm. Moreover, due to the intricate relationship between the different characteristics of firms and subsidies, the reaction of a firm's R&D effort to the subsidy's intensity is expected to be non-linear. From the previous analysis, it would appear that whether R&D subsidies stimulate or crowd out private R&D expenditures is, therefore, an empirical matter.[1]

The empirical literature evaluating public R&D subsidies has become increasingly devoted to analysing possible heterogeneous effects depending on the characteristics of firms and the subsidies. Apart from analysing the full impact of R&D subsidies on recipient firms, knowing whether the effects are heterogeneous across firms provides relevant information for the design of technology policy.

Recent studies have taken into account a number of characteristics of the firm, including size, sector and location, in examining possible differences in the effects of R&D subsidies (Lach, 2002; Czarnitizki and Fier, 2002; Czarnitzki, 2006; González et al.,

[1] Note also that we restrict ourselves to the effect of the subsidy on a firm's own R&D expenditures. Subsidies may also have implications for other non-R&D activities, both contemporaneously and over time, and, through inter-firm spillovers or rivalry channels, subsidies may have effects on other firms' R&D activities.

González and Pazó 2008, Cerulli and Poti, 2010). The main conclusion of these analyses is that the effects of R&D subsidies are not homogenous. For instance, for Spanish manufacturing firms, González and Pazó (2008) examine the differences in the effectiveness of subsidies according to firm size and industry type and conclude that public support is more effective in small firms and firms operating in low-technology sectors. In addition, other recent analyses have sought to determine whether the effects of public subsidies differ depending on their specific characteristics. For instance, using countries as their unit of analysis, Guellec and van Pottelsberghe (2003) point out that the effectiveness of government support seems to have an inverted U-shape, increasing up to a particular threshold and decreasing after that. Busom (2000) suggests that a small subsidy does not modify the scope of a firm's R&D plans, but admits that without knowing the exact amount of the subsidy it is impossible to confirm this hypothesis. González *et al.* (2005) show that subsidies induce modest increases in privately financed effort and that the impact grows, albeit only in a small proportion, with the size of the subsidy. They also estimate the amount of the subsidy, as a percentage of a firm's R&D expenditures, needed to induce non-performing firms to perform innovative activities.

Recent contributions also show that the effects of public subsidies may vary with their size and intensity. Specifically, Görg and Strobl (2007) use three different subsidy size categories (small, medium and large) and examine their effects for domestic plants and multinationals in Ireland. In the case of domestic plants, small- and medium-scale subsidies do not crowd out private R&D spending, while some additional effects are found for small subsidies, and a crowding out effect is reported for large-scale subsidies. For foreign multinationals, the effect does not vary with subsidy size. Aschhoff (2009) shows for Germany that small subsidies do not have an effect on privately financed R&D expenditures, whereas medium and large subsidies do have additional effects. Finally, Cerulli and Poti (2010) consider three classes of financing intensity, defined as the subsidy share of the total project cost, and their results show that the positive effect of the subsidy only appears above a certain threshold, when about 50% of the total project cost is being financed.

In short, on the basis of both the theoretical considerations and the empirical analyses, it can be concluded that the effects of R&D subsidies are not homogenous. Identifying possible differences, depending on the characteristics of the subsidies, would ensure an improvement in the effectiveness of public support to private R&D. In particular, the intensity of the subsidy is one of the main decisions to be taken by public agencies, and knowing how firms react to different financing intensities would provide essential information for a better understanding of this policy, and lead to an improvement in the impact and efficiency of public programmes.

3. Empirical strategy

Given the nature of our goal, i.e., analysing the optimal percentage of R&D subsidy (or R&D intensity), we draw on all relevant econometric techniques that might help us understand, as identified by recent empirical analyses and theoretical models, the possible non-linear relationship between the percentage of R&D subsidy granted by the public agency and the private R&D effort made by recipient firms.

As such, our empirical strategy is two-fold: a parametric and a non-parametric set-up. The former seeks to compare our results with those reported in the R&D literature. Here, we use a well-established methodology which also allows us to control for well-known problems including selection bias and endogeneity. The non-parametric set up, a more flexible framework, adds important information and evidence.

3.1 Parametric set-up: two-step procedure

The main equation to estimate relates a given percentage of an R&D subsidy as a determinant of a firm's private R&D effort, or in formal terms,

$$RDe = f(\%RDi, X_i), \qquad [1]$$

where RDe is the private R&D effort of a recipient firm measured as private R&D expenditure as a percentage of sales; $\%RDi$ is the R&D subsidy intensity measured as the percentage (on eligible cost) of the R&D subsidized by the public agency and X_i is a set of firm characteristics (see section 4 for more details on data issues and the definition of variables). By estimating Eq. [1], we aim to explain whether receiving a given percentage of subsidy to perform R&D activities has any impact on a firm's R&D

effort. Thus, we do not seek to determine whether receiving a public subsidy has an impact on R&D effort, as has been usual in the literature to date. Rather, we go a step further and ask whether the specific percentage received has an impact on the R&D effort of private firms.

Two important issues must be taken into account when estimating Eq.[1] econometrically: a) possible problems of endogeneity of the actual intensity of the R&D subsidy and b) possible problems of selection bias. Below, we deal with these two potential econometric problems.

a) First step: endogeneity

Our first concern is that our main variable of interest, *%RDi*, could be endogenously determined, that is, the percentage of private R&D activities subsidized publicly could determine the effort in R&D made by recipient firms; but it could also be the case that firms with a higher R&D effort receive a higher percentage of public subsidy precisely because the effort they dedicate to R&D is higher. Therefore, we need to control for the likely existence of endogeneity in Eq. [1]. To deal with this, we initially estimate the determinants of R&D subsidy intensity as follows:

$$\%RDi = f(X_i, P_i) \qquad [2]$$

where X_i is again a vector of variables including firm characteristics and P_i are the scores obtained by the R&D projects presented by firms to obtain public subsidies (section 4 explains the nature of this variable in more detail). Therefore, Eq. [2] presents the determinants of receiving a specific percentage of the total subsidy applied to the public agency and allows us to study the role of the scores given to private R&D projects in deciding the subsidy intensity. In this sense, we are able to analyse the granting decision of the public agency in detail.

Note that Eq. [2] must be estimated using a Tobit model given the distribution of *%RDi*. This variable has a specific distribution: for non-recipient firms it is 0, while for recipient firms it takes a positive value between 0 and an upper bound of 60% according to EU criteria for subsidy intensity. Moreover, the estimation of Eq. [2] does not suffer from selection bias because this variable only exists for firms that apply for a public subsidy. The percentage of publicly subsidized R&D is at the total discretion of the public agency granting the subsidies and, hence, this variable exists only for firms that apply for subsidies and, in our case, we account for all of them.

We use the estimation of Eq. [2] to obtain the predicted values for *%RDi*, that is, *pred*[*%RDi*]. If this first stage is well specified, the predicted values can be used in the second stage to tackle the possible problem of endogeneity outlined above. Therefore, we can re-estimate Eq. [1] as follows:

$$RDe = f(pred[\%RDi], X_i) \qquad [3]$$

b) Second step: selection bias

The estimation of Eq. [3], i.e., the determinants of the firms' R&D effort, may likewise suffer from selection bias. The possible existence of this bias (which has been well established in the empirical literature dealing with R&D subsidies) is attributable to the fact that all firms may have a certain R&D effort, but we are only able to observe the R&D effort of those firms that apply for a public subsidy. Therefore, extending our results to all firms would be misleading, since we are observing the R&D effort of a particular sample of firms that could, *a priori*, have a higher R&D effort than the rest of firms.

Hence, we need to estimate Eq. [3] by taking into account the possible existence of this selection bias. Various econometric techniques allow us to perform statistical tests to verify if this selection bias exists. In line with the literature (see, for instance, Hussinger, 2008), we estimate Eq. [3] using the Heckman procedure:

$$RDe = f(pred[\%RDi], X_i, \lambda) \qquad [4]$$

In Eq. [3] we introduce the Inverse Mills Ratio (λ) derived from the estimation of a selection equation (binary participation decision) that models the probability of receiving a public subsidy, using a probit model. More formally the selection equation is:

$$Receive = f(X_i,\ Y_i) \qquad [5]$$

where *Receive* is a dummy variable indicating the receipt of a public R&D subsidy; X_i are the same variables as before while Y_i corresponds to the characteristics of the project that could affect the probability of receiving a public subsidy. Under normality the coefficient of λ in Eq. [4] is proportional to the hazard rates and depends only on known parameters of Eq. [5].

Hence, combining Eq. [5] and Eq. [4] we perform a Heckman estimation, which in our case accounts for the possible problems of selection bias as well as those of endogeneity (since we use the predicted values obtained in the first stage).

3.2. Non-Parametric set-up: conditional quantile regression approach

In our context, the assumption of linearity in the relationship between public R&D subsidy intensity and the firms' private R&D effort may not be appropriate: the issue of specifying the functional form of the model emerges, and this is a particularly difficult choice especially when the impact of the regressors on the regressand is not well established by a theoretical model, as in our case.

For this reason, we avoid any a priori assumptions about the specific functional form, and use a complete non-parametric estimator. By so doing, we obtain a graphical idea of the relationship existing between the variables under examination.

The joint cumulative density function *F(%RDi, RDe)*, assuming that the bivariate distribution *f(%RDi, RDe)* exists, is given by:

$$F\left(RDe \middle| \%RDi\right) = \int_{-\infty}^{RDi} f\left(RDe \middle| \%RDi\right) dRDe = \int_{-\infty}^{RDi} \frac{f\left(\%RDi, RDe\right)}{f\left(\%RDi\right)} dRDe \qquad [6]$$

where

$$f\left(\%RDi\right) = \int_{-\infty}^{\infty} f\left(\%RDi, RDe\right) dRDe \qquad [7]$$

represents the marginal distribution of *%RDi*.

The inverse function $F^{-1}(p|\%RDi)$ of Eq. [6] gives the *p*-quantile (parametrically estimated) of *RDe* conditional on *%RDi*. The problem is that the functional form of *f*(.) is unknown and must be estimated. Instead of using a priori assumptions about its shape, we estimate it non-parametrically (Trede, 1998). Different non-parametric approaches have been used in the literature, such as spline smoothing (Koenker, Portnoy and Ng, 1992) and kernel density estimation (Abberger, 1997). We use the latter because we consider the idea that the shape of *f(%RDi*, *RDe*) in Eq. [6] is unknown and has to be replaced by its non-parametric estimate (Trede 1998) intuitively appealing. Let *n* be the number of observations for which the private R&D effort and the public R&D subsidy intensity are available, rde_i and rdi_i being the measured variables relative to the *ith* firm of the sample, and *i* = 1,…,*N*. The bivariate density can be defined as:

$$\hat{f}(rdi, rde) = \frac{1}{nh_1h_2}\sum_{i=1}^{n} K\left(\frac{rdi - rds_i}{h_1}\right) K\left(\frac{rde - rde_i}{h_2}\right) \qquad [8]$$

where h_1 and h_2 are the bandwidths, and *K*(.) is the Kernel.[2] Then substitute this expression into Eq. [6], setting the cumulative density function of the Kernel equal to:

$$H(z) = \int_{-\infty}^{z} K(x)\delta x \qquad [9]$$

we obtain:

[2]More generally, a multivariate density with dimension *d* may be estimated as:

$$\hat{f}_H(x) = \frac{1}{n}\sum_{i=1}^{n} k_H(x - X_i)$$

where *k(.)* is a *d*-dimensional Kernel function, and *H* is a bandwidths matrix. Setting in such function *d=2* gives the bivariate density function. "A convenient choice in practice is to take $H=hS^{0.5}$, where *S* is the sample covariance matrix and *h* is a scalar bandwidth sequence, and to give *k* a product structure" (Härdle and Linton, 1994). In other words, with respect to the univariate case, in the multivariate setting the issue of choosing a relation between kernels arises, and it is usually solved by using a multiplicative structure:

$$k(u) = \prod_{j=1}^{d} K(u_j),$$

where *K(.)* is the univariate Kernel function.

$$\hat{F}(rde|rdi) = \frac{\sum_{i=1}^{n} K\left(\frac{rdi - rdi_i}{h_1}\right) H\left(\frac{rde - rde_i}{h_2}\right)}{\sum_{i=1}^{n} K\left(\frac{rdi - rdi_i}{h_1}\right)} \quad [10]$$

that represents the conditional density function of *rde* to *rdi*. By inverting equation Eq. [10] we obtain the non-parametric quantile p that we are looking for, which depends on the percentage of R&D subsidy received by firms. Again, by choosing $p \in [0,1]$, an infinite number of quantiles of the relationship under investigation can be obtained; by a similar procedure (Local Least Squares) it is also possible to derive a non-parametric version of the mean function (Härdle, 1990). Interestingly for our purposes, this method allows us to estimate the relation of *%RDi* for different types of firms, in this case, types defined by the distribution of the private R&D effort (*RDe*).

Unlike the parametric analysis, the non-parametric approach is bivariate: the non-parametric conditional quantile gives the effect of the percentage of R&D subsidy on the firms' R&D effort, together with the effect of variables that may possibly influence this relationship.

4. Data

In order to proceed with the empirical strategy proposed above, we need data on the characteristics of the applicant firms and their R&D projects, the scores awarded by the agency to each project and, finally, data on the characteristics of the subsidy granted. For this purpose, we draw on a complete database, which covers all the relevant information needed, for a sample of 968 firms that applied for a public R&D subsidy in Catalonia (Spain) in the years 2005 and 2006.

Catalonia has one of the largest regional innovation systems in Spain, concentrating around 26% of private R&D expenditure. Its total R&D expenditure represents 1.6% of regional GDP. Moreover, it was one of the first regions to pursue an independent R&D subsidies policy in Spain. In Catalonia, R&D subsidies are granted by the Catalan public agency in a process similar to international procedures (see Jaffe, 2002 and Tanayama, 2009). The procedure is as follows. First, the agency allocates an overall budget to the call for R&D subsidies. Second, firms apply for subsidies by submitting a proposal for an R&D project. This application contains qualitative and quantitative information on both the firm and the R&D project itself. Third, in accordance with established (and public) criteria, experts evaluate the projects and award a numerical score that allows all projects presented to be ranked. Finally, a committee appointed by the agency uses this information to determine which projects will be granted a subsidy and the intensity of that subsidy. Therefore, by drawing on this complete database, we have access to all the information required to estimate the optimal subsidy applying the methodology described above.

Scores

As explained above, in order to overcome the possible problem of endogeneity in the estimation of the determinants of public R&D subsidy intensity we use, as an instrument, the scores (P_i) received by each private R&D project submitted. The agency publishes in their calls for firms' R&D projects the criteria used in the evaluation and selection process. These criteria are related to the four main objectives of the agency and (internal and external) referees are asked to evaluate each project accordingly. The four variables used are:

i) Technological contribution (**tech_contrib**): refers to the agency's goal to promote technologically outstanding projects.

ii) Socio-economic impact (**se_impact**): refers to the assessment of the impact of projects in terms of their Gross Value Added and/or R&D investment.

iii) Internationalization (**international**): refers to the estimated contribution of the project to the internationalization of firms.

iv) Diffusion (**diff**): takes into account the impact of the project on other sectors and on other firms.

In addition to these four variables, which capture the extent to which the private R&D projects fulfill the agency's four main objectives, we also use, as a robustness exercise, the overall score obtained by each project (**total**).

A priori these variables should be highly correlated with the percentage of the subsidy eventually granted, but they could be considered as being independent of the firms' private R&D effort, thereby making them a good instrument for tackling the possible problem of endogeneity in the first stage of the estimations.[3] Interestingly, and unlike in most previous studies evaluating R&D subsidies, this information allows us to examine the agency's allocation procedures because, as a number of recent analyses show (Takalo *et al*., 2008, Huergo and Trenado, 2010), project-level characteristics are more important than firm-level characteristics in the decision to grant a public subsidy.

Characteristics of firms, projects and subsidies

As mentioned above, we have data on different characteristics of both the firms and the projects submitted to the public agency. Applications to obtain a public subsidy in Catalonia require the firms to complete a questionnaire regarding both the proposed R&D project and their own characteristics. More specifically, firms must report past, current and projections of their main economic variables. This means we are able to use past values of some variables of interest in our econometric estimations, as is common practice in the literature, and thus avoid the problems of endogeneity of some contemporaneous regressors to private R&D effort. Table 1 contains descriptions of the explanatory variables used in the empirical estimations.

Firm-level characteristics are mainly used to control for firm specific factors that may affect decisions about the concession and intensity of subsidies. They include such characteristics as age, size, location and sector, as well as R&D and export activities. Information about the firm's application is also included, for example, whether the firm has applied for several projects in one year and whether the firm applied in the two years included in our sample. Given the cross-sectional approach, this information is

[3] For instance, in our case, scores are determined at the project level, while private R&D effort is given at the firm level. A simple partial correlation between project scores and firm R&D effort shows results below 10%.

likely to capture some of the unobserved heterogeneity across firms related to their innovative activities.[4]

<INSERT TABLE 1 AROUND HERE>

Table 2 describes the available data. From this table we observe that firms that were granted a subsidy for their R&D projects tended to be larger in terms of their number of employees, to be older, to have greater export intensity and, in terms of R&D activities, to have registered more patents and, on average, to have higher R&D expenditure. Moreover, R&D projects that have applied for a public subsidy account for a large proportion of the firms' private R&D expenditure, with an average percentage of the cost of the R&D project of almost 70% of firms' private R&D expenditure.

As for the variables used in the project evaluation process, the main two criteria employed by the agency were, first, the technological content of the proposal (with a range from 0 to 175) and, second, its expected socio-economic impact (with a range from 0 to 125). This suggests that the agency seeks to select the best projects in terms of their technological potential while taking into consideration their effects on the whole economy. In addition, the agency seems to adopt a "picking-winners" strategy, thus promoting projects that develop products which can be introduced in the market and which can contribute to the internationalisation of the firm. Finally, diffusion effects and possible intra- and inter-firm spillovers are also considered by including among the criteria the effects on other firms and on other sectors. Yet, the scores recorded by firms in this last criterion are, on average, quite low. The descriptive statistics show, as expected, that successful projects receive higher scores on average for all the items considered. However, the scores differ substantially in the criteria corresponding to the expected effect of private R&D projects on the internationalisation of the firms and on their socio-economic impact.

<INSERT TABLE 2 AROUND HERE>

5. Results and discussion

[4] Unfortunately, we were unable to obtain information as to whether the firms were participating in other public calls for R&D subsidies (at the Spanish or European level).

5.1 Parametric results

Table 3 shows the results for the estimation of the Tobit model, Eq. [2], in the first stage of the two-step procedure. This estimation concerns the public agency's rule of subsidizing a specific percentage of the awardable cost of a successful applicant's R&D project (*%RDi*), i.e., the public R&D subsidy intensity. The set of independent variables are firm-level and project-level characteristics. The selection of firm characteristics is in line with the literature (Busom, 2000; Lach, 2002; Czarnitizki and Fier, 2002; Czarnitzki, 2006; González and Pazó 2008, among others) and includes both past and current indicators of the technological activity of the firms such as the existence of an R&D department (**RDdept**), the number of patents (**patents**$_{t-1}$), the export intensity of the firm (**exports**$_{t-1}$) and the percentage of private R&D subcontracted to other firms and public research centres (**subcontract_R**$_{t-1}$). We also include variables to capture other firm characteristics, such as, size (**emp**), sector (**sht** and **dht**) and **age**, that may influence the selection of the R&D projects by the agency and the percentage of public funds received. This set of variables also includes a dummy to control for whether the firm applied for a subsidy in the previous period (**repeat**), thereby taking into account the persistence of R&D activities and the experience of the firm in applying for public subsidies.

In addition, to estimate the probability of a firm receiving a specific subsidy intensity, we complemented this set of firm characteristics with project-level scores (given their influence on the agency's decision) in a similar procedure to that reported in Takalo *et al*. (2008). As explained above, we used the total score received by R&D projects (**total**) and the four main criteria used in the evaluation of these projects: technological contribution (**tech_contrib**), economic impact (**se_impact**), effects on internationalisation (**international**) and the diffusion of the results and cooperation with other agents (**diff**).

<INSERT TABLE 3 AROUND HERE>

Note from Table 3 the importance of taking into account the project scores when analysing the agency decision, a procedure adopted in only a very few recent empirical studies (Takalo *et al*., 2008; Huergo and Trenado, 2010). Our results show that the decision making of the Catalan agency is in line with their publicly stated objectives and funding principles. The scores awarded to the projects have a greater influence on the agency's decision regarding the intensity of the subsidy than do the specific characteristics of the firms. The four criteria used by the agency to evaluate the firms' R&D projects are statistically significant. Among these, the technological content of the projects and their estimated contribution to the internationalisation of the firms have the greatest effect on subsidy intensity.

Furthermore, our results regarding firm-level characteristics are consistent with the literature. Thus, having previous experience in R&D projects with public support has a positive impact on the intensity of the subsidy. The results indicate that the agency prefers to give a higher subsidy to firms that acquire external research, in most instances from universities or public research centres. Except in the case of age (the public agency shows a higher propensity to support the projects of well-consolidated firms) and size (the agency seems to favour smaller firms), the rest of the variables are not significant. Specifically, the location of firms operating in a high technology sector does not influence the agency's decision regarding the intensity of the subsidy.

The Tobit estimations of Eq. [2] presented in Table 3 allow us to calculate the predicted values of the subsidy intensity (*pred*[*%RDi*]) and to use them in the second-stage estimation of the R&D effort equation (see Eq.[4] and Eq.[5]). As explained above, this second stage is performed using the Heckman two-step procedure to avoid possible problems of selection bias. Nevertheless, we also perform OLS estimates to compare both sets of results. The results are presented in Tables 4 and 5.

<INSERT TABLE 4 AROUND HERE>

In the estimation of the selection equation, Eq.[5], i.e., the first-step in the Heckman procedure, and in line with the literature, we include a number of indicators of the firms' technological activity and other firm characteristics such as size, sector and previous private R&D activities. This estimation provides further information regarding the agency's decision to allocate subsidies and shows that previous private R&D spending, location outside the metropolitan area of Barcelona, and previous participation in a call for public R&D subsidies positively affect the propensity to receive a subsidy. Therefore, the agency seems to prefer supporting firms with the capacity to undertake R&D activities. Our results also show the need to include a variable (**repeat**) that takes into account the persistence of a firm in applying for public subsidies (González and Pazó, 2008; Hussinger, 2008). These results suggest that the strategy of the agency is to fund the most promising candidates with experience in R&D activities. Nevertheless, since most R&D activities are concentrated in the Barcelona metropolitan area, the agency does follow certain criteria of regional distribution by favouring R&D activities outside Barcelona.

In the estimation of the impact of subsidy intensity (*%RDi*) on firms' R&D effort (*RDe*), using both OLS and the Heckman procedure, we introduce both the linear predicted value of *%RDi* and the square of the predicted value of *%RDi*, that is, we allow our estimates to account for the possible existence of nonlinearities in our main relation of interest.

<INSERT TABLE 5 AROUND HERE>

The results in Table 5, controlling for the variables that may affect the firms' private R&D effort, show a positive, albeit non-significant effect of public R&D subsidy intensity. In the estimates using the Heckman procedure, a priori more reliable given that the Mills ratio is statistically significant, the square term of public R&D subsidy intensity is negative (again not significant), pointing to the possible existence of an inverted U-shape in the relationship between subsidy intensity and the private R&D effort.

The effects associated with the main variables accounting for the firms' R&D effort are in line with recent analyses conducted for the Spanish and Catalan economies (Herrera and Heijs, 2007; Duch *et al*., 2009). Specifically, our results show that the firms' R&D effort is related positively with performing R&D systematically, having more R&D employees, being located in the metropolitan area of Barcelona and, finally, belonging to sectors classified as knowledge intensive services. In addition, younger and smaller innovative firms make a greater R&D effort measured as a percentage of their turnover.

In short, from the whole parametric set-up we can highlight the following results. The Tobit stage shows, as expected, the key role played by the scores awarded by the public agency to the R&D projects presented for public subsidies. This variable has a high explanatory potential of the percentage of R&D subsidy eventually granted and allows us to avoid possible problems of endogeneity (of public R&D subsidy intensity with regards to private R&D effort) in the next step of the estimation procedure. Hence, in the estimation of the determinants of firms' R&D effort, using the well-known two-step Heckman procedure, we find that the Mills ratio is significant, which indicates that there is selection bias in our sample. Moreover, the first step in this procedure allows us to account for the determinants of a firm being granted a public subsidy and to compare our results with those in the literature. Having controlled for endogeneity and selection bias, we can then estimate the equation explaining the determinants of the private R&D effort. In this case, our variable of interest [*%RDi*] is positive and its square (which accounts for possible nonlinearities in the established relation) negative, both being non-significant. Therefore, the results of the estimations, although not conclusive, seem to indicate a possible inverted U-shape. This means that, on average, R&D subsidy intensity could foster private R&D intensity, although this impact may not be equal for all firms and may depend on the R&D subsidy intensity itself. Moreover, the parametric estimates indicate the need to examine in more detail the existence of a non-linear relationship between subsidy intensity and the firms' R&D effort.

5.2 Non-Parametric results

Given that we cannot take the parametric set-up any further, we shift the analysis to a more flexible framework to capture a possible non-linear relationship between the percentage of subsidy awarded and the R&D effort made by recipient firms. Figure 1 presents a basic non-parametric quantile regression of private R&D effort on public R&D subsidy. It seems that there is a positive relationship between subsidy intensity (*%RDi*) and private R&D effort. Nevertheless this simple relationship suffers from the possible endogeneity problem.

<INSERT FIGURE 1 AROUND HERE>

As in the previous framework, if we use the Tobit predicted values of *%RDi* to control for endogeneity, we obtain a different picture. Figure 2 shows the relationship between public R&D intensity and private R&D effort when controlling for endogeneity in the whole distribution of private R&D effort. Note that there would only appear to be an impact of the public R&D subsidy intensity for high quantiles (90%) of the private R&D effort distribution.

<INSERT FIGURE 2 AROUND HERE>

The non-parametric evidence seems consistent with the parametric evidence reported above and provides more detailed information on the effects of R&D subsidy intensity. The results of the estimations in the parametric framework pointed to the possibility of a non-linear effect of subsidies on firms' R&D effort, although this effect was not statistically significant. This non-significance is now well accounted for by the fact that the impact of R&D subsidy intensity (*%RDi*) on private R&D effort for firms located at the mean and in the low quantiles of the private R&D effort distribution is close to zero. However, there is an impact of the subsidy intensity for those firms with high R&D effort.

These results point to the need to take the analysis beyond that of the average effects of R&D subsidies when evaluating public R&D programmes. Public support to firms' R&D projects, aimed at encouraging the firms to allocate more of their own resources to R&D activities, reduces the marginal costs and increases the profitability of these projects. On the one hand, our results indicate that firms with a low R&D effort tend to undertake projects that are sufficiently interesting to them and which they can finance themselves. In these circumstances, public support has no additional effect on a firm's R&D effort. On the other hand, firms with a higher R&D effort are able to undertake new projects, probably ones with lower expected returns, and to increase their R&D if they receive public support. Nevertheless this public support needs to reach a certain threshold in order to be effective and stimulate new privately financed R&D.

For the most R&D intensive firms, the relationship between R&D effort and the intensity of the R&D subsidy is highly non-linear[5]. The specific shape of the relationship depends on the intensity of the R&D subsidy and we have identified two clearly separated sets. In the first, corresponding to firms with a low level of R&D subsidy intensity, the relationship takes a U-shaped form. In the second, corresponding to firms with a high level of R&D subsidy intensity, we find that the relationship adopts an inverted-U shape. Overall, as the intensity of the R&D subsidy increases up to a point around 11%, R&D effort declines. From that value up to an R&D subsidy intensity of around 42%, R&D effort increases steadily before falling again. Thus, there exists an optimal percentage for the public subsidy in terms of maximizing firms' R&D effort.

According to Lee (2002, 2011), a firm's profit-maximizing R&D effort is determined by the interaction of consumer characteristics, represented by the elasticity with respect to price (quality), and firm-specific technological competence (or R&D productivity) measured as the R&D elasticity or technological output. As we have seen in section 2, an R&D subsidy can affect both variables, but the intensity of the effect is likely to vary with firm and subsidy characteristics. Considering the fact that all firms in the same industry face almost the same consumer preferences, technological competence plays a key role in determining a firm's R&D effort. Our results show that for extreme values of the distribution of the R&D subsidy intensity the R&D elasticity of demand (or the firm's R&D productivity) declines. In these cases, the indirect effect of the R&D subsidy displaces some R&D expenditure and R&D effort falls. On the other hand, for intermediate values of intensity distribution, R&D effort increases as a consequence of a rise in R&D productivity. At these values, the effects of the R&D subsidy stimulate privately financed R&D.

6. Conclusions

Public subsidies constitute an essential tool of any technology policy given their role in overcoming market failures and ensuring that the allocation of private resources to R&D

[5] Note that the relationships underlined in the non-parametric framework cannot be captured with the parametric regressions that only show the sign and significance for the linear term (positive) and for the square term (negative).

activities reaches the social optimum. In designing technology policy, the question as to whether public support complements or substitutes privately financed R&D is fundamental and, as such, has been the subject of numerous empirical analyses. However, most studies evaluating R&D subsidies tend to analyse only the average effects of these subsidies on recipient firms, despite the fact that some recent analyses have shown that the degree of effectiveness of R&D policy may differ substantially according to allocation procedures and the characteristics of the R&D subsidies themselves. Among the latter, the amount and intensity of the subsidy are particularly relevant characteristics for the design of public schemes in support of private R&D.

This paper contributes to the empirical literature on the evaluation of R&D policy by examining whether the magnitude of the effects of R&D subsidies depend on the intensity of this public support. In addition, firm and project characteristics have been included to examine the process followed by public agencies in their allocation of R&D subsidies. To carry out the analysis, parametric and non-parametric econometric techniques have been used. In the econometric procedure, the two main problems that an analysis of this type must face - endogeneity and selection bias - have been taken into account. The main results of the econometric analysis, and the conclusions that can be drawn from it, are the following.

Firstly, our knowledge regarding how public R&D subsidies are allocated by agencies remains insufficient. Our empirical analysis shows the importance of taking into account project-level characteristics (specifically, the scores awarded to them) in any examination of the allocation of R&D subsidies by the public agency. These characteristics appear to have a stronger influence than firm-level characteristics, which to date have served as the common explanatory variables in the empirical literature. As such, information about a project is particularly relevant for strengthening our understanding of the objectives of the public agency and its procedures for awarding R&D subsidies. Our results show that the granting agency's decision making is consistent with its publicly stated objectives. Subsidies are oriented mainly to promote projects with a high technological content, while considering their impact on the economy as a whole. Moreover, the use of project scores in this first stage of the analysis allows us to tackle the possible problem of endogeneity when relating private R&D effort with public subsidy R&D intensity.

Secondly, for a better understanding and evaluation of R&D subsidies we need a fuller picture than that provided by their average impact on recipient firms, since the effects are heterogeneous depending on the specific characteristics of the firms and the subsidies themselves. Our results show that the effect of subsidy intensity on a firm's R&D effort seems to be non-linear and that while, on average, the subsidies have no effect, their impact acquires relevance according to the firm's R&D effort and the subsidy intensity. In the case of less R&D intensive firms, the impact of subsidy intensity on private R&D effort is close to zero. However, for firms with high R&D effort, subsidy intensity has a positive impact. For this latter group, the relationship between R&D effort and the intensity of the R&D subsidy is highly non-linear, with the actual shape of the relationship depending on the intensity of the R&D subsidy. Thus, it is possible to identify an optimal percentage for the public subsidy at which the R&D effort of firms is maximized.

Our results provide information for evaluating R&D subsidies and have implications for the design of R&D subsidy programmes, specifically, and technology policy, in general. Determining the intensity of such subsidies is one of the key issues that public agencies must respond to as part of the process of granting subsidies. Our results show that only after a certain threshold are subsidies effective. Furthermore, we show that in the case of firms with a low R&D effort, subsidies may not be sufficient to increase their R&D effort.

Our analysis is not free of limitations. Although our results show that firms with greater R&D effort are able to develop new projects - albeit probably with lower expected private returns - the fact that they receive public support is insufficient to conclude that these projects are the ones of greatest social interest. In this sense, and although financial additionality is important and a necessary condition, a comprehensive *ex-post* evaluation would need to take into account the whole set of effects of R&D subsidies and, in particular, the spillovers generated.

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Table 1. Description of the explanatory variables

Variable (abbreviation)	Description
Firm-level	
Size (emp)	Number of employees
Age (age)	Number of years the firm has been operating
Location (dloc)	Dummy indicating whether the firm is located in Barcelona
High technology manufacturing (dht)	Dummy indicating whether the firm is in a high technology manufacturing sector
Knowledge intensive services (sht)	Dummy indicating whether the firm is in a knowledge intensive service sector
Export intensity (exports)	Exports as a percentage of sales
Number of patents (patents)	Number of patents registered by the firm
Availability of an R&D department (RDdept)	Dummy variable indicating whether the firm has an R&D department
R&D employment (RDemployment)	Number of employees dedicated exclusively to R&D activities
R&D expenditure (RDexpenditure)	R&D expenditure, in euros
R&D effort (RDe)	R&D expenditure as a percentage of sales
Subcontracting of research activities (subcontract_R)	Percentage of research activities subcontracted by the firm
Subcontracting of technological activities (subcontract_D)	Percentage of development activities subcontracted by the firm
Firms submitting several projects simultaneously (multiproject)	Dummy variable indicating if the firm submits several R&D projects to the agency
Firms applying for R&D subsidies in 2005 and 2006 (repeat)	Dummy variable indicating if the firm applies for subsidies in the two years of the sample
Project-level	
Proposed cost of the project (cost)	Expected cost of the project according to the firm, in euros
Subsidised project (receive)	Dummy variable indicating whether the project has been selected to be subsidised
Project score for technological contribution (tech_contrib)	Technological contribution of the project, values from 0 to 175
Project score for socio-economic impact (se_impact)	Socio-economic impact of the project, values from 0 to 125
Project score for internationalisation (international)	Contribution of the project to the internationalisation of the firm, values from 0 to 75
Project score for diffusion (diff)	Impact of the project on other sectors and/or firms, values from 0 to 75
Overall project score (total)	Sum of previous scores, values from 0 to 450
Subsidy-level	
Awardable cost of the project (awardable_cost)	Expected cost of the project according to the agency, in euros
Amount of the subsidy (subsidy)	Subsidy conceded to the project, in euros
Subsidy’s intensity (RDi)	R&D subsidy as a percentage of awardable cost of the project

Table 2. Descriptive statistics

	Total (968 firms)					Accepted (551 firms)					Rejected (417 firms)				
	Mean	**Median**	**Std. Dev.**	**Min**	**Max**	**Mean**	**Median**	**Std. Dev.**	**Min**	**Max**	**Mean**	**Median**	**Std. Dev.**	**Min**	**Max**
emp	196.5	54.0	524.5	1	6697	250.5	64.0	645.9	2	6697	125.1	47.0	281.1	1	3009
age	26.4	21.0	22.2	1	171	28.6	23.0	23.4	1	171	23.4	20.0	20.2	1	139
dloc	0.2	0.0	0.4	0	1	0.2	0.0	0.4	0	1	0.2	0.0	0.4	0	1
dht	0.1	0.0	0.3	0	1	0.1	0.0	0.3	0	1	0.1	0.0	0.3	0	1
sht	0.1	0.0	0.3	0	1	0.1	0.0	0.3	0	1	0.2	0.0	0.4	0	1
$exports_{t-1}$	0.3	0.2	0.3	0	1	0.3	0.3	0.3	0	1	0.2	0.1	0.3	0	1
$Patents_{t-1}$	13.6	0.0	138.1	0	3000	20.2	0.0	180.5	0	3000	4.7	0.0	33.6	0	536
RDdept	0.8	1.0	0.4	0	1	0.8	1.0	0.4	0	1	0.7	1.0	0.4	0	1
$RDemployment_{t-1}$	0.1	0.1	0.2	0	1	0.1	0.1	0.2	0	1	0.1	0.1	0.1	0	1
$RDexpenditure_{t-1}$	1067.5	250.0	4190.0	0	80678	1342.4	304.0	4950.1	0	80678	696.0	170.1	2822.6	0	48413
RDe	0.1	0.0	0.2	0	0.9	0.1	0.0	0.2	0	0.9	0.1	0.0	0.2	0	0.9
$subcontract\_R_{t-1}$	0.1	0.0	0.2	0	1	0.1	0.1	0.2	0	1	0.1	0.0	0.2	0	1
$subcontract\_D_{t-1}$	0.1	0.1	0.2	0	1	0.1	0.1	0.2	0	1	0.1	0.1	0.2	0	1
multiproject	0.2	0.0	0.4	0	1	0.2	0.0	0.4	0	1	0.1	0.0	0.3	0	1
repeat	0.5	0.0	0.5	0	1	0.6	1.0	0.5	0	1	0.3	0.0	0.5	0	1
cost	989.4	342.1	3763.3	21.6	78664.2	1321.7	393.0	4907.4	60.4	78664.2	550.4	301.6	860.9	21.6	10245.6
tech_contrib	79.8	77.0	36.3	0	168	95.0	91.0	31.8	0.0	168	59.7	62.0	31.8	0	154
se_Impact	36.4	32.3	24.1	0	125	47.2	40.1	24.4	0.0	125	22.0	21.1	14.1	0	79
international	23.2	13.5	21.8	0	75	31.2	27.0	23.5	0.0	75	12.8	8.0	13.4	0	75
diff	17.7	13.0	15.0	0	75	22.3	21.0	15.1	0.0	75	11.6	6.0	12.5	0	62
total	234.7	255.0	82.7	0	422.6	288.9	278.0	38.4	0.0	422.6	163.1	173.0	70.2	0	389.7
awardable_cost	143.1	73.1	273.7	0	3744.1	251.4	170.0	323.1	60	3744.1	0.0	0.0	0.0	0	0
subsidy	32.3	16.2	55.4	0	645.9	56.7	38.4	63.3	6.1	645.9	0.0	0.0	0.0	0	0
RDi	0.1	0.2	0.1	0	0.6	0.2	0.2	0.1	0.1	0.6	0.0	0.0	0.0	0	0

Table 3. First stage Tobit results. Dependent variable: percentage of public subsidy received (*%RDi*).

Variables	**No scores**	**Total project scores**	**Detailed project scores**
log(emp)	-0.0038 (-0.66)	**-0.0083** **(-2.40)****	**-0.0113** **(-2.62)*****
log(age)	**0.0184** **(1.85)***	**0.0113** **(1.92)***	**0.0201** **(2.72)*****
dloc	-0.0284 (-1.46)	-0.0166 (-1.41)	-0.0137 (-0.94)
sht	0.0363 (1.46)	-0.0050 (-0.33)	0.0209 (1.11)
dht	-0.0102 (-0.41)	0.0178 (1.21)	0.0043 (0.23)
$exports_{t-1}$	**0.0454** **(1.80)***	-0.0122 (-0.83)	0.0055 (0.30)
$log(patents)_{t-1}$	0.0067 (1.07)	0.0042 (1.16)	-0.0057 (-1.21)
RDdept	**0.0334** **(1.74)***	-0.0102 (-0.86)	0.0020 (0.34)
$subcontract\_R_{t-1}$	0.0577 (1.43)	0.0117 (0.47)	**0.0615** **(2.02)****
repeat	**0.0868** **(5.87)*****	**0.0225** **(2.55)****	**0.428** **(3.90)*****
total	--.--	**0.0024** **(28.50)*****	--.--
tech_contrib	--.--	--.--	**0.0028** **(15.04)*****
se_impact	--.--	--.--	**0.0011** **(4.49)*****
international	--.--	--.--	**0.0027** **(7.73)*****
diff	--.--	--.--	**0.0019** **(3.85)*****
constant	**-0.0568** **(-1.72)***	**-0.5258** **(-17.42)*****	**-0.3426** **(-11.13)**
N	968	968	968
R^2	0.128	0.557	0.438
$LR\text{-}\chi^2$	68.65***	1040.69***	623.36***

Notes: *t*-values in parenthesis. *, ** and *** indicate significance at 10, 5 and 1 percent levels, respectively.

Table 4. The selection equation. The first stage of the Heckman procedure (probit model). Endogenous variable *receive*.

Variables	**Determinants of receiving a public subsidy or not**
log(emp)	-0.0295 (-0.66)
log(age)	0.0874 (1.42)
$log(RDexpenditure)_{t-1}$	**0.1193** **(3.04)*** **
dloc	**-0.2482** **(-2.13)** **
sht	0.0808 (0.54)
dht	-0.1915 (-1.24)
$exports_{t-1}$	0.2244 (1.43)
$log(patents)_{t-1}$	0.0309 (0.74)
RDdept	0.0267 (0.22)
repeat	**0.5139** **(5.77)*** **
constant	-0.8982 (-4.15)***
N	931
Pseudo-R^2	0.0719
LR-$\chi^2(11)$	91.32***

Notes: *t*-values in parenthesis and *p*-values in brackets. *, ** and *** indicate significance at 10, 5 and 1 percent levels, respectively.

Table 5. The impact of subsidy intensity (*%RDi*) on firms' R&D effort (ln*RDe*)

Variables	OLS		Heckman 2-stage estimator	
pred(%RDi)	0.0405 (0.98)	0.0362 (0.25)	0.0582 (1.41)	0.0848 (0.60)
pred(%RDi)^2	--.--	0.0098 (0.03)	--.--	-0.0600 (-0.20)
log(emp)	**-0.0476** **(-11.24)*****	**-0.0476** **(-11.20)*****	**-0.0489** **(-10.87)*****	**-0.0489** **(-10.83)*****
log(age)	**-0.0270** **(-4.95)*****	**-0.0270** **(4.92)*****	**-0.0233** **(-3.86)*****	**-0.0234** **(-3.86)*****
log(RDexpenditure)$_{t-1}$	**0.0315** **(7.98)*****	**0.0315** **(7.97)*****	**0.0373** **(7.73)*****	**0.0373** **(7.72)*****
dloc	**0.0306** **(2.79)*****	**0.0306** **(2.79)*****	**0.0211** **(1.72)***	**0.0210** **(1.70)***
sht	**0.0430** **(3.06)*****	**0.0431** **(3.06)*****	**0.0424** **(2.85)*****	**0.0423** **(2.84)*****
dht	-0.0027 (-0.21)	-0.0027 (-0.21)	-0.0092 (-0.63)	-0.0093 (-0.64)
exports$_{t-1}$	**-0.0227** **(-1.77)***	**-0.0227** **(-1.77)***	-0.0111 (-0.76)	-0.0111 (-0.76)
log(patents)$_{t-1}$	0.0035 (1.08)	0.0035 (1.08)	0.0041 (1.17)	0.0041 (1.17)
RDdept	0.0030 (0.22)	0.0031 (0.23)	0.0072 (0.51)	0.0070 (0.50)
RDemployment$_{t-1}$	**0.0892** **(3.56)*****	**0.0892** **(3.55)*****	**0.0896** **(3.62)*****	**0.0895** **(3.62)*****
subcontract_R$_{t-1}$	0.0074 (0.32)	0.0074 (0.32)	0.0122 (0.54)	0.0120 (0.53)
subcontract_D$_{t-1}$	-0.0085 (-0.41)	-0.0085 (-0.41)	-0.0057 (-0.28)	-0.0056 (-0.28)
multiproject	0.0015 (0.16)	0.0015 (0.16)	0.0025 (0.26)	0.0026 (0.27)
constant	**0.1585** **(6.79)*****	**0.1588** **(6.22)*****	**-0.8982** **(4.15)*****	**-0.8982** **(4.15)*****
Mills (λ)	-.-	-.-	**0.0668** **(2.33)*****	**0.0673** **(2.34)****
N	535	535	931	931
Censored obs.	--.--	--.--	396	396
Uncensored obs.	--.--	--.--	535	535
R^2	0.497	0.497	--.--	--.--
LR-χ^2	--.--	--.--	432.88***	432.06***

Notes: for OLS estimation *t*-ratio in parenthesis, for Heckman 2-stage estimation z-values in parenthesis. *, ** and *** indicate significance at 10, 5 and 1 percent levels, respectively. Predicted values obtained from the Tobit model with the detailed project scores (column 3 in Table 3).

Figure 1. Non-parametric conditional quantile regression

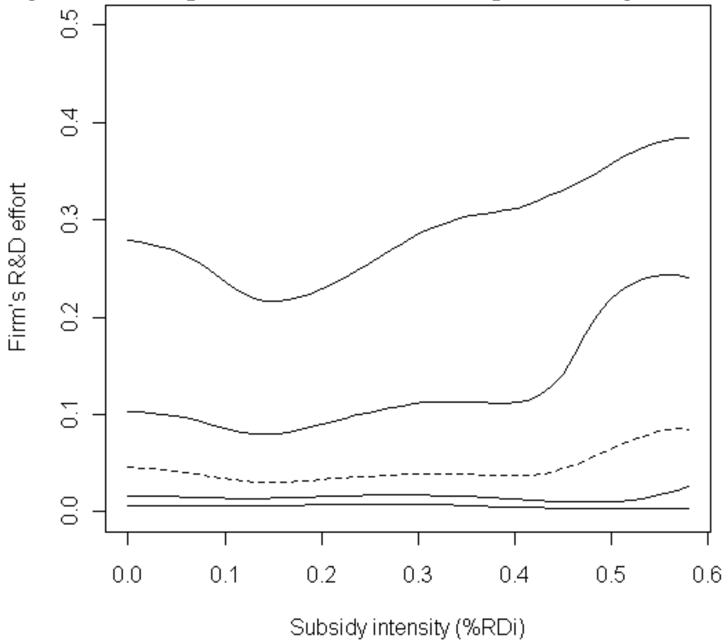
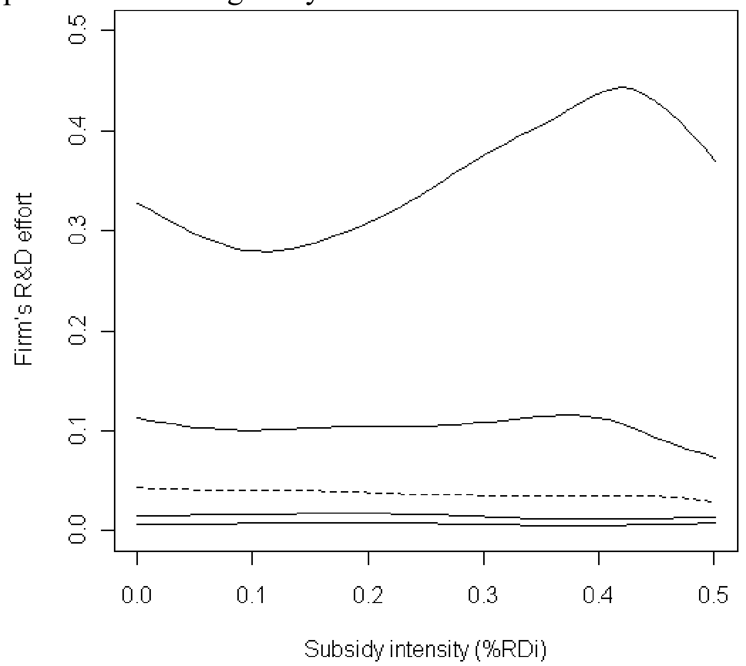


Figure 2. Non-parametric conditional quantile regression controlling for possible problems of endogeneity.



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