Barriers to innovation and subsidies e¤ectiveness[¤]

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Preliminary

Abstract

This paper is aimed at exploring the e¤ects of R&D commercial subsidies by modelling the …rm decisions about performing R&D when some government support can be expected. To estimate the parameters of interest we use an unbalanced panel sample of 2,000 Spanish manufacturing performing and non-performing …rms. For the non-performing …rms, we compute the trigger subsidies required to induce R&D spending (a measure of the market failure). Among the performing …rms, we compute the proportion that would cease to perform R&D if subsidies were suppressed (a measure of subsidy efectiveness). In addition, we assess subsidy e…ciency for all the performing …rms by looking at the e¤ective cost reduction obtained by means of the grant. Results show, among other things, that subsidies turn out to be decisive in inducing to perform R&D among 20% of the performing small …rms and only 4% among the biggest.

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1. Introduction

Public sectors of all industrialized countries spend considerable amounts of money in supporting commercial R&D of manufacturing …rms. Firms apply for subsidies for research, and agencies choose the research to be funded. The economic justi…cation of these programs lies in the presumable failure of market to incentive …rms to allocate enough resources to the innovative activities (Arrow (1962), Romer(1990)). Positive externalities a¤ecting other …rms and consumers induce a divergence between the social and private returns of such activities.

Despite the spread of these subsidies, the evidence on their e¤ects on …rms' behavior remains relatively modest and controversial (see, for example, the survey on recent micro-econometric evidence by Klette, Moen and Griliches (1999); or the related works by Hall and Van Reenen (1999), on …scal incentives, and David, Hall and Toole (1999) on public/private R&D). Questions currently addressed by researchers include whether subsidies stimulate R&D, in the sense that …rms undertake projects that would otherwise have not been carried out, and if the public funds crowd out the …rm R&D expenditure. The answers are far from clear, often depending on the employed methodology. For instance, a recent …rm-level econometric study by Wallsten (1999) claims that, controlling by grants endogeneity, no e¤ort e¤ect is detected and crowding out is present.

This paper is aimed at exploring the e¤ects of R&D commercial subsidies by focussing on the modelling of the …rm decisions when some government support can be expected: whether perform or not R&D projects and the associated level of R&D expenditure. Pro…tability thresholds for the expenditure on innovative activities are estimated for every …rm, and the …rm actions explained in relation to these thresholds and expected subsidies (González and Jaumandreu (1998)) .

For non-performing …rms, the gap between their optimal R&D spending and the profitability threshold is a measure of the market failure. For these …rms, we compute the trigger subsidies required to induce R&D spending. Among the performing …rms, we detect the ones that would cross back the pro…tability threshold and cease to perform R&D if

subsidies were suppressed. The proportion that these …rms represent over all the performing …rms gives a measure of subsidy efectiveness. In addition, we assess subsidy e…ciency for all the performing …rms by looking at the e¤ective cost reduction obtained by means of the grant. Results show that subsidies turn out to be decisive in inducing to perform R&D among 20% of the performing small …rms and only 4% among the biggest. On the other hand, trigger subsidies have an average size of 25% of R+D expenditures, and the e¤ectivity of cost reduction of public subsidies is about 1.3.

To model …rms decisions, we use the following theoretical framework. Each …rm is considered a competitor in prices in a product di¤erentiated industry, which can shift the demand for its product by enhancing product quality through R&D expenditures. Demand characteristics, technological opportunities and setup costs of R&D projects interact to determine a pro…tability threshold of spending. Under this threshold, R&D costs are not completely recovered in the market by means of the sales increment. Firms can then …nd more profitable not to undertake innovative activities, but this decision can be modi…ed if expected subsidy reduces the cost of R&D. The same framework explains how performig …rms take into consideration the available expected grants to determine the size of the R&D planned expenditures.

This framework leads naturally to a Tobit type modelling of the censored variable optimal e¤ort, that is employed to estimate the model parameters. Previously, unobservable expected subsidies must be estimated from data on ex-post observed grants. This two step procedure rends also the estimation robust to possible biases derived from endogeneity of subsidies.

The data set we use is an unbalanced panel of more than 2,000 Spanish manufacturing …rms observed during the period 1990-97. The data come from a sample of Spanish manufacturing …rms representative by industries and size strata, and hence results can be claimed to be valid for the whole industry. Spanish central and regional governments, as well as the European Union, maintained during the period several commercial R&D subsidy programs as the main way to support innovative activities. Firm sample behavior is, however, highly heterogeneous. Almost 20% of the …rms with more than 200 workers and about 70% of the

firms under this size do not report to perform formal R&D. And only a fraction of performig firms, that increases with firm size, obtains subsidies.

The rest of the paper is organized as follows. Section two details the theoretical framework. Section three presents the econometric model and explains how can be used to measure the different subsidy effects. Section four describes the data set and the main facts about subsidies. Section five reports the econometric results and section 6 concludes.

2. R&D with set-up costs

This section characterises the R&D decisions of firms and relates them to subsidies. Firms compete in prices in product differentiated industries, can make R&D investments to enhance the demand for its products, and can apply for and obtain subsidies of a fraction of its R&D expenditures. Decisions are taken according to the profitability of the innovative activities given the subsidy expected by the firm. The innovation activities enlarge demand, but performing R&D has set-up costs and so it is not always worthwile. A firm can find that the profit increase obtained by performing R&D does not cover the incurred expenditures. The model follows González and Jaumandreu (1998).

Firm i competes in prices in a given product differentiated industry, facing a negatively sloped demand. Demand, however, can be shifted by enhacing the quality of the product. We will write demand as $\phi_i(p_i, p_{-i}, s_i)$, where p_i stands for the own price, p_{-i} for the vector of prices of the rivals, and s_i for the level of quality, and we will suppose $\partial\phi_i/\partial s_i > 0$ and $\partial\phi_i^2/\partial s_i^2 \leq 0$. In what follows, we will assume that price competition can be taken as stable over time and subsumed in the relevant own demand elasticity, and hence we will write $\phi_i(p_i, p_{-i}, s_i) = q_i(p_i, s_i)$. We also drop momentarily the subscript i for simplicity.

Quality can be improved by incurring in R&D expenditures, denoted henceforth by x, according to some technological rules. In particular, to surpass the industry current standard quality $s(0)$, firm i must incur in some set-up costs that we will denote by F. Beyond F, R&D expenditures affect quality according to the "production function" $s = s(x)$, where $\partial s/\partial x > 0$ and $\partial^2 s/\partial x^2 \leq 0$. Set-up costs usually stem from the indivisibility of some

resources.

A firm can apply to have its R&D expenditures subsidized with public funds by a monetary fraction ρ. At the same time, public subsidies can be associated to a given expenditure efficiency, since they are often linked to the access to other facilities or advantages. On the other hand, the firm ex-ante decisions (at the time of setting its R&D plans) must be based on its expectation about the subsidy that will be obtained. Accordingly, we will parametrize the expected cost of a unit of efficient R&D as $(1-\rho^e)^{\beta}$, where β is a measure of subsidy efficiency.

Suppose now that production marginal cost is c. To set the product price and decide the pertinence and level R&D expenditures, the firm must solve the problem

$$\max_{p,x}\,(p-c)q(p,s(x))-(1-\rho^e)^{\beta}x \qquad [1]$$

subject to

$$s(x)=\begin{cases} s(0) & \text{if } x<F \\ s(x) & \text{otherwise}\end{cases}$$

that turns out to be an optimization problem with a non-convex costraint. The equilibrium of the firm will be characterized by the pair (p^e,x^e) such that $(p^e,x^e)=\max\{\Pi(p^*,x^*),\Pi(p^{**},0)\}$, where p^* and p^{**} may diverge, and (p^*,x^*) is the interior solution. That is, the firm will choose performing or not R&D activities according to an incremental profit-expenditures comparison condi

This formulae shows that optimal effort -for given set-up costs- increases with the elasticity of demand with respect to quality (demand conditions), the elasticity of quality with respect to R&D expenditure (technological opportunities), the degree of market power(the inverse of the price elasticity), and the expected subsidy. But this effort will only be observed in practice when it surpasses a threshold effort $\overline{E}$ jointly determined by the above elasticities and the value of the set-up costs, being $\overline{E}$ the level of R&D effort for which the firm will be indifferent between performing or not R&D in the absence of subsidies.

According to [2] subsidies have two different effects. On the one hand, they enhance R&D expenditures of firms that would perform innovative activities in any case. On the other, they induce to perform R&D to some firms that would not perform innovative activities in the absence of subsidies.

3. Barriers to R&D and subsidy effects

Take logs in [2] and let z stand for the vector of “reduced-form” variables that determine the value of the (log of) elasticities. We have the following semi-structural econometric relationship

$$e^* = -\beta \ln(1 - \rho^e) + z\beta_1 + u_1 \qquad [3]$$

where $e^* = \ln E^*$.

According to our theoretical framework, e^* is a censored variable. Hence, to estimate consistently the parameters we must take into account its observability rule. Let specify this rule as

$$e = \begin{cases} e^* & \text{if } e^* > \overline{e} \\ 0 & \text{otherwise} \end{cases} \qquad [4]$$

with

$$\overline{e} = z\beta_2 + u_2 \qquad [5]$$

where e represents observed e¤ort and the equation for $\bar{e}$ speci…es the thresholds. Thresholds are considered presumably a function of the same variables that determine elasticities, but the e¤ects of these variables give here the height of the "barriers" to the pro…tability of R&D.

Equations [3],[4] and [5] de…ne a Tobit type model, in which optimal e¤ort $e^{¤}$ is taken as a partially observable variable, only observed when stochastically surpasses the …rm profitability threshold $\bar{e}$. Firms are taken as competing each one in heterogeneous environments and hence having idiosyncratic thresholds.

Given parameter estimates of this model, one is ready to compute individual threshold estimates and to use them to assess the e¤ects of subsidies when the …rm is confronted to the barriers to R&D.

Let …rst evaluate the required trigger subsidies. We de…ne these subsidies as the value of the $½^e$'s that would induce non-performing …rms to undertake innovative activities. These subsidies can be computed as the values of $½^e$ that solve the equations $¡\hat{b}\ln(1 ¡ ½^e) + z(\hat{b}_1 ¡ \hat{b}_2) = 0$ for non-performing …rms.

Let then evaluate the subsidy e¤ectiveness. We take as an index of efectiveness the proportion of performing …rms that would cease to perform R&D if subsidies were supressed. This proportion can be computed as the proportion of performing …rms for which $¡\hat{b}\ln(1 ¡ ½^e) + z(\hat{b}_1 ¡ \hat{b}_2) > 0$ but $z(\hat{b}_1 ¡ \hat{b}_2) < 0$.

Estimation of the model requires solving the problem of the unobservability of the expectation variable $½^e$. In fact, only ex-post granted subsidies are observable. Then, we will employ this variable to estimate the conditional expectation of subsidies and we will substitute the estimated values for the unobservable expectations.

Let us write and decompose the expected subsidy as follows

$$½^e = E(½jy) = P(½ > 0jy)E(½ j ½ > 0; y) \qquad [6]$$

where $P(½ > 0jy)$ stands for the probability of the grant, $E(½ j ½ > 0; y)$ for the expected value of the subsidy conditional on its granting, and y represents the vector of other condi-

tioning variables. We will estimate these two conditional expectation functions using firm observable characteristics as components of y, and we will use the fitted values to estimate $\hat{\rho}^e$.

Substituting $\hat{\rho}^e$ for ρ^e in the relevant equations, we will estimate the whole model by maximum likelihood. The model turns out to be a type 2 generalized Tobit according to the classification in Ameniya (1985), where alternative identification conditions are discussed (see also Maddala (1983)). One of these conditions is the availability of at least one variable that enters the equation for the censored variable but can be excluded on theoretical grounds of the thresholds equation. This condition arises naturally in our model, where expected subsidies can be safely excluded among the determinants of thresholds. Technical details on the ML estimation procedure are given in Appendix 1.

4. Data and description

The data set is an unbalanced panel of manufacturing firms surveyed during the period 1990-1997, which includes almost 2,000 firms. The sample can be considered approximately representative of manufacturing. At the beginning of the period, firms under 200 workers were sampled randomly by industry and size strata retaining 5%. Firms with more than 200 workers were all requested to participate, and the positive answers more or less represented a self-selected 60% of firms within this size. To keep representation, samples of newly created firms have been added every subsequent year. Exits from the sample come both from death and attrition, but they can be distinguished and attrition has been maintained under sensible limits.

The survey provides information on the total R&D expenditures of the firms, including intramural expenditures, R&D contracted with laboratories or research centres, and technological imports, that is, payments for licensing or technical assistance. We consider a firm performing technological or innovative activities when it reports some R&D expenditure. The variable to explain is technological effort, defined as the ratio of R&D expenditures to firm sales. In explaining effort, we use the extensive information on the firms' activities

covered by the survey. After deleting the …rms' data points for which some variable needed in the econometric exercise is missing we retain a panel with 8,711 observations. In what follows, we summarise some facts about R&D expenditures and granted subsidies.

Commercial R&D subsidies may have in Spain three sources. Firstly, the European Framework program, with a wide variety of subprograms (information, telecommunications, biotechnologies, aerospace...) but which reach a very small number of …rms. Secondly, the Ministry of Industry programs, that include the subsidies granted for the specialised agency CDTI (Centre for Industrial Technological Development). Finally, the technological actions of regional governments. During the nineties, subsidies as a whole have been the main incentive available for manufacturing …rms to undertake research programs.

Tables 1 and 2 report some facts about the degree by which Spanish manufacturing …rms engage in formal R&D activities. Table 1 shows that the probability of undertaking R&D activities a given year increases sharply with size (20% of the …rms under 200 workers and 75% of …rms with more than 200 workers), and that this probability has been increasing smoothly over time for the …rms of all sizes. Table 2 adopts another perspective by distinguishing permanent and stable performers during the period. Stable R&D performers are …rms that report R&D expenditures every year they remain in the sample. Occasional performers are the …rms that report R&D expenditures only some of the years they remain in the sample. Stable performance of R&D activities is strongly correlated with size.

Tables 3 and 4 report the main facts about grants. Table 3 shows that only a small fraction of R&D performers receive subsidies and that the proportion of granted …rms increases with …rm size, at least for the stable performers. Table 4 shows that the typical subsidy covers between 20% and 40% of the R&D expenditures and also that the rate of subsidised expenditure, unlike its granting, does not show a clear relationship with …rm size.

Tables 5 and 6 take a …rst look at the relationship between subsidies and e¤ort. Both tables show a positive association between R&D e¤ort and the granting of subsidies, both in the whole period and year to year. Therefore, data suggest the likelihood of positive e¤ort e¤ects of subsidies. But this can be solely the e¤ect of other non-controlled variables or a

simultaneity bias. Only the implementation of the econometric model can provide further insights on this relationship.

5. Econometric results

In what follows, we …rstly detail the speci…cation and estimation of the equations aimed at estimating the expected subsidy. Then, we comment the speci…cation and estimation of the Tobit type e¤ort model. Finally, we employ the results of the estimated model to assess the e¤ects of subsidies.

5.1 Expected subsidies

Firstly, we estimate the unobservable …rms' expectations $½^{e}$ starting from the ex post observable granted subsidies using the two equations speci…cation given by [6]. This is a way to deal descriptively with the presumably high non-linearity of the expected subsidies. Underlying the process by which subsidies are granted there is a complex process of some …rms applying for subsidies and the relevant public agency granting the subsidies to a subset of them. We want simply to predict the expected result of this process by means of a set of variables that can be considered exogeneous or, at least, predetermined. We use the same set of variables to estimate the conditional probability of receiving a subsidy, using a probit speci…cation, and the conditional expected value of the subsidy when it is granted, using a linear equation to be estimated by OLS. The expected subsidy for each …rm is the product of the predicted conditional probability by the expected value.

In estimating the equations we consider the following set of explanatory variables. Firstly the value of subsidy in the previous period, in order to pick-up persistence, which can be based either in projects spread over several years or the renewal of grants by experienced …rms. Secondly, two indicators of the degree of commitment with the R&D activities: lagged R&D e¤ort and R&D employment. Thirdly, a series of characteristics that may enhance the eligibility of …rms: skilled labour, size and sector.

Table 7 reports the results of the estimation of both equations. Persistence appears as

signi…cant. Commitment in‡uences heavily probability but tends to have a (small) negative impact on the expected value of the subsidy. Characteristics that enhance eligibility work similarly. The …t of both equations is good, with more than 90% of subsidies correctly predicted and almost 60% of the variance of the subsidies' value explained.

5.2 Tobit Model

Let us now discuss the speci…cation of equations [3] and [5] -e¤ort and threshold equations respectively- of the Tobit model. It must be admitted that the same variables can explain in principle optimal e¤ort and the threshold for pro…table e¤ort, but with the important exception of expected subsidies. This happens because e¤ort thresholds for pro…table technological activities are de…ned in terms of the total expenditure needed, independently of its composition. However, either unobserved or observed optimal e¤ort is given in terms of total optimal expenditure to be carried out by the …rm, and this amount depends on the expected subsidy (the fraction of expenditure that would be not really a¤orded by the …rm). The exclusion of expected subsidies from the thresholds equation plays a crucial role in identifying the determinants of e¤ort and thresholds.

The model can be considered semistructural, as far as the expected subsidies enter the e¤ort equation in the way they appear in the …rst order condition, but elasticities -or their associated variables: price or margins, shares, etc...- are endogeneous variables of the underlying model that we replace by a set of reduced form determinants (i.e. the other explanatory variables). In determining such a set, we will take into account that the three determinants of optimal e¤ort are, according to [2]: the elasticity of demand with respect to quality, the inverse of the elasticity of demand with respect to price or market power, and the elasticity of quality with respect to R&D expenditures. These are presumably also the determinants of the thresholds jointly with the set up costs.

We include the same set of explanatory variables other than the expected subsidy in the two equations, but we expect di¤erent e¤ects of the same variable at each equation. Firstly, the elasticity of demand with respect to quality and the elasticity of quality with respect to R&D expenditures are likely to have a positive impact on e¤ort and, by the

contrary, to reduce thresholds. Secondly, the same variable may be proxying for different factors in the two equations. Here, however, we do not pay special attention to these effects because we are more concerned with obtaining good predictions of the optimal efforts and thresholds than in identifying the components of each elasticity (for a work more oriented at the explanation of effort and thresholds see González and Jaumandreu,1998).

As variables that can be mainly related to market power we include the firm' lagged market share, the firm' export intensity, a dummy reporting the dimension of the firm' market (national or international as opposed to regional and local) and another indicating if the market must be considered expanding. Spanish firms are typically found to have less market power in foreign and big markets. But, of course, the operation in such markets may also be an indicator of products with higher sensitivity to quality.

As variables that may perform as indicators of (or of the lack of) a high sensitivity to quality we include a dummy of standard product, another indicating the performance by the firm of many quality controls on the product, and another reporting if the market has a fragmented structure. The variables quality controls and fragmented market can be also obviously related respectively to a higher cost of the R&D activities or a stronger weight of set-up costs.

Finally, we include three variables that may be considered mainly aimed at detecting a higher elasticity of quality with respect to R&D expenditure: an indicator of firm' skilled labour, the average industry patents registered and a rough indicator of geographical spillovers. Of course patents may also perform as an indicator of high set-up costs of the industry specific R&D.

In addition to these variables we include a set of 6 dummies to control for the size of firms, measured according the number of employees, and a set of 18 sector dummies to control for permanent differences arising from activities. Details on all the employed variables can be found in Appendix 2.

Table 8 reports the results of the estimation of the model by maximum likelihood. The key variable expected subsidy is included in the form $\ln(1-\hat{\rho})$, and is expected therefore to attract a β coefficient about minus unity. The value effectively obtained is -1.3, which

indicates a slightly higher efficiency of public funds that may be attributed to other public facilities obtained by firms that obtain grants (use of public laboratories, access to public researchers, etc...).

The estimated coefficients and statistics seem reasonable. The interpretation of the results obtained in the thresholds and effort equations may be done as follows. Expenditure thresholds for profitable R&D activities are high in sectors with high technological opportunities (many patents) because of high set-up costs, while the dimension of the market and the firm size lessen these thresholds and a small scale of operation (fragmented market) increases them. However, a high quality sensitivity of products (quality controls) reduces thresholds further. Effort is higher the higher are technological opportunities (many patents) and lower the higher are the R&D activities cost (quality controls), increases with the importance of variety (fragmented market) and decreases with margins (market dimension). There remains, however, a puzzling effort effect of size that must be read as the sign of some misspecification of this equation.

Given the estimates, we can evaluate the goodness of fit of the model according to its predictions and use them to infer a series of conclusions about the effects of subsidies. Firstly, the model predicts that the firm will engage in R&D activities when the difference $\hat{e}^{*} - \hat{e}$ is positive. Table 9 reports the results of comparing the model predictions with the actual observations in the sample for three subgroups of firms: stable R&D performers, occasional performers and firms never observed performing R&D. The model predicts very well the zero-one variable that denotes the presence of expenditures for the firms that never or always engage in R&D activities (91% and 86% of observations correctly predicted). The model is however much less accurate in predicting the yearly activity of the occasional performers. Prediction continues to be quite good when R&D expenditures are positive (72% of observations correctly predicted), but assigns erroneously positive predictions in half of the cases in which the firms do not show expenditures. This is hardly surprising if we take into account the high degree of arbitrariness of some firm accounting practices in allocating costs over time and the lack of dynamic structure of the model.

5.3 Subsidy e¤ects

Using the model predictions and the parameter estimates we can evaluate trigger subsidies or the value of subsidies that would induce non-performing …rms to undertake R&D activities. This is done as explained in section 3, using all the correctly predicted non-expenditure observations. Results are reported in Table 10. This Table shows an important di¤erence in the average pro…tability gap or required subsidies according to …rm size: 9% of the expenditure for the big …rms and 25% for the small ones.

On the other hand, the model predictions and parameter estimates can be also used to evaluate subsidies e¤ectiveness by estimating the proportion of …rms that would cease to perform R&D if subsidies were suppressed. This is done using the method explained in section 3 and employing all the correctly predicted positive-expenditure observations. Table 11 shows that, taking away subsidies, …rm optimal e¤ort of a signi…cant number of …rms ceases to surpass the pro…tability threshold and hence they would not perform innovative activities. A strong size e¤ect is again present: only 4% of big …rms would cease to perform R&D versus 20% of the small ones.

According to the estimations, the e¤ect of subsidies on the probability of performing innovative activities is likely to change signi…cantly across …rm sizes and sectors. To assess this heterogeneity, Table 12 reports the marginal probability e¤ect of the expected subsidy across 2 sizes and 18 sectors. Interestingly enough, expected subsidies reach their maximum impact among the smallest …rms of technology intensive sectors and the biggest …rms of less technology intensive ones.

All this refers to the ability of subsidies to induce …rms to expend in R&D. But, according to the estimations, how subsidies change the expenditure of …rms that would also perform innovative activities in their absence?. The estimated parameters provide also some insights on this question.

We have denoted total R&D expenditure by x and total e¤ort by E. Total expenditure may be written as the product of e¤ort by sales $x = Epq$. This makes clear that the change in expenditure may be conceptually decomposed in the sum of two changes: the change due to sales and the change in e¤ort. In our model R&D expenditures are expanded to

increment sales, and therefore the rate of change in effort constitutes a lower bound for the rate of increase in expenditure.

Changes in effort depend on subsidies in a complex way, because all the elasticities in [2] may change with the firm equilibrium. But assume the simplest case in which the ratio of elasticities is constant . Call $E(\rho)$ total effort with subsidy and $E(0)$ total effort in its absence, and write $(1-\rho)E(\rho)$ for private effort when expenditures are subsidised. It is easy to check that $(1-\rho)E(\rho) - E(0) = (1-\rho)E(\rho)[1-(1-\rho)^{\beta-1}] \gtrless 0$ according to $\beta \gtrless 1$. If subsidy efficiency beta is unity, private effort do not increases with subsidies (R&D private expenditures will increase at the pace of sales), and total effort will be augmented only by the public effort fraction $\rho E(\rho)$. By the contrary, if β exceeds unity, the subsidy will increase private effort, and total effort will become higher than the sum of the public fraction and the private effort without subsidy. Our estimated β value implies, for example, that a subsidy of 30% enlarges the private effort contribution about 10%.

6. Conclusions

This paper has been aimed at exploring the effects of R&D commercial subsidies on the firms decisions about R&D expenditures. Despite the spread of this subsidies, the evidence on firms' behaviour remains relatively modest and controversial. Here, however, we obtain a series of positive findings about the potential and actual roles of subsidies by estimating an explicit and theoretically founded model about the firms' decisions. Firms' decisions on whether to spend or not in R&D emerge from the comparison of optimal effort and threshold efforts for profitability, and the impact on this comparison of the expected subsidy (or fraction of the effort that is expected to be publicly supported). Firms' decisions on the level of expenditure implement optimal effort in the presence of subsidy. The model is estimated by a suitable censored variable econometric method, robust to the endogeneity of subsidies.

The main findings, based in our panel sample of 2,000 Spanish manufacturing firms, are the following. Non-performance of innovative activities can be traced back to the presence

of optimal e¤orts under the pro…tability thresholds (that is, market failures). Small …rms experiment the greatest pro…tability gaps (25% of expenditure should be subsidised) due presumably to high set-up costs of R&D. Subsidies seem simultaneously to be e¤ective in inducing …rms to expend in R&D, specially in the case of small …rms. One over …ve small …rms that present R&D expenses maintains them thanks to the help of subsidies. Finally, subsidies also change the level of expenditures chosen by the …rms that would not cease to perform innovative activities in the absence of subsidies. We …nd evidence of some cost e¢ciency of subsidies that induces increases in privately …nanced e¤ort.

Appendix 1: Econometric model and estimation strategy.

The model to be estimated is

$$e_i^* = -\beta \ln(1 - \rho_i^e) + z_i \beta_1 + u_{1i}$$
$$\overline{e_i} = z_i \beta_2 + u_{2i}$$

$$e_i = \begin{cases} e_i^* & \text{if} \quad e_i^* > \overline{e_i} \\ 0 & \text{otherwise} \end{cases}$$

where we will consider (u_{1i}, u_{2i}) i.i.d. drawings from a bivariate normal distribution with zero mean, variances σ_1^2, σ_2^2 and covariance σ_{12} . This has the form of a generalized Tobit (or Type 2 Tobit model in the Amemiya classification; Amemiya, 1985).

We can rewrite

$$e_i = \begin{cases} -\beta \ln(1 - \rho_i^e) + z_i \beta_1 + u_{1i} & \text{if} \quad -\beta \ln(1 - \rho_i^e) + z_i(\beta_1 - \beta_2) > u_i \\ 0 & \text{otherwise} \end{cases}$$

where $u_i = u_{2i} - u_{1i}$. Here $(u_1; u)$ are i.i.d. drawings from a bivariate normal distribution with zero mean, variances $\sigma_1^2; \sigma^2$; and covariance $\sigma_{u_1 u}$, where $\sigma^2 = \sigma_1^2 + \sigma_2^2 - 2\sigma_{12}$ and $\sigma_{u_1 u} = \sigma_{12} - \sigma_1^2$. We will simplify the notation by writing

$$e_i = \begin{cases} w_i \delta_1 + u_{1i} & \text{if} \quad w_i \delta_2 > u_i \\ 0 & \text{otherwise.} \end{cases}$$

where $w_i = (\ln(1 - \rho_i^e); z_i); \delta_1 = (-\beta; \beta_1')'$, and $\delta_2 = (-\beta; (\beta_1 - \beta_2)')'$.

The likelihood function of the model is given by

$$L = \prod_0 P(\tilde{e}_i \leq 0) \prod_1 f(e_i^* | \tilde{e}_i > 0) P(\tilde{e}_i > 0)$$

where $\tilde{e}_i = e_i^* - \overline{e_i}$; $\prod_0$ and $\prod_1$ stand for the product over those i for which $e_i = 0$ and $e_i \neq 0$; respectively, and $f(e_i^* | \tilde{e}_i > 0)$ stands for the conditional density of e_i^* given $\tilde{e}_i > 0$. We can rewrite the previous expression as

$$L = \prod_0 P(\tilde{e}_i \leq 0) \prod_1 \int_0^1 f(\tilde{e}_i | e_i^*) f(e_i^*) d\tilde{e}_i = \prod_0 P(\tilde{e}_i \leq 0) \prod_1 P(\tilde{e}_i | e_i^*) f(e_i^*)$$

and it is possible to determine a specific form for $f(\mathbf{e}_i|e_i^*)$ from the fact that the conditional distribution of $\mathbf{e}_i$ given $e_i^* = e_i$ is normal with mean $w_i\delta_2 + \frac{\sigma_{u_1u}}{\sigma_1^2}(e_i - w_i\delta_1)$ and variance $\sigma^2 - \frac{\sigma^2_{u_1u}}{\sigma_1^2}$. Thus we can rewrite the likelihood as

$$L = \prod_0 \left[1 - \Phi(w_i\delta_2\sigma^{-1})\right] \prod_1 \Phi\left(\left[w_i\delta_2\sigma^{-1} + \sigma_{u_1u}\sigma^{-1}\sigma_1^{-2}(e_i - w_i\delta_1)\right] \Big/ \left(1 - \frac{\sigma^2_{u_1u}}{\sigma^2\sigma_1^2}\right)^{1/2} \right) \sigma_1^{-1}\phi[\sigma_1^{-1}(e_i - w_i\delta_1)]$$

Note that L depends on σ only through $\delta_2\sigma^{-1}$ and $\sigma_{u_1u}\sigma^{-1}$; this implies that σ can be normalized to 1 and the remaining parameters can be identified. If however, there is at least one common element between δ_1 and δ_2, all parameters are identified. In our case, the common parameter β allows us to identify σ and β_2.

Apendix 2: Variable de…nitions

Average industry patents: yearly average number of patents registered by the …rms in the same industry (excluding the patents registered by the …rm under consideration).

Expansive market: dummy variable which takes the value one if the …rm reports that its demand is increasing.

Export intensity: ratio of exports to sales.

Fragmented market: dummy variable which takes the value one if …rm reports that its main market is atomized.

Geographical opportunities: dummy variable which takes the value one if the …rm has its main plant in a big city (more that 500.000 inhabitants).

Market dimension: dummy variable which takes the value one if the …rm reports that its main market is national and/or international, as opposed to local or regional.

Market share: the market share reported by the …rm in its main market. Firms are asked to split their total sales by markets and report their market shares. If a …rm reports that its share is not signi…cant, market share is set to zero.

Quality control: dummy variable which takes the value one if the …rm reports that it carries out quality controls on a systematic basis.

R&D e¤ort: ratio of total R&D expenditures to sales. Total R&D expenditures include the cost of intramural R&D activities, payments for outside R&D contracts, and expenditures on imported technology (patent licenses and technical assistance).

R&D employment: dummy variable which takes the value one if the …rm has R&D employment.

Skilled labor: ratio of the number of highly quali…ed workers (engineers and graduates), once the R&D personnel is deducted, to total personnel.

Standard product: dummy variable which takes the value one if the …rm reports that its products are highly standarized (as opposed to speci…cally designed for the customers) and that rivals rarely change their products.

Subsidy: ratio of total public subsidies to total R&D.

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Table 1.- Firms with R&D activities

(percentages of …ms)

Year	· 200 workers	> 200 workers
1990	17.8	73.0
1991	20.5	73.9
1992	19.8	74.4
1993	20.9	74.7
1994	21.1	75.6
1995	21.5	72.9
1996	21.7	75.4
1997	22.7	76.8

Table 2.- Firms with R&D activities during the period 1990-1997

(percentages of …rms in the whole period)

Firm size	Stable performers[1]	Occasional performers[2]	Total
· 20 workers	5.5	15.7	21.2
21-50	10.4	18.3	28.7
51-100	19.5	24.4	43.9
101-200	36.0	27.0	63.0
201-500	46.7	35.5	82.2
>500	65.1	26.1	91.2

[1] Firms reporting R&D expenditures every observed year

[2] Firms reporting R&D expenditures some of the observed years

Table 3.- R&D performers granted at

Table 5.- Total R&D e¤ort with and without subsidies

(Period averages of non-zero e¤orts)

Firm size	Without subsidies	With subsidies
· 20 workers	2.8	4.3
21-50	2.4	2.6
51-100	1.4	3.8
101-200	2.0	3.3
201-500	1.7	2.5
>500	1.5	2.7

Table 6.- Total R&D e¤ort with and without subsidies

(Averages of non-zero e¤orts)

	< 200 workers		>200 workers	
Year	Without subsidies	With subsidies	Without subsidies	With subsidies
1990	2.9	4.6	1.6	3.7
1991	2.4	5.2	1.7	3.1
1992	2.2	5.4	1.7	3.2
1993	2.2	5.3	1.9	3.4
1994	2.2	4.2	1.8	2.9
1995	1.9	4.0	1.5	3.7
1996	2.0	4.2	1.7	3.1
1997	2.0	3.7	1.6	3.5

Table 7.- Estimates of the equations $P(\rho > 0|y)$ and $E(\rho|\rho > 0; y)$

(coefficients and t-ratios)

	Probability equation	Subsidy equation
Constant	-2.58 (-38.5)	0.49 (12.2)
Subsidy t-1	1.17 (13.0)	0.16 (4.9)
R&D effort t-1	0.08 (12.5)	-0.002 (-1.5)
R&D Employment	0.89 (14.3)	-0.12 (-3.5)
Skilled labor	0.23 (3.2)	-0.11 (-3.3)
Size (>200 workers)	0.47 (7.9)	-0.055 (-2.4)
Chemical products	0.19 (2.9)	-0.12 (-6.1)
Machinery	0.41 (4.3)	0.04 (0.9)
Motor vehicles	0.22 (2.8)	-0.05 (-1.9)
Textiles and clothing	-0.26 (-3.2)	-0.07 (-2.2)
Estimation method	PROBIT	OLS
Nº of observations	8711	676
Correctly predicted (%)	92.7	
R^2 (%)		58.23

Table 8.- The e¤ect of public funding on R&D decisions

Dependent variable: R&D e¤ort (in logs)

	R&D decision	R&D e¤ort	Threshold
Constant	-0.396 (-7.10)	-2.157 (-10.41)	-1.761 (-7.86)
Expected subsidy[1]	-1.29 (-7.76)		
Market share$_{t-1}$	0.0004 (1.87)	-0.0004 (-0.32)	-0.0008(-0.55)
Export intensity	0.001 (3.62)	-0.002 (-1.46)	-0.002 (-1.89)
Market dimension	0.082 (5.78)	-0.196 (-2.45)	-0.278 (-3.22)
Expansive market	0.032 (3.54)	-0.060 (-0.99)	-0.09

Table 9.- Correctly predicted observations	
Non-performers	91.0%
Stable performers	85.8%
Occasional performers	
when R&D is positive	72.2%
when R&D is zero	52.3%

Table 10: Required subsidy to engage in R&D				
	mean	median	max	min
All …rms	24.1	25.8	42.8	0.3
> 200 workers	8.8	7.5	25.3	0.6
· 200 workers	24.9	26.	42.8	0.3

Table 11.- Subsidies e¤ectiveness (The impact of subsidy withdrawal)		
	Cease R&D	%
All …rms	166	7.2
> 200 workers	65	3.6
· 200 workers	101	20.1

Table 12: Marginal effect of subsidies

	51-100 workers	> 500 workers
1.-Ferrous and non-ferrous metals	0.43	0.46
2.-Non-metallic mineral products	0.42	0.47
3.-Chemical products	0.51	0.25
4.-Metal products	0.41	0.48
5.-Agricultural and industrial mach.	0.51	0.32
6.-Office and data processing mach.	0.49	0.40
7.-Electrical goods	0.51	0.34
8.-Motor vehicles	0.46	0.44
9.-Other transport equipment	0.40	0.48
10.-Meats,meat preparation	0.31	0.52
11.-Food products and tobacco	0.42	0.47
12.-Beverages	0.44	0.46
13.-Textiles and clothing	0.43	0.47
14.-Leather,leather and sking goods	0.49	0.40
15.-Timber,wooden products	0.40	0.49
16.-Paper and printing products	0.37	0.50
17.-Rubber and plastic products	0.44	0.45
18.- Other manufacturing products	0.46	0.43