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An Empirical Evaluation of the Effects of R&D Subsidies

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Abstract

R&D subsidies are a common tool of technology policy, but little is known about the effects they have on the behavior of firms. This paper presents evidence on the effects that R&D subsidies have on the R&D effort of recipients, and on the probability that a firm will participate in a program granting R&D subsidies. The empirical model consists of a system of equations: the first a participation equation; and the second an R&D effort equation. Endogeneity of public funding is controlled for. Estimates are obtained with a cross-section sample of Spanish firms. The main findings are that: 1) small firms are more likely to obtain a subsidy than large firms, probably reflecting one of the public agency's goals; 2) overall, public funding induces more private effort, but for some firms (30% of participants) full crowding out effects cannot be ruled out, and 3) firm size remains related to effort, whether or not a firm gets public funding.

KEYWORDS: Technology policy, R&D subsidies, policy evaluation.

JEL Classification: O31, H32, L52

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1. INTRODUCTION.

Promoting the generation and diffusion of innovations is becoming an important goal of public intervention in most OECD countries, as technological change is acknowledged to be one of the main determinants of economic growth. Within the European Union the increasing budget allocated to successive Framework Programs, complementing national level science and technology programs, illustrates this point. Yet, evidence on the effects of technology policy tools on the behavior and productivity of firms is rather limited.[1] This paper develops an empirical model to analyze an R&D subsidy program in Spain, focusing on both the determinants of firms'participation in the program and on the effects that participation has on the firms'R&D effort.[2].

Three of the several issues that can be raised in evaluating this specific policy tool are the following. The first issue concerns the analysis of who are the participants in a program: What types of firms end up getting public subsidies? To what extent does the observed result agree with the public agency's intended goals? The second issue refers to how receiving a subsidy affects a firm's behavior with respect to R&D decisions: does the firm increase its R&D effort or does public financing crowd out private financing, partially or completely? Are there interaction effects between a firm's participation in a public R&D program and its R&D effort? Does the type of product market competition matter equally, whether participating or not? Finally, the third question is in a way the real test of the effectiveness of the policy: how does the productivity of firms receiving

[1] There are a number of recent empirical studies, closely related to the endogenous growth literature, that focus on the effect of public and private R&D on growth at the aggregate level. Lichtenberg (1992) finds, using aggregate data for several countries, that government funded research has a much lower marginal product than privately funded research. Park (1995) provides additional references to this literature. However, to understand how and why public and private R&D have an effect on growth requires an analysis at the decision-maker level, that is, firms and public agencies. Kauko (1996), Mowery (1995) and Capron (1992) provide a review of studies at a disaggregate level.

R&D subsidies change (a direct effect) and what is the impact on the productivity of other firms (the indirect or spillover effect) and on consumers ?

This paper addresses the first two, not having enough information in the data used here to address the third. However, because they are related issues it is worthwhile to comment briefly on the evidence available so far. The relationship between publicly funded R&D and productivity at the firm or industry level has been addressed in studies by Griliches (1986), Griliches and Lichtenberg (1984), Cuneo (1984), and Hall and Mairesse (1995). These authors use production function models to estimate and test the effects of publicly provided R&D funding on the productivity of firms receiving it. In general, very small or non-significant effects were found. The alternative dual approach is followed by Nadiri and Mamuneas (1994, 1995), who estimate cost and factor demand functions that depend on publicly financed R&D capital and infrastructures. Using two-digit industry-level data, they do find significant positive effects of public R&D capital on the cost structure of industries but also find that these effects vary over time and across industries. As pointed out in these and other studies, more attention has to be paid to the composition of R&D, to the dynamic structure of effects, to measurement of spillovers, and to the interaction between public and private R&D effort.

As a first step in evaluating public funding for R&D it may be of interest to investigate the firms immediate response to subsidies. The question is whether public funding induces or replaces private R&D spending. If it replaces private R&D spending, it must be concluded that a subsidy policy may not be appropriate. The evidence here is again controversial. Scott (1984), Levin and Reiss (1984) for U.S. firms, Holemans and Sleuwaegen (1988) for Belgian firms, Antonelli (1989) for Italian firms, and Klette and

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[2] Work evaluating similar R&D policy tools is found in Hall (1993), on tax credits in the USA, or Folster (1992) on subsidies to encourage cooperative R&D in Sweden.

Moen (1997) for Norwegian firms, address this issue by estimating regression models where private R&D expenditure is the dependent variable and publicly financed R&D is one of the explanatory variables. Sample sizes and empirical methods vary,[3] but in all of these studies authors find evidence of a statistically significant and positive elasticity of privately funded R&D with respect to the subsidy. Using a similar empirical framework Lichtenberg (1984,1987,1988), however, finds evidence of crowding-out. Lichtenberg (1984), controlling for the possible endogeneity of being a recipient of public funding through firm fixed effects, finds that public funding may substitute for company funding.[4] In Lichtenberg (1987), he finds further evidence of overestimation of the positive effects of public funding of R&D, when sales are decomposed into sales-to-Government and other sales. When controlling for the buyer, Lichtenberg finds that federally funded R&D has no effects on private R&D investment. Finally Lichtenberg (1988) concludes that government R&D contracts obtained through competition have a positive effect on company funded R&D spending, but that non-competitive R&D contracts have a negative effect.[5]

These simple regression models have two shortcomings. First, there is the problem of the endogeneity of public funding, only implicitly addressed in Lichtenberg and Klette and Moen, and not in the remaining studies. In order for a firm to receive public funding it must apply for funding, and the public agency may or may not award it, given firm and project characteristics. This makes public funding an endogenous variable, and its

[3] Scott uses a sample of 3388 line of business observations corresponding to 437 U.S. firms; Holemans and Sleuwaegen a sample of 236 observations of Belgian firms and Antonelli a sample of 83 Italian firms. Levin and Reiss use industry-level data (20 industries, 3 years). Klette and Moen use 816 observations of line of business data for high tech sectors in Norway.

[4] Lichtenberg (1984) used NSF firm-level panel data with 991 observations. His 1987 and 1988 work is based on a panel of 187 firms observed for 6 years (1979-1984).

[5] This suggests that the way public funding is provided (with firms competing or not competing for it) may matter a lot in changing firms incentives.

inclusion in a linear regression will cause inconsistent estimates if it happens to be correlated with the error term. It is very likely that this correlation will be non zero, because unobservable factors may determine both receiving public funding and private R&D effort decisions. On the other hand, if the sample of firms used to evaluate the effect of public funding includes only recipient firms, then there will be truncation or self selection effects, and estimation methods must account for this in order to obtain consistent estimates.

Second, the conclusion that should be drawn from finding a negative relationship between public and private R&D expenditure in former studies is not clear, as the public agency may choose precisely to finance more heavily R&D projects with higher spillover potential (for instance, those involving basic research or higher appropriability difficulties), where incentives for private funding may be small. In that case, there is no reason to expect positive or higher private spending by the recipient firm, unless the project triggers additional applied and development research generating private returns. So higher public funding may be associated with very small private funding, producing a non significant or even a negative coefficient in this type of regression, yet not implying crowding-out effects. In addition, if the public subsidy is granted on the basis of some matching condition, a positive relationship is likely to be found in the regression equation, but the firm may have reduced its private effort relative to what it would have done without the subsidy, implying partial crowding out. Therefore, to make inferences about crowding out effects, what is needed is a consistent estimator of the firm's hypothetical effort in R&D in absence of a subsidy.

The study presented here intends to address these difficulties to some extent. First, it investigates which factors are associated with receiving R&D subsidies, an issue not addressed before. An attempt will be made to identify the decision of the firm to apply for funding and the decision of the public agency to give it. Second, it estimates how much R&D effort firms that received subsidies would have made had they not received the subsidies, using the sub-sample of non-participants and controlling for selection. It can only be concluded that public funding has had crowding out effects if the private spending of a subsidy recipient is found to be smaller than the effort it would have made had it not received a subsidy. The remainder of the paper is organized as follows. Section II presents the econometric model, section III contains a description of the data, section IV explains the behavioral hypothesis, and sections V and VI contain a discussion of the results.

2. A STRUCTURAL MODEL OF PARTICIPATION IN A PUBLIC R&D PROGRAM AND OF R&D PRIVATE EFFORT.

In most public R&D promotion programs a firm has to apply for a subsidy in order to get one. Then the public agency has to decide whether to give it or not. There are two decisions involved, one by the firm and one by the public agency. Together these decisions give rise to the participation status of the firm: participant or non-participant in the program. Conditional on obtaining or not obtaining public funding, a firm then decides how much R&D effort to make, in terms of expenditure, personnel or type of project (i.e., process or product, basic research content). If this is the process generating the observations, an empirical model to represent it will include four structural equations, the first two being a sort of demand and supply equations for subsidies, and the third and fourth being the R&D effort decision if participating and if not participating respectively. These equations are:

$$A^* = f_a(Z, u) \qquad (1)$$

$$G^* = f_g(W, v) \qquad (2)$$

$$y_1^* = h_1(X_1, w_1) \qquad (3)$$

$$y_0^* = h_2(X_0, w_0) \qquad (4)$$

where Z, W, X_1 and X_0 are vectors of explanatory variables, and u,v, w_0 and w_1 are error terms that may contain unobservable characteristics of the firm. The covariance matrix will be non-diagonal if common unobservable variables underlie u, v, w_1 and w_0.

A* in equation (1) represents the firm's expected profitability of applying for an R&D subsidy relative to not applying. Equation (2) captures the decision rule of the public agency granting the subsidies. The dependent variable, G*, is the value to the agency of funding a particular project, and it is not observed. The agency's decision may be based on a number of factors, some related to the social interest of the R&D project, and some to the estimated ability of the firm to carry it out. Equations (3) and (4) capture the total R&D effort made by a firm, usually measured by R&D expenditure or R&D personnel. To the researcher, A* and G* are unobservable. y_1^* is observed only for participating firms; y_0^* is observed only for non-participants.[6] These two equations will allow for differences in the coefficients associated to explanatory variables under each participation regime. These differences may arise as a result of the policy. For instance, firm size is often found to be positively related to R&D effort, but for firms receiving an

[6] This framework is very similar to that used in evaluating the impact of training programs on wages; see for example Heckman and Robb (1985).

R&D subsidy, size may not be a relevant factor to explain effort. These type of effects can be tested within this framework.

Because of the unobservable nature of the profitability of a decision for each agent, the model above is in fact a latent variable model, where only the qualitative outcome of the decisions is observed. If we know whether a firm applies or not, we can define a binary variable I_f that equals 1 if the firm applies. We may observe whether the agency awards the subsidy or not, which can in turn be translated into a binary variable I_g. The observation mechanism gives rise to a discrete choice model for participation in the R&D program and to an effort model with endogenous switching. The complete structural model includes in addition to equations (1)- (4), the following:

$$I_f = 1 \text{ if } A^* > 0 \text{ and } I = 0 \text{ otherwise} \qquad (5)$$

$$I_g = 1 \text{ if } G^* > 0 \text{ and } I = 0 \text{ otherwise} \qquad (6)$$

If we only observe who is a participant in the program (a case of limited observability) and who is not, then(5) and (6) collapse into

$$I = I_f * I_g \quad = g(Z, W, u, v) \qquad (7)$$

where I=1 implies that a firm has applied for and obtained a subsidy.

Equations (1) and (2), and their observable counterparts (5) and (6) or (7), are a discrete choice model of participation or selection equation and may be estimated with probit or logit multivariate models. Equations (3) and (4) may be estimated for each subsample (of participants and non-participants) correcting for endogenous self-selection.

To sum up, this model allows for testing the public agency's allocation rule, inferring additional effects of the policy and estimating the hypothetical R&D expenditure of participants, using non-participants as the comparison group after controlling for selection.

3. THE DATA.

The data used consists of a sample of 154 Spanish firms that were conducting R&D activities in 1988, 75 (45%) of which received public funding for their R&D projects through the Centro para el Desarrollo Tecnológico e Industrial (CDTI), an agency of the Spanish Ministry of Industry.[7]. That year, the CDTI granted subsidized loans to 213 projects of a total of 541 applications (a 39% approval rate). Some firms had more than one project approved. According to CDTI's annual report, on average public funding amounted to 39 % of total R&D investment for approved projects (CDTI, 1988).

Firms in the sample were asked three sets of questions. First, standard questions related to firm characteristics such as size, export volume, industry, firm's age, ownership. Second, some questions concerning R&D activities such as R&D expenditure (total expenditure, including the subsidy if received), R&D personnel, availability of public funding, patents obtained in the previous 10 years, type of research, sources of ideas for R&D projects. And finally, questions related to strategic attitudes or behavior of firms in the product market or with respect to R&D. Most of the answers to the last type of questions were finally coded as binary variables. Table 1 provides the definition of the variables constructed from the survey.

[7] For a description of data sources, see Appendix I.

Firms could apply for two possible sources of public funding: from national programs or from European-level programs. Eighty three firms in the sample (about 54 %) declared having applied for a national R&D subsidy, and 75 obtained it.[8] As for European-level programs, 47 firms applied for and 40 obtained funding. Only 15 % of firms declared having both types of public funding. However, we do not have information for firms in our sample about how many projects did a firm submit, nor of the magnitude of the subsidy received.

Some information was obtained on how is R&D done. Main sources of ideas for their projects and reaction to a rival's R&D activities were issues of particular interest, the first as an indicator of possible knowledge spillovers, the second as one of strategic behavior. A firm's own patents were an important source of ideas for 56 % of firms, but even more (63 %) considered rivals' patents or licenses or their rivals' products to be an important source of ideas. Almost all firms considered general sources of information (Universities or research centers, scientific and technical publications) quite or very important. The existence of knowledge spillovers in research ideas will be proxied by binary variables constructed on the basis of these questions.[9]

In an attempt to obtain information on firms' strategic behavior in the product market, firms were asked about their pricing strategy.[10] Most firms (44%) declared to choose prices and then adjust production to demand, and about 29 % declared to set production plans first, and determine the price afterward. Some firms were regulated, and a specific

[8] The rejection rate in the sample is very small relative to that in the population; CDTI reports rejection rates of about 60 % of the submitted proposals for that year. It is possible that some firms that were rejected declared not having applied. This will have implications for estimation.

[9] These are knowledge spillovers a firm benefits from. We do not have a measure for extent of appropriability of the firm's own R&D.

[10] Firms were asked in particular whether they usually set prices and then production was adjusted to demand (price competition), or vice versa. Firms following the first rule may be interpreted to be Bertrand competitors, while those following the second rule would be Cournot competitors.

binary variable was constructed for this case. As for R&D specific strategies, 58 % of firms would accelerate their own R&D effort if they found out a rival firm was doing similar R&D rather than cooperate or stop. Finally, all firms said R&D played a very important role in the firm's strategy in the long run, but only half of them thought R&D was important in the short run.

Table 1. Variable Definition.

Binary Variables	*Definition*
Subsidies	
Cdti	=1 if a firm received a subsidy from CDTI; 0 otherwise.
European	=1 if a firm was a partner in EUREKA or any EC R&D program.
Ownership	
Public	=1 if firm was partly publicly owned
Foreign	=1 if firm was participated by foreign capital
Strategic Variables	
Price	=1 if firm declared to set prices and then adjust production to sales
Quantity	=1 if firm declared to make production plans and then adjust prices
Regulated	=1 if firm declared prices to be regulated
Other	=1 if none of the above
Monopoly	=1 if firm declared behaving as such
Frival	=1 if firm declared it would increase own R&D in response to a rival's
Shortrun	=1 if firm declared R&D to be important in the short run
R&D Process	
Ideariv	=1 if firm looked into competitor's products for ideas for own R&D
Ideapt	=1 if firm used own patents as sources of ideas
Ideaext	=1 if firm declared scientific and technical publications to be important
Cooperate	=1 if firm cooperated with others in R&D activities
Basic	=1 if firm does basic or applied research
Development	=1 if firm does development
Process	=1 if R&D activities are oriented towards process innovation
Product	=1 if R&D activities are oriented towards product innovation
Industry	
Dchemical	=1 if firm is in chemical or pharmaceutical industry
Detronics	=1 if firm is in electrical o electronics industry
Dequipmt	=1 if firm is in machinery or transportation equipment industry
Denergy	=1 if firm is in the energy sector
Dtraditional	=1 if firm is in textile, food, metal industries
Dservices	=1 if firm provides services to other industries
DOtherI	=1 if firm is in other industries
Continuous Variables	
Patents	Number of patents obtained by firm during the previous 10 years
R&D expenditure	Total R&D expenditure in 1987, in Million pesetas
R&D personnel	Number of employees involved in R&D activities
Age	Number of years since firm was created
Employment	Total number of employees
Exportshare	Exports/total Sales

Tables 2 and 3 show descriptive statistics for the sample, which contains 147 firms after those with missing values were deleted. The sample is biased towards large firms, thereby producing high means for some variables (see Appendix I).

Table 2.
Descriptive Statistics. Continuous Variables.

Variable	*N*	*Mean*	*Stand. Dev.*	*Minimum*	*Maximum*
R&D Expenditure (M. Pts)	147	330	721	1	4366
R&D Personnel	147	51	105	1	650
Num. Employees	147	1622	3310	2	24890
Age of the firm (years)	147	31	24	2	89
Patents (Number)	147	6	18	0	99
R&D expend/employee	147	0.61	1.1	0.05	7.5
R&D pers/employee (%)	147	13	19	0.1	100
Exports share	147	16	18.6	0	83

Table 3
Descriptive Statistics. Binary Variables.

Variable	*Num of firms with X=1*	*Percent*	*Variable*	*Num of firms with X=1*	*Percent*
Subsidies			**Strategy**		
CDTI	71	48.3	Price	66	44.0
European	40	27.2	Quantity	42	28.6
			Regulat	21	14.3
R&D Process			Monopoly	4	2.7
Patent	74	50.3	Other	14	9.5
Royalty	44	29.9	Frival	85	57.8
Ideaext	139	94.5	Shortrun	79	53.7
Ideariv	93	63.3			
Cooperate	105	71.4	**Industry**		
Basic	98	66.7	Chemical	30	20.4
Development	114	77.5	Electronics	26	17.7
Process	70	47.6	Equipment	16	10.9
Product	139	94.5	Energy	16	10.9
			Services	12	8.2
Ownership			Traditional[a]	41	27.9
Public	29	19.7	OtherI	6	4.1
Foreign	50	34.0			

[a] It includes several industries: food, textile, steel and metallic products.

4. SELECTION OF EXPLANATORY VARIABLES: BEHAVIORAL HYPOTHESES.

The data described above may have been generated by the process outlined in section 2. Given the available information and the model, the dependent variables will be the following: application for an R&D subsidy (equation (5)), granting a subsidy (equation (6)) and R&D effort (equations (3) and (4)). Some hypothesis may now be formulated as to which variables enter the vectors of explanatory variables Z, W, and $X_{i.}$

Firms' decisions: R&D effort and subsidy application.

Both the theoretical and empirical literature point to a number of factors associated with private R&D effort in general. Research has focused on the role that firm size and market power or strategic behavior have on incentives to undertake R&D activities. Ease of imitation or a low degree of appropriability of R&D results are also a crucial trait which creates a wedge between private and social returns. The interaction with market structure is complex, but theoretical models of patent races do predict it will affect R&D activity. One example is found in Delbono and Denicolo (1990), who develop a model predicting that firms competing in quantities in the product market will spend less in R&D than firms competing in prices. Other factors that may affect R&D investment decisions are liquidity constraints (Hall et al, 1998), type of ownership (Veugelers and Vanden-Houten (1990) provide a model and empirical evidence that multinational firms may lead to reduced domestic R&D), and the extent to which a firm sells its products in foreign markets. Finally, differences in technological opportunity and in expected demand growth may explain interindustry differences in R&D effort. Consequently, total employment, strategy and ownership indicators, share of exports over total sales and industry dummies will be included in the effort decision. In addition, the indicator of spillovers the firm receives from others and the previous patents, measuring experience in R&D will be added. The sign to be expected of the spillover indicator is ambiguous: on one hand, benefiting from others' ideas may lower the firm's costs of innovating, but on the other it may trigger more projects, and thus more effort.

Turning now to the application decision, it would seem that since all firms in the sample conduct R&D activities, and the eligibility conditions set by the public agency do not appear too restrictive ex ante in Spain, all firms would be expected to apply for a subsidy, provided there are no fixed costs associated with applying.[11] The benefits from obtaining a subsidy need not be equal for all firms, however. If there are fixed costs associated with research, small firms will presumably be less able to finance them and more eager to participate in the subsidy program. Also firms that perceive R&D to be an important strategic variable for competing with rivals even in the short run[12] and firms that compete in international markets (exporters) may also profit relatively more from R&D subsidies than other firms. Finally, firms with fully domestic capital are more likely to apply, because those with foreign capital participation may benefit from R&D conducted in another location, and their R&D activities in Spain may be limited to adapting products or technology. Included explanatory variables in the application equation will be firm size (expecting a negative relationship), capital ownership,

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[11] This may be true for firms already conducting R&D, but firms not doing R&D may have to incur expenses just to present a good proposal, and the expected subsidy may be too low for them to make applying worthwhile.

[12] Managers' perceptions about the importance of R&D in the short run may explain differential behavior across firms. These different perceptions may reflect to some extent differences in human capital .

importance given to R&D in the short run, pricing strategy, share of exports in total sales and industry dummies.[13]

The probability of applying may be explained by other factors which are not considered here because there is not enough information in the data. One is the information the firm has: some might be unaware of the existence of the program. Another possibility is that some may find it not profitable to apply if their project would not generate a private return, and the expected subsidy does not cover all the costs of the project (recall that the public agency requires firms to finance at least 30 % of the project). Finally, some firms may be interested in strictly development projects, while one of the public agency's conditions is that projects should have a genuine innovative content. Such firms may then not apply.

The public agency.

The public agency is assumed to have a systematic selection criterion, therefore it does not choose randomly which firms and projects to subsidize. In addition to selecting on the basis of the quality and feasibility of the proposal, the agency may want to encourage R&D in small firms (because of fixed costs involved in R&D and of capital market imperfections), or in some research fields (i.e., defense, health) where a higher gap between private and social returns is assumed to exist.[14]

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[13]Some variables related to the type of research done (product or process, extent of basic content, duration of R&D projects, whether to apply for other sources of public R&D funding, such as EC Framework Program or Eureka) are available as well for this data set. They may be jointly determined with the decision to apply for a subsidy. An additional equation for each of them could be added to the system of equations above. However, because of the limited number of observations and of exogenous variables a more complex model is not estimated here.

[14]According to Navas (1984), the ability of the project to generate secondary technological effects was also considered. This suggest that spillovers may play a role in policy decisions.

In 1988 the CDTI financed projects in three broad areas: production technology (information and communications technology, space, microelectronics, new materials, robotics and automation), quality of life (toxicology, pharmaceuticals, immunology, biotechnology), and natural resources and agriculture (including food technology). The information and forms made available to applicants do not establish requirements for application other than those related to the quality of the project (extent of innovative content and technical, commercial, and economic feasibility) and to the ability of the firm to carry it out (in terms of human capital) and to finance at least 30 % of the total cost of the project.

Practically all firms seem eligible, given the breadth of the technological areas, and no explicit reference is made to requirements affecting the size of the firm. Because the quality and feasibility of a project is likely to be related to a firm's experience in R&D (measured by patents obtained in the past) and general experience (proxied by the age of the firm) both variables will be included in the selection rule. Firm size, presence of public or foreign capital, and industry dummies will be included as well. The public agency is assumed not to give any weight to the firm being an exporter, nor to be concerned about competitive conditions in the product market, so dummies for strategic variables will be excluded from the equation capturing the agency behavior, in principle facilitating identification.

Whether an R&D project proposal has or does not have some basic research content might be an indicator of potential research externalities, and thus a possible justification for public support of R&D. Although a basic research variable can be constructed, it will not be used as explanatory variable because in this cross-section data it is jointly determined with the subsidy, and thus endogenous.

The error term will contain non-observed factors such as more accurate indicators of the quality of the projects and of the human capital of the firm, which the public agency is assumed to consider.

5. PARTICIPATION IN PUBLIC R&D PROGRAMS: ESTIMATION AND RESULTS.

Equations (5) and (6) of the model outlined in section 2 determine the participation status of each firm, with four possible outcomes. Since for a given firm I_g is not observed unless I_f equals one, three outcomes are possible in theory. But the information contained in this sample is even more limited, because too few firms declare applying and not obtaining a subsidy. So in fact the reasonable equation to estimate is (7), the participation status.[15]

$$I = I_f * I_g \quad = g(Z, W, e) \qquad (7)$$

where I = 1 iff A* > 0 and G* > 0 (the firm has a public subsidy), and I = 0 otherwise. There are two types of observations, participants and non-participants, and it will be assumed that the probability of being a participant is given by the bivariate normal density. The structural parameters associated to vectors Z, W could still be estimated provided that identification conditions hold. However, the particular configuration of the binary explanatory variables may generate identification problems[16] as it turns out to happen with this data set. Therefore, a simple univariate probit model is estimated. This equation may then be interpreted as a reduced form, where coefficients of explanatory variables capture the net effect of each variable on the final status, participation. What is

[15]This is one of the partial observability cases discussed in Poirier (1980).

lost is the ability to identify separately the different weight a particular variable may have on the firm's application decision and on the agency's rule.

Estimation results are shown in Table 4, Appendix II. The first column of coefficients shows the estimates obtained for a model with all explanatory variables, and the second column shows the estimates of a restricted model where non-significant variables have been dropped. The third column presents the marginal effect that each variable included in the restricted model has on the probability of being a participant, that is, $\delta(\Pr(I=1))/\delta x_j = b\,*f(x'b)$ where x is the vector of explanatory variables and $f(\cdot)$ the density function evaluated at the mean of vector x. Columns 4 and 5 show the results obtained when the variable SHORTRUN is included, but industry dummies are excluded.[17] Models 2 and 3 correctly predict 80 % of non-participants and 70 % of participants. The predictive performance of either of these two models is not negligible, given that a naive model would have correctly predicted 52 % of non-participants and none of participants.

According to these results, six factors had a significant net effect on the probability of having national public funding in Spain in the late 1980s. Public participation in the ownership and being in the chemical or pharmaceutical sector are found to increase the probability of participation significantly. A firm's overall experience (proxied by age) and its experience in R&D (proxied by the number of previous patents) increase this probability as well. These variables could well affect both decision makers in the same direction, as more experienced firms are more aware of the value of innovation and may present better proposals, becoming thus more likely to be selected by the agency. The fact

[16]Meng and Schmidt (1985) illustrate the implications that inclusion of binary explanatory variables has for identification and estimation in discrete choice models.

[17]Considering R&D an important strategic variable in the short run might be correlated with unobserved variables that also affect the participation status, such as managerial ability. Shortrun is thus instrumented with exports, Electronics and Frival in order to obtain consistent estimates. The only

that experience related variables are significant suggests that subsidies might not be the best policy to induce firms that did not have previous R&D activities to get them started.

Two factors reduce the probability of having a subsidy: large firm size and the presence of foreign capital. In both cases the estimated net effect may again be the result of a variable affecting both agents' decisions in the same direction. Small firms may be more credit constrained, and the public agency may be willing to favor small firms because of this. The negative sign of size also suggests that application costs probably were not high. Firms with foreign capital ownership are found less likely to participate. One possible explanation is that core R&D activities may be located in another country, and those carried out in Spain may be mostly focused toward development, with little innovative content, and thus these firms don't apply for a subsidy. Or if they do, the public agency may reject their application and prefer to promote mostly domestic firms. Finally, strategic variables are not found to have any significant net effect on participation.

A comment about participation in European-level R&D programs.

Model specification becomes more complex if firms have two sources of public funding, and the decisions of the agencies are not independent. This could happen if a firm having domestic funding is more likely to receive funding from European institutions, or vice versa. Twenty seven percent of the firms in this sample did participate in European-level programs (Eureka or Framework Programs), and 16 % participated in both. A bivariate probit model to explain the joint probability of having domestic and European funding was estimated. Because results suggest that the two types of participation were independent at the time, consistent estimates for participation in each program can be

effect its inclusion has is that industry dummies become non significant, suggesting some degree of multicollinearity.

obtained by estimating a univariate probit model for each.[18]. Results obtained with the univariate probit model to explain European-level participation are shown in the last column of Table 4. They suggest that contrary to the domestic program, the probability of participating was positively related to firm size and that experience related variables were not relevant at the time. The negative role of foreign capital ownership is observed also in this case. Interestingly firms that declared to compete in prices were less likely to participate. However, the overall predictive capacity of the model is low, as more than half of participants are missclassified by the model. Because the number of firms participating in European R&D programs is small in our sample and because of the novelty of these programs for Spanish firms (Spain had joined the EU only in 1986), it may be difficult to find systematic patterns of behavior. Results obtained here must therefore be interpreted with caution.

6. A COMPARISON OF R&D BEHAVIOR OF PARTICIPANTS AND NON-PARTICIPANTS.

Next step involves estimating R&D effort for participants and for non-participants, taking into account that group membership is not random. The purpose of estimation is to provide evidence regarding two questions: 1) does participation induce a higher R&D effort than would have been made otherwise? and 2) does participation make the firm's choice of R&D effort less conditioned by factors such as firm size?

Several equations will be estimated, because two measures for R&D effort are used, R&D expenditures and R&D personnel. Each in turn is estimated in levels and intensity

[18]Independence may not hold in posterior years, though. As information about European-level programs

(R&D expenditure per employee and share of R&D personnel over employees, respectively.[19] One reason to use both expenditure and personnel is that expenditure may capture differences in R&D equipment intensity or costs, while personnel may reflect a more permanent, human capital component of R&D effort. R&D expenditures are total spending by the firm, which in the case of participants includes the subsidy received. The magnitude of the subsidy itself is not known. Explanatory variables will once again capture the effect they have on private effort plus the effect they have on the magnitude of the subsidy.

Because some firms received funding through participation in European level R&D programs, an additional dummy variable (EUROPEAN) is introduced to control for this fact, under the assumption that this variable and the error term are uncorrelated.

Each equation is estimated by four procedures. By ordinary least squares, using the whole sample of firms, and including a participation binary variable (CDTI), as in previous studies. This is the most restrictive specification, since it imposes equality of coefficients for both groups of firms, as well as exogeneity of participation. The second procedure consists of splitting the sample, not imposing equality of coefficients; but estimating by OLS, thus imposing exogeneity of participation. The third consists of using Heckman's two step procedure to correct for endogenous sample selection; this will allow testing for exogeneity of participation.[20] Finally both equations are estimated by maximum likelihood, jointly with the participation equation.

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improves over time, and as the national agency encourages firms to participate in them, firms with experience in participating in the national program may be more likely to do so.

[19]Sales were not used because they were obtained as intervals in the original survey.

[20]The selection model is:

$y_1 = b_1'x + r_{1s}\sigma_1 \lambda_i + e_1$

$y_0 = b_0'x + r_{0s} \sigma_0 \lambda_i + e_0$

where r_{is} is the correlation between the error term in each effort equation and the error term in the participation or selection equation, and λ_i is the inverse Mill's ratio.

Tables 5 through 8 in Appendix II show the results.[21] Columns 1, 2 and 3 in each table show that running OLS on the whole sample of firms with the participation dummy as explanatory variable, will generate biased estimates because it imposes the restriction that the coefficients of the explanatory variables are the same for both types of firms, when this hypothesis should be rejected.[22] This is so for all measures of R&D effort used. Once different behavior is allowed for both types of firms, there are no sharp differences between OLS estimates and Heckman's method estimates in the expenditure equations. The coefficient for lambda in either of the sample selection equations is not significant, suggesting that the hypothesis of no selection bias cannot be rejected. Maximum likelihood estimates are very close to the sample selection model, but there are some differences in estimated standard errors. The fit is in general better for R&D personnel equations than for R&D expenditure (especially in case of the relative effort equation), and better for participants than for non-participants.

Participants and non-participants differ in the way explanatory variables affect total R&D effort. Because the hypothesis of selection bias based on unobservables has been rejected, participants do not have an unobserved comparative advantage at doing R&D (are not more likely to have higher R&D effort because of unobserved factors) relative to non participants. Differences in coefficients may be partly attributed to the public agency´s funding decision.

In absence of public funding, R&D expenditure is explained by firm size (with a positive but smaller than one coefficient in the level equation, and a negative sign in the relative effort equation) and by being either in the chemical/pharmaceutical industry or in

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[21] Four firms were excluded from the sample, as they behaved as outliers and results were sensitive to their inclusion.

[22] A Chow-test leads to rejection of the null hypothesis of equality of slopes in equations for participants and non-participants.

the electrical/electronic industries. None of the remaining variables is found to have significant effects (experience, capital ownership, or strategic and spillover variables). These results are consistent through all estimation methods, except for the case of R&D personnel for non participants, where industry variables are somewhat sensitive to specification.

Participants show a different pattern. There are two main differences. The first is that firms in the equipment and services to firms industries spend more relative to participants from other industries. These firms are equally likely as firms in traditional industries to be participants, but once they are, they may be getting higher subsidies. The second difference is that having obtained patents in the past makes firms spend more on R&D, as do firms mostly oriented to the domestic market.[23] A possible interpretation is that the public agency may prefer subsidizing this type of firms, which may make sense from the perspective the welfare of domestic consumers.

There is some evidence that participants that declared to set production plans first and then adjust prices spend less, in line with the prediction of the theoretical model by Delbono and Denicolo, but this doesn't hold across all estimations. The role of firm size on R&D expenditure remains unchanged, the sign being negative in the relative effort equations, but with a slightly smaller absolute value. Other strategic variables and existence of spillovers weren't found significant in any of the equations.[24] As a final remark, participating in a European-level R&D program does not seem to have led to increased expenditure.

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[23]The share of exports has a negative sign. This result is contrary to what was expected, but other studies using larger samples of Spanish firms (2400 observations) have obtained this result. See Labeaga and Martinez-Ros (1994).

[24]In previous work with this same data set (Busom 1993) it was found that the measure of spillovers affected negatively the probability of a firm doing basic research, and positively the probability of doing process innovations.

When effort is measured by R&D personnel, the same basic regularities appear. No evidence of selection bias is found for participants, and relative effort decreases with an increase in firm size or in export share, and increases with previous patenting activity. Participating firms in the chemical and electronic industries increase their R&D personnel, although not expenditure. Non-participants allocation of R&D personnel seems to be mostly determined by firm size and industry.

7. DID PUBLIC SUBSIDIES CROWD OUT PRIVATE EFFORT?

Crowding out occurs when public funding drives private funding out partially or completely. Complete crowding out takes place when a recipient firm would have privately spent the same total amount for a given project. It indicates that firms would have made the R&D effort anyway and that private returns were high enough. Partial crowding out occurs when total effort increases, but the private contribution is smaller than if the firm had been on its own.

Testing the presence of crowding out effects involves constructing a counterfactual for recipient firms, which will be done using the estimation of effort of non-participants. If data on privately financed R&D effort are available, then the extent of partial or complete crowding-out effects could be estimated for each participant by computing an estimate of its expected private effort as a participant, using the coefficients of the "Participants" column ($y_1^{predicted} = \hat{E}\{Y_1 \mid I_1\}$) and comparing it to an estimate of its expected potential effort, had the firm not been a participant ($y_0^{potential} = \hat{E}\{Y_0 \mid I_1\}$), obtained with the coefficients of the “Non-Participants”. If $y_1^{predicted} \geq y_0^{potential}$, then crowding out effects (total or partial) can be ruled out.

In our case, however, only total R&D effort, which includes the subsidy received, is known for participants. The amount of subsidy is unknown. So for each participant, the expected hypothetical private effort had it not received a subsidy can be computed ($y_0^{potential}$), but it has to be compared to total expected effort, which includes the subsidy. With this information we can say that there are full crowding out effects if the effort a firm makes after receiving the subsidy is not greater than the effort it would have made had it not received the subsidy. The presence and extent of partial crowding out cannot be estimated, however, because private spending is not known for participants.

To calculate an estimate of $y_1^{predicted} = \hat{E}\{Y_1 | I=1\}$, the coefficients of OLS estimates in the participants' simplified regression are used.[25] To calculate an estimate for participants' potential effort had they not received the subsidy, $y_0^{potential} = \hat{E}\{Y_0 \mid I = 1\}$, the coefficients of the non-participants regression are used. Because the goodness of fit of the regression for non-participants suggests that relevant variables may be missing, the following results must be taken with caution for policy assessment purposes. Measuring effort with expenditure, it turns out that in aggregate (calculating $\Sigma y_0^{potential}$), these 70 firms would have spent 15,368 MPta. instead of the estimated expected total of 27,798 MPta., just over one half. According to the public agency’s annual report, that year it subsidized one third of the total cost of the projects, so this means that public funding induced an additional 20 % of private expenditure, in the aggregate. However, inspection of results for individual firms shows that in 29 cases, firms would have spent at least as much on their own. It is possible that some of these firms had received such a small subsidy that it did not change the scope of their R&D plans. But they also suggest that

[25] Non-significant variables, except for Quantity, were dropped. Quantity was kept because it became significant, with a negative sign.

there were cases where firms reduced private funds after receiving the subsidy, even to the extent of full crowding-out.

In the remaining 41 cases of subsidy recipients, firms did spend overall more than they would have otherwise. But again, not knowing the size of the subsidy rules out the possibility of inferring whether, for a particular firm, this induced more private effort or not. All that can be said is that complete crowding-out can be ruled out in those cases.

Results are similar if R&D personnel is used as a measure of effort. On aggregate, and on their own, these 70 firms would have allocated 2,547 people to R&D activities, instead of 3,730 (an increase of 46 %). For 30 firms, predicted potential effort is not smaller than the prediction with the subsidy, suggesting as before that these firms would have carried out the R&D projects anyway. For 20 of these firms (almost 30% of participants) this prediction is obtained using both expenditure and R&D personnel. Further analysis should attempt to find an explanation for these cases. This could be useful for the public agency, helping it improve the selection rule in order to encourage R&D activities that would not have been undertaken otherwise.

Finally, the estimates for potential effort, $y_0^{potential}$, are positive for all participants (for expenditure and for personnel), implying that all participants would have incurred some R&D expenditures even if they had not received a subsidy. This is not surprising, since the sample only includes firms doing R&D. But it also suggests that a more complete evaluation of the subsidy program could be made if the sample included firms that did not do in R&D in the past, so the ability of the program to induce new comers to R&D activities could be tested.

8. CONCLUSIONS.

Few studies have used econometric modeling to test the systematic effects that different technology policy tools have on firms; yet ex-post evaluation of any policy at the microeconomic level is a necessary step for checking its effectiveness and for detecting unanticipated effects. Using a sample of Spanish firms, where half of them received public subsidies for R&D, this paper provides evidence on some factors explaining participation in a domestic R&D subsidy program, and on the effects that participation has on R&D effort. Although the information available in this sample does not allow for separate estimation of the application decision by a firm and the granting decision by the public agency; a reduced form of the determinants of participation status can be estimated.[26] These confirm that smaller firms have a higher chance of being participants, which, given that R&D doers tend to be large, means that smaller firms are more likely to apply for and be granted a subsidy. This conclusion can also be inferred from annual reports from CDTI or the Ministry of Industry. But results obtained here also show that other variables have an important weight in the participation status, in particular foreign capital participation. Whether this is mostly the result of the application process or of the granting process deserves further attention, as over time, and as a result of economic integration, more foreign capital participation in Spanish firms is to be expected. The estimated weights that experience (age and past patents) and industry variables have for participation could be used by the public agency to assess the performance of its selection rule.

The analysis developed here also shows that firm size remained related to R&D intensity, whether or not a firm received public funding, but that R&D intensity diminishes somewhat more slowly with size for participants. This effect could not have been

[26] If the firm anticipated correctly the agency's selection criterion, then the determinants of application would be exactly the same as those of the granting decision, and there would be no identification

observed with the simple regression model pooling all firms and adding a participation indicator.

Finally, in the aggregate, public funding induced more effort by firms in this sample, but for a sizeable proportion (about 30%) of participants complete crowding out effects cannot be ruled out. This result, if confirmed by further analysis, could be helpful in improving the grant allocation rule.

There are several ways to improve the analysis carried out here if better data can be obtained. An obvious way is by having observations on the same firm for several periods, including before, during and after receiving a subsidy for participants. This should allow a better control for unobserved firm specific effects. It would also be helpful to have better variables, in special those related to the human capital of the firm, to a firm's strategy and markets, and to organizational characteristics. The analysis presented here is just a step for a better understanding of the effects of R&D subsidies to private firms.

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problem. The coefficients would capture entirely the agency's selection rule.

APPENDIX I.

The data originated in a survey conducted in 1988 for a report on the participation of Spanish firms in European research programs. Researchers at the Universitat Autonoma de Barcelona and the Institut d'Analisi Economica (CSIC) designed the questionnaire. The sample was designed to contain firms active in R&D and/or technology acquisition, including among them firms that had participated in some public R&D program. The national public agency, CDTI, provided a list of applicants for subsidies, from which a random sample was drawn. The rest of the sample was drawn from listings of firms doing R&D. The sample is not meant to be representative of the whole population of Spanish firms, because all firms in this sample conduct R&D, while at that time at most 20 % of all Spanish firms did so. It is thus not a good sample to study why some firms do R&D and some do not, but this is not the purpose of this research, which focuses on the sub-population of R&D doers. In the sample compiled by the Instituto Nacional de Estadística in 1988, which consisted of 1232 firms doing R&D, about 19 % had more than 500 employees (large), 34 % between 100 and 499 (medium), and 47 % less than one hundred employees (small). In the sample used here, almost 50 % of the firms are large, 20 % are medium and 30 % are small firms. Large firms are thus over represented in our sample.

In addition to the descriptive statistics shown in Tables 2 and 3 for the whole sample, it is of interest to compare the sub-samples of participants and non-participants in the R&D program, as the second sub-sample will be used to construct estimates of the potential R&D effort of non-participants.

	Participants		Non-Participants	
	Mean	Median	Mean	Median
R&D expenditure (M. Pta.)	397	88	219	55
R&D personnel	59	19	43	13
R&D expenditure/employee	0.73	0.46	0.43	0.13
R&D personnel/employee (%)	16	9	8	2.5
Total employment	1303	432	1911	622
Age	34	26	30	25
Patents	12	2	1.7	0
Exports share (%)	17	9	15	6.2

APPENDIX II.

Table 4. Determinants of the Probability of Participation

	Participation in the National R&D subsidy program					Participation in European-level Programs
	Model 1	Model 2	Marginal Effects	Model 3	Marginal Effects	
Constant	-0.61	-0.39		-0.67		-1.71
	(-1.2)	(-0.9)		(-1.4)		(-3.14)
Employment	-0.29	-0.30	-0.12	-0.30)	-0.12	0.24
	(-3.2)	(-3.3)		(-3.3)		(2.7)
Age	0.52	0.54	0.21	0.57	0.23	-0.11
	(2.7)	(2.9)		(3.1)		(-0.6)
Exportsh	-0.01					-0.01
	(-0.1)					(-0.2)
Patents	0.44	0.46	0.18	0.45	0.18	0.05
	(3.7)	(4.0)		(3.9)		(0.4)
Public	0.64	0.55	0.22	0.67	0.27	0.44
	(1.7)	(1.5)		(1.8)		(1.3)
Foreign	-0.91	-0.76	-0.30	-0.79	-0.32	-0.87
	(-2.9)	(-2.7)		(-2.8)		(-2.6)
Price	0.31					-0.48
	(1.1)					(-2.6)
Regul	-0.10					0.51
	(-0.2)					(1.2)
FRival	0.26					
	(0.3)					
Dchemical	0.50	0.50	0.20			-0.20
	(1.4)	(1.6)				(-0.5)
Detronics	0.51	0.51	0.20			0.79
	(1.5)	(1.5)				(2.2)
Dequipment	-0.09					0.39
	(-0.4)					(1.0)
Denergy	0.24					0.31
	(0.4)					(0.7)
Shortrun				0.54	0.22	
				(2.0)		
LogLikelihood	-75.5	-76.9		-76.9		-61.9
Restricted L	-101.8	-101.8		-101.8		-86.0
$\chi 2$	52.5	49.6		49.7		48.2
Pseudo R^2	0.26	0.24		0.24		0.28
N	147	147		147		147

(t-values shown in parenthesis)

Table 5. Absolute R&D Effort: Expenditure[a].

	Ordinary Least Squares			Sample Selection		Maximum Likelihood	
	Participants	Non-Participants	All	Participants	Non-Participants	Participants	Non-Participants
Constant	0.69	0.04	-0.18	0.70	-0.11	0.95	-0.39
	(0.43)	(0.64)	(0.39)	(0.47)	(0.84)	(0.57)	(1.03)
European	-0.17	-0.17	-0.14	-0.17	-0.18	-0.20	-0.22
	(0.30)	(0.42)	(0.25)	(0.26)	(0.38)	(0.40)	(0.51)
Employmt	0.62**	0.53**	0.61**	0.62**	0.54**	0.65**	0.56**
	(0.07)	(0.10)	(0.06)	(0.07)	(0.09)	(0.08)	(0.10)
Exportsh	-0.02*	0.01	-0.003	-0.02**	0.01	-0.02**	0.01
	(0.006)	(0.009)	(0.005)	(0.005)	(0.008)	(0.006)	(0.009)
Patent	0.22**	0.26	0.20**	0.22*	0.22	0.13	0.13
	(0.08)	(0.20)	(0.08)	(0.12)	(0.26)	(0.14)	(0.33)
Public	0.03	0.70	0.27	0.03	0.66	-0.03	0.63
	(0.28)	(0.50)	(0.27)	(0.25)	(0.46)	(0.35)	(0.65)
Foreign	0.38	0.06	0.03	0.39	0.13	0.56	0.25
	(0.30)	(0.38)	(0.24)	(0.33)	(0.43)	(0.41)	(0.52)
Quantity	-0.37	-0.20	-0.30	-0.37*	-0.18	-0.38	-0.11
	(0.25)	(0.37)	(0.22)	(0.22)	(0.34)	(0.27)	(0.49)
Frival	0.22	-0.12	0.12	0.22	-0.17	0.13	-0.27
	(0.24)	(0.39)	(0.22)	(0.22)	(0.40)	(0.26)	(0.49)
IdeaRiv	-0.02	-0.21	-0.11	-0.02	-0.21	-0.04	-0.18
	(0.22)	(0.34)	(0.22)	(0.20)	(0.30)	(0.25)	(0.41)
Dchemical	0.41	0.86*	0.71**	0.41	0.85**	0.37	0.88
	(0.30)	(0.46)	(0.28)	(0.23)	(0.41)	0.30)	(0.57)
Detronics	0.45	1.85**	1.17**	0.45	1.84**	0.47	1.82**
	(0.33)	(0.47)	(0.29)	(0.30)	(0.42)	(0.30)	(0.49)
Dequipmt	0.89**	0.61	0.74**	0.89**	0.58	0.86	0.55
	(0.42)	(0.54)	(0.35)	(0.37)	(0.49)	(0.71)	(0.51)
Denergy	0.10	0.83	0.62**	0.11	0.83	0.13	0.89
	(0.40)	(0.64)	(0.36)	(0.35)	(0.53)	(0.42)	(0.84)
Dservice	1.74*	0.47	0.90**	1.74**	0.46	1.79**	0.49
	(0.47)	(0.55)	(0.37)	(0.42)	(0.50)	(0.47)	(0.59)
Lambda[b]				-0.01	-0.19		
				(0.43)	(0.79)		
CDTI			0.61**				
			(0.22)				
R2 Adjust	0.80	0.49	0.61	0.79	0.48		
Log Likel.						-265.8	
N	70	73	143	70	73	143	

Notes:

a) In this and all remaining tables, standard errors are in parenthesis. One asterisk denotes a 10 % significance level; two asterisks a 5 %.

b) Lambda is the inverse of the Mill’s ratio, the term included to correct for selection. Its coefficient is $b_{lambda} = \sigma_i\rho_i$. Testing for $b_{lambda}=0$ is equivalent to testing for selection.

Table 6. Relative R&D Effort: R&D Expenditure/employee.

	Ordinary Least Squares			Sample Selection		Maximum Likelihood	
	Participants	Non-Participants	All	Participants	Non-Participants	Participants	Non-Participants
Constant	0.69	0.04	-0.18	0.70	-0.11	0.95*	-0.39
	(0.42)	(0.64)	(0.39)	(0.47)	(0.84)	(0.54)	(1.03)
European	-0.17	-0.17	-0.14	-0.17	-0.18	-0.20	-0.22
	(0.30)	(0.42)	(0.25)	(0.27)	(0.38)	(0.40)	(0.51)
Employmt	-0.38**	-0.47**	-0.39*	-0.38**	-0.46**	-0.35**	-0.44**
	(0.07)	(0.09)	(0.05)	(0.07)	(0.09)	(0.09)	(0.11)
Exportsh	-0.01**	0.01	-0.003	-0.02**	0.01	-0.02**	0.01
	(0.005)	(0.009)	(0.005)	(0.005)	(0.008)	(0.006)	(0.009)
Patent	0.22**	0.27	0.20**	0.22*	0.22	0.13	0.13
	(0.08)	(0.20)	(0.09)	(0.12)	(0.27)	(0.14)	(0.33)
Public	0.03	0.70	0.27	0.03	0.66	-0.03	0.63
	(0.28)	(0.50)	(0.27)	(0.25)	(0.47)	(0.35)	(0.65)
Foreign	0.38	0.06	0.03	0.39	0.13	0.56	0.25
	(0.30)	(0.38)	(0.24)	(0.34)	(0.44)	(0.41)	(0.52)
Qquantity	-0.37	-0.20	-0.30	-0.37*	-0.18	-0.38	-0.11
	(0.25)	(0.37)	(0.22)	(0.22)	(0.34)	(0.27)	(0.49)
Frival	0.22	-0.12	0.12	0.22	-0.17	0.13	-0.27
	(0.24)	(0.39)	(0.22)	(0.22)	(0.41)	(0.26)	(0.50)
IdeaRiv	-0.02	-0.21	-0.11	-0.02	-0.21	-0.04	-0.18
	(0.23)	(0.34)	(0.21)	(0.20)	(0.30)	(0.25)	(0.31)
Dchemical	0.41	0.86*	0.71**	0.41	0.85**	0.37	0.88
	(0.30)	(0.46)	(0.28)	(0.27)	(0.41)	(0.30)	(0.57)
Detronics	0.45	1.85**	1.17**	0.45	1.84**	0.47	1.82**
	(0.33)	(0.46)	(0.29)	(0.29)	(0.42)	(0.30)	(0.49)
Dequipmt	0.89**	0.60	0.74**	0.89**	0.58	0.86	0.55
	(0.42)	(0.54)	(0.35)	(0.37)	(0.49)	(0.71)	(0.52)
Denergy	0.10	0.83	0.62*	0.11	0.84	0.13	0.89
	(0.40)	(0.64)	(0.36)	(0.35)	(0.57)	(0.42)	(0.85)
Dservice	1.74**	0.47	0.90**	1.74**	0.46	1.79**	0.49
	(0.47)	(0.56)	(0.37)	(0.42)	(0.50)	(0.47)	(0.59)
Lambda				-0.01	-0.19		
				(0.43)	(0.79)		
CDTI			0.61*				
			(0.22)				
R2 adjust	0.46	0.37	0.42	0.45	0.36		
LogLikelih.						-265.8	
N	70	73	143	70	73	143	

Table 7. Absolute R&D effort: R&D Personnel.

	Ordinary Least Squares			Sample Selection		Maximum Likelihood	
	Participants	Non-participants	All	Participants	Non-Participants	Participants	Non-Participants
Constant	-0.51	-0.71	-0.98**	-0.71*	-1.18*	-0.67	-1.56*
	(0.35)	(0.50)	(0.33)	(0.36)	(0.60)	(0.43)	(0.56)
European	-0.37*	0.001	-0.l0	-0.31	-0.07	-0.33	-0.08
	(0.22)	(0.34)	(0.20)	(0.21)	(0.31)	(0.30)	(0.43)
Employmt	0.54**	0.45**	0.50**	0.51**	0.49**	0.52**	0.51**
	(0.05)	(0.07)	(0.04)	(0.06)	(0.07)	(0.07)	(0.07)
Exports	-0.01**	0.01	-0.002	-0.01**	0.007	-0.01**	0.01
	(0.005)	(0.007)	(0.005)	(0.005)	(0.007)	(0.005)	(0.01)
Patent	0.19**	0.19	0.17**	0.26**	0.03	0.24**	-0.06
	(0.07)	(0.16)	(0.07)	(0.09)	(0.20)	(0.12)	(0.21)
Quantity	-0.11	-0.21	-0.15	-0.10	-0.16	-0.10	-0.03
	(0.20)	(0.30)	(0.19)	(0.18)	(0.27)	(0.21)	(0.31)
Frival	0.22	-0.01	0.11	0.28	-0.05	-0.26	-0.09
	(0.19)	(0.28)	(0.18)	(0.18)	(0.26)	(0.23)	(0.30)
IdeaRiv	-0.18	-0.13	-0.13	-0.14	-0.13	-0.15	-0.10
	(0.18)	(0.27)	(0.17)	(0.17)	(0.24)	(0.22)	(0.35)
Dchemical	0.67**	0.57	0.70**	0.69**	0.62*	0.69**	0.67*
	(0.25)	(0.37)	(0.24)	(0.22)	(0.33)	(0.26)	(0.42)
Detronics	0.88**	1.58**	1.19**	0.84**	1.58**	0.86**	1.46**
	(0.27)	(0.37)	(0.24)	(0.25)	(0.34)	(0.32)	(0.37)
Dequipmt	1.05**	1.14**	1.04**	1.07**	1.05**	1.03**	0.87*
	(0.34)	(0.44)	(0.30)	(0.31)	(0.40)	(0.34)	(0.52)
Denergy	0.25	0.77	0.55*	0.25	0.71	0.25	0.64
	(0.32)	(0.50)	(0.30)	(0.29)	(0.45)	(0.37)	(0.51)
Dservice	1.41**	-0.68	0.14	1.39**	-0.68*	1.39**	-0.57
	(0.38)	(0.45)	(0.32)	(0.34)	(0.41)	(0.33)	(0.48)
Lambda				0.32	-0.61		
				(0.29)	(0.49)		
CDTI			0.47**				
			(0.18)				
R2 adjust.	0.79	0.52	0.60	0.79	0.52		
Loglikelih.						-238.52	
N	70	73	143	70	73	143	

Table 8. Relative Effort: R&D personnel/employee.

	Ordinary Least Squares			Sample Selection		Maximum Likelihood	
	Participants	Non-Participants	All	Participants	Non-Participants	Participants	Non-Participants
Constant	4.10	3.88**	3.62**	3.91**	3.43**	3.93**	3.04**
	(0.35)	(0.50)	(0.33)	(0.36)	(0.62)	(0.43)	(0.56)
European	-0.37	0.001	-0.10	-0.31	-0.07	-0.33	-0.08
	(0.22)	(0.34)	(0.20)	(0.21)	(0.31)	(0.30)	(0.43)
Employmt	-0.46**	-0.55**	-0.49**	-0.49**	-0.51**	-0.48**	-0.48**
	(0.05)	(0.07)	(0.05)	(0.06)	(0.07)	(0.07)	(0.07)
Exportsh	-0.01**	0.007	0.002	-0.01*	0.01	-0.01**	0.01
	(0.005)	(0.007)	(0.004)	(0.004)	(0.07)	(0.005)	(0.009)
Patent	0.19**	0.19	0.17**	0.26**	0.04	0.24**	-0.06
	(0.07)	(0.16)	(0.07)	(0.09)	(0.20)	(0.12)	(0.21)
Qquantity	-0.11	-0.21	-0.15	-0.10	-0.16	-0.10	-0.03
	(0.20)	(0.30)	(0.18)	(0.18)	(0.28)	(0.21)	(0.31)
Frival	0.22	-0.01	0.11	0.28	-0.06	0.26	-0.09
	(0.19)	(0.29)	(0.18)	(0.18)	(0.26)	(0.23)	(0.30)
IdeaRiv	-0.18	-0.13	-0.13	-0.14	-0.13	-0.15	-0.10
	(0.18)	(0.28)	(0.17)	(0.17)	(0.25)	(0.22)	(0.35)
Dchemical	0.67**	0.57	0.70*	0.69**	0.61*	0.69**	0.68*
	(0.25)	(0.37)	(0.24)	(0.22)	(0.33)	(0.26)	(0.42)
Detronics	0.88**	1.58**	1.19**	0.84**	1.59**	0.86**	1.46**
	(0.27)	(0.38)	(0.24)	(0.25)	(0.34)	(0.32)	(0.37)
Dequipmt	1.06**	1.14**	1.04**	1.07**	1.06**	1.03**	0.87*
	(0.34)	(0.44)	(0.29)	(0.31)	(0.40)	(0.34)	(0.52)
Denergy	0.25	0.77	0.55*	0.25	0.71	0.25	0.64
	(0.32)	(0.50)	(0.30)	(0.28)	(0.45)	(0.37)	(0.52)
Dservice	1.41**	-0.68	0.14	1.39**	-0.68*	1.39**	-0.56
	(0.38)	(0.45)	(0.32)	(0.34)	(0.41)	(0.33)	(0.49)
Lambda				0.32	-0.58		
				(0.29)	(0.57)		
CDTI			0.47**				
			(0.18)				
R2 adjust.	0.68	0.58	0.60	0.68	0.58		
Loglikelih.						-238.5	
N	70	73	143	70	73	143	

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