INFLUENCE OF R&D SUBSIDIES ON EFFICIENCY: THE CASE OF SPANISH MANUFACTURING FIRMS

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Abstract

This work provides new evidence about the effects of subsidies for research and development on technical efficiency in a sample of Spanish manufacturers during the period 1993-2002. We estimate a Cobb-Douglas stochastic production frontier using Battese and Coelli's (1995) model to analyse an incomplete panel of innovative firms, introducing the subsidies received by the firms as explanatory variable of their inefficiency. One of the findings is that there is a curvilinear relation between inefficiency and subsidies. Despite this behaviour, more than 85% of the sample firms are in the growth part of the relation, and 78% are in the area of steepest slope. From the perspective of economic policy, this finding would suggest that extreme caution is required in the use of subsidies to incentivise R&D activity among Spanish manufacturing firms.

Keywords: Subsidies, research and development, efficiency, technical progress.

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1. INTRODUCTION

This work analyses the influence that public assistance for R&D activities may have on firms' technical efficiency. It uses a sample of Spanish manufacturing firms during the period 1993-2002.

The Governments of some of the most industrialised nations have shown increasing interest in recent years in public programmes for encouraging R&D activities in firms. The role of government intervention in economic and industrial development has been a constant topic of discussion and concern in the literature and in different social arenas. As Heijs (2003) mentions, since industrialisation began, non-interventionism, or laissez faire, has received broad support (Smith, 1776). On the other hand, an active role for the public institutions can ensure a fast process of industrialisation. Economic arguments justifying public intervention and related to the neo-classical perspective focus largely on market failures, linked to the public nature of the result of the R&D, the presence of spillovers, and the costs or risks inherent to the innovation process that are presupposed by a suboptimal level of investment among firms in market economies. This line includes modern growth theories (Romer, 1986, 1990; Lucas, 1988; Grossman and Helpman, 1991), as well as the evolutionary perspective (Nelson and Winter, 1982; Hall, 1994; Freeman, 1994, among others).

As indicated in Marra (2005), although an abundant empirical literature has analysed the effectiveness of public policies on firms' innovative activity, the results have been inconclusive. In general, the majority of works have focused on estimating the stimulus effect of public subsidies for R&D in companies, in an attempt to determine whether or not public funds are substituting for private funds. The main difficulties in analysing the effects of public subsidies are generally, on the one hand, problems to do with the sample selection. Studies usually include only subsidised firms, which generates biases in the results obtained. On the other hand, there is the problem of endogeneity. When a firm receives a subsidy for R&D investment, it first records this as an income, but later, in one or more periods, it becomes a cost, generally research spending. This makes the variable conceptually endogenous. Some recent work, such as David, Hall and Toole (2000), Lach (2002), Almus and Czarnitzki (2003) and González, Jomandreu and Pazó (2003), address such methodological problems.

The current work contributes to this empirical literature, analysing the relation between public subsidies and technical efficiency in a sample of innovative Spanish manufacturers during the period 1993-2002. For this purpose, we apply Battese and Coelli's (1995) model. While this econometric model, which proposes a stochastic production frontier (SFA), has been widely used in economics, it has been largely ignored until recently in the management literature. One of the pioneering works in this respect is Lieberman and Dhawan (2005), which analyses the efficiency of a sample of auto producers, proposing to use this methodology as an alternative to the well-known resource-based view. These authors use the model to examine the differences in efficiency between the firms, as well as the sources of such differences.

The work is structured as follows. Section 2 presents a descriptive analysis of the data, as well as the variables used in the research. In Section 3, we explain the methodology. The fourth section reports the results of the production function and an analysis of the sectorial efficiency using kernel distributions, stressing the comparative analysis of the firms' technical efficiency with respect to their receipt or otherwise of subsidies. Finally, Section 5 presents the final conclusions of the work and possible future extensions.

2. DATA AND DESCRIPTIVE ANALYSIS

The data used in this work come from the Survey on Business Strategies (ESEE), built by the SEPI Foundation (Fundación SEPI) during the period 1993-2002. The ESEE has been built combining criteria of exhaustiveness and random sampling in order to maintain the representativeness of the industrial firms of between 10 and 200 employees, by size interval and sector of activity. With regard to the firms with over 200 employees, there is a higher level of representativeness[3]. The initial sample consisted of 14 687 observations, of which we finally worked with an incomplete sample of 5 349 observations (with which we estimated the econometric model described in the following section). This reduction was a result of considering only those firms engaging in R&D. On the other hand, we included both subsidised and non-subsidised firms.

Table 1 shows the distribution of the firms engaged in R&D activities and of the firms receiving public R&D subsidies, classified by size into two subsamples: SMEs (≤200 workers) and large firms (>200 workers) in the period 1993-2002.

Table 1

As can be seen, there are important differences in the proportion of firms engaged in R&D activities during this period in function of the size. On average, the findings confirm that the large firms (>200 workers) have a greater proportion of innovative firms, while the smaller firms (≤200 workers) have far fewer, in no case exceeding 29%. This result suggests that size has a significant and positive effect on the firm's decision to invest in R&D activities. On the other hand, a certain variability is evident in the proportion of firms engaged in R&D activities in each size group over time. With regard to the proportion of firms receiving public subsidies, only a small percentage of firms of under 200 workers receive assistance in this period. The proportion is higher in the firms of over 200 workers, reaching around 25%. There is consequently a positive relation between firm size and proportion of firms receiving public financing. This type of financing comes from three different sources: the regional administration, the central government and European funds.

Table 2 summarises the relevant variables of this work – innovation effort, measured by R&D spending as a proportion of output; and subsidies as a proportion of private R&D spending – differentiating between subsidised firms and all innovative firms, during the period 1993-2002.

Table 2

As can be seen, for the manufacturing firms analysed the R&D effort of the firms receiving subsidies always exceeds that of the innovative firms as a whole, which suggests that receiving subsidies has a positive effect on private R&D effort. With regard to the average subsidy received as a proportion of spending, subsidies represent around 9.05% of total R&D spending for all innovative firms and 32.01% for the firms receiving public financing. Thus, subsidies clearly represent an important part of R&D spending in innovative firms, so in principle they cannot be regarded as a marginal source of financing for firms' R&D.

2.1 Variables employed in the model

Table 3 shows the sample descriptive statistics of the variables used to estimate the model of R&D investment during the period 1993-2002. To measure the output, the production of goods and services, we consider the sum of the sales and the variation in sales inventory for each of the firms analysed. The input variables are the intermediate spending carried out in the production process. Intermediate spending is defined as the sum of purchases and external services, plus the variation in purchase inventory. These variables are converted into constant euros using deflators from the Spanish National Statistics Institute (INE). The variable capital for the period 1993-2002 is represented by the capital stock, which is approximated using the value of net capital at replacement cost less the corresponding accrued depreciation[4]. Spending on research and development is the sum of the internal and external spending, with this latter figure a consequence of any sub-contracting carried out by the firm.

Table 3

3. METHODOLOGY AND MODEL SPECIFICATION

From the management perspective, technical efficiency (TE) for the entrepreneur is understood as a measure of the firm's ability to produce the greatest output possible starting from a set of inputs subject to a particular productive technology and particular resources, and given environmental conditions in terms of threats to, and opportunities for, the entrepreneur's activity. In this respect, TE is a relative concept, with which it is possible to observe each firm's production level comparing it with the best practice in the input-output relation and measuring firms' individual deviations from the best practice considered on the production frontier $Y= F(K,L)$, where Y denotes the firm's output and K, L the inputs, respectively capital and labour. The methodology proposed in this work has been frequently used in economic theory, giving rise to a large variety of works, but it is barely known in the field of management. Recently, Lieberman and Dhawan (2005) proposed a production frontier as an alternative to the more commonly used resource-based view.

In particular, stochastic frontier theory is based on estimating Equation 1:

$$\text{Ln } y_i = \beta_o + \sum_{i=1}^{N} \beta_n \text{ Ln}(x_{n,i}) + v_{it} - u_{it} \qquad [1]$$

where yi is the output of productive unit i, x the vector of inputs x = x1……xn, and β a vector of unknown parameters to be estimated. In this analysis the error term is decomposed into a variable v_{is}, distributed as iid $v_{it} \sim N(0, \sigma_{vi}^2)$, which captures the random noise, and a non-negative variable u_{it}, distributed as semi-normal iid $u_{it} \sim N^+(0, \sigma_{ui}^2)$, which measures the inefficiency in the production. Both terms are independently distributed, and consequently $\sigma_{uv}=0$. This specification is Battese and Coelli's (1992) version of the stochastic frontier model proposed by Aigner et al. (1977) and Meesusen and Van der Broeck (1977).

Figure 1 illustrates the production frontier concept, where *y* denotes the output and *x* the input. The deterministic production function $y = exp(x\beta)$ is drawn assuming that no random noise exists. Nevertheless, the final estimation of the production frontier is stochastic. This means that due to random noise, there may be observations above (point D) or below (point C) the deterministic frontier that belong to the stochastic frontier. On the other hand, the inefficiency level Θ_E for the productive unit E graphically represents the relation between the current production y_E and the maximum production that it should have (y_F) given its level of input x_E. In the general case, the technical inefficiency, estimating Equation 1 by maximum likelihood, can be measured as follows:

$$TE_E = \frac{E[\exp(y_i)/u_i, x_i]}{E[\exp(y_i)/u_i = 0, x_i]} = \exp(-u_i) \quad [2]$$

Figure 1

In recent years, production frontier models have been developed for panel data. This work uses Battese and Coelli's (1995) model, which permits estimation of each firm's technical efficiency as a factor varying over time. Consider a production function of the following form: $Y_{it}= F(K_{it},L_{it})TE(Z_{it})$

where Y_{it} denotes the output of firm i in period t, and K_{it} and L_{it} are capital and labour considered as inputs. The output is determined by the product of *F(•)* and *TE(•)*. Parametrically, the model to estimate in one single stage is an extension of the one described in Equation [1], such that:

$$Y_{it}=exp(x_{it}\beta+ v_{it}-u_{it}) \quad [3]$$

where Y_{it} denotes the production of the observation in t $(t =1,2,....T)$ for firm i $(i = 1,2,...N)$.

x_{it} is a (1 x k) vector of known values, function of the production inputs and other explanatory variables associated with firm i in observation t.

β is a (k x 1) vector of unknown parameters to be estimated.

V_{is} is distributed as iid $v_{it} \sim N(0, \sigma_{vi}^2)$, which captures the random noise, and u_{it} is a non-negative variable, distributed as a semi-normal iid $u_{it} \sim N^+(0, \sigma_{ui}^2)$, which measures the inefficiency in the production. Both terms are independently distributed, and consequently σ_{uv}=0, with mean z_{it} δ, and variance σ^2.

Z_{it} is a (1 x m) vector of explanatory variables associated with the technical production inefficiency of the firms over time, and
δ is an (m x 1) vector of unknown coefficients.

Equation [3] specifies the stochastic production frontier in terms of the original production values. Consequently, the effects of the technical inefficiency, from the term u_{it} are assumed as a function of the explanatory variables, and so we have:

$$u_{it} = z_{it}\,\delta + W_{it}\ ; \qquad [4]$$

where W_{it} is a random variable defined by the truncation of the distribution with mean 0 and variance σ^2, such that the truncation point is – z_{it} *δ.,* W_{it}≥0. Finally, we should mention that the maximum likelihood method is proposed to simultaneously estimate the parameters of the stochastic production frontier and the model of technical inefficiency. This likelihood function and its partial derivatives with respect to the parameters of the model are proposed by Battese and Coelli (1993). The likelihood function is a function of the variance of the parameters $\sigma_s^2 = \sigma_v^2 + \sigma^2$ y $\gamma \equiv \frac{\sigma^2}{\sigma_s^2}$.

The technical efficiency of firm i in observation t is defined as follows:

$$TE_{it} = \exp(-Uit) = \exp(-\, z_{it}\,\delta - W_{it}) \qquad [5]$$

This work assumes the Cobb-Douglas production function, with technological progress through the temporal trend *t*[5]. In this way it is possible to observe the frontier shifting after controlling for the other factors considered. In particular, the function to estimate has the following form:

$$Ln(sales) = \beta_o + \beta_1 Ln\ C_{it} + \beta_2 Ln\ E_{it} + \beta_3\ Ln\ K_{it} + \beta_4\ Ln\ G_{it-1} + \beta_5\, t + \sum_{1}^{20} \beta_6\, sec + v_{it} - u_i \quad [6]$$

where $U_{vi} = Z_{it}\delta + W_{it}$

$$U_{vi} = \delta_0 + \delta_1 S + \delta_2 S^2 + \delta_3\, t + W_{it} \quad [7]$$

where, considering the variables in logarithms, K is the capital variable already explained in the previous section, E is employment, C the intermediate spending, and G the variable that measures spending in R&D. This variable has been lagged one productive period, which is shorter than the period used in studies for more technologically-developed countries. This generally ranges from 1.7 to 2.6 years, depending on the sector and type of activity (Rodríguez, 1995)[6]. Sec denotes a vector of dummies capturing the sectorial effect. Finally, t captures the technological change. With regard to the inefficiency term, S represents the subsidies received by those firms carrying out R&D activities, while S^2 is the quadratic component of the subsidy and *t* the temporal trend. The coefficient *t* in u_{it} [Equation 7] measures the change in inefficiency over time. Consequently, if δ_3 is negative, "catch-up" technical change (movement towards the frontier) is observed, and $-\delta_3$ can be indicated as the coefficient of technological change in U_{vi}.

4. ESTIMATION OF MODEL AND RESULTS

4.1 Estimation of production frontier

Table 4 shows the results of the model estimated in a single stage [6 and 7]. The data used, as mentioned above, are a panel of incomplete data in the period 1993-2002 from the ESEE survey on business strategies.

Table 4

As was mentioned in the previous section, the results shown in Table 4 assume a Cobb-Douglas stochastic production function, which has found ample acceptance in the literature[7]. The chi-square is statistically significant at the 1% level (χ^2_{24}=261473.5). The coefficients of the input variables (capital, employment, purchases and R&D spending) of the production frontier are all positive and statistically significant at the 1% level, which means that as the output produced increases, bigger quantities of all the inputs of production are needed. The coefficient of the trend in the deterministic part of the function, β_5, is positive and statistically significant, indicating a technological change of 0.5% in the period under analysis.

One of the most important stylised facts refers to the results obtained in the part of the error term where the explanatory variable of inefficiency, i.e., the R&D subsidies received, shows a curvilinear behaviour (in the form of an inverted U), since its coefficients δ_1 and δ_2 are positive and negative, respectively, and statistically significant at the 5% and 1% levels. This finding is important for economic policy in Spain, since it allows us to determine the effect of subsidies on the management of resources in firms, and to what extent these incentives are useful. The result obtained indicates a priori that the size of the subsidies relates positively to inefficiency up to a maximum point, from where inefficiency declines as the subsidy grows further. In other words, the subsidies, which are meant to support innovation among Spanish manufacturers, may not be benefiting some of the firms. On the other hand, we accept the hypothesis of constant returns to scale (χ^2=16.02).

We now look more closely at the distribution of the firms receiving subsidies and its relation with inefficiency, by examining the curvilinear model from the coefficients estimated in the model. The function is as follows:

Inefficiency (I) = $\delta_0 + \delta_1 S + \delta_2 S^2 + \delta_3 t$; (I) = $763{,}04+0{,}003 \cdot S - 9.10 \cdot 10^{-7} \cdot S^2$ [8]

Figure 2 illustrates the relation between inefficiency and subsidies. As can be seen, although the relation is curvilinear – the inefficiency dropping as the level of subsidies rises – the mean subsidy is at approximately 445 000 euros, which corresponds to almost 80% of the firms under analysis. Only 2.4% of the observations are located in the downward part of the inefficiency curve. This shows that the important part of the inefficiency curve is where the slope is rising. Subsidies do not incentivise the sample firms under analysis to improve their efficiency.

Figure 2

4.2 Analysis by sector

In this section we analyse the intra-sectorial efficiency for the 20 sectors of activity in Spanish manufacturing industry. Table 5 shows the mean efficiency results obtained for each of the CNAE classification sectors the ESEE survey uses to divide the firms for every year in the period 1993-2002. The average efficiency of the Spanish manufacturing firms carrying out research and development activities ranges from 0.96 to 0.99%. This means that on average the firms are producing around 96-99% of what they could produce given the quantity of resources used. In other words, the firms could raise their production by 4% in the worst case if they were fully efficient[8].

Table 5

Analysing the mean efficiency by sector, some observations stand out (see Figure 3):

Figure 3

a) No significant differences in mean efficiency levels are appreciated between the sectors, since differences do not exceed 3 or 4%.
b) Despite the similar average sectorial efficiencies, there are intra-sectorial inequalities in the evolution of the mean efficiency over time. For example, the mean efficiency of the sectors office machinery and other transport material shows considerable swings, rising and falling abruptly over time, particularly the latter sector.
c) In general terms the mean efficiency of the sectors tends to converge on high efficiency levels.

4.3 Efficiency in function of subsidy behaviour: kernel distributions

In order to observe the relation between firm efficiency and subsidies received or not received, we built a classification variable as follows (Mañez et al., 2004)[9]:

a) Continually subsidised firms: firms receiving subsidies every year in the period under analysis. Such firms represent 6.57% of the sample firms.
b) Incoming firms: firms that do not receive a subsidy at first, begin to receive one at some point, and continue to do so until the end of the period. These firms represent 7.96% of the sample firms.
c) Outgoing firms: firms that receive a subsidy at first, stop doing so at some point, and remain unsubsidised until the end of the period. They represent 6.92% of the sample firms.

d) Alternating firms: firms that change status at least twice in the period under analysis, i.e., they start to receive a subsidy and stop receiving a subsidy at some point in the period. They represent 32.13% of the sample firms.
e) Non-subsidised firms: firms not receiving any type of subsidy at any time in the period of analysis. They represent 46.43% of the sample firms.

Table 6 shows the years for which the firms' subsidy behaviour is observed, using the classification variable mentioned above.

Table 6

The great majority of the firms analysed are found in the two categories non-subsidised and alternating firms, with 46.43% and 32.13%, respectively, while the other groups have far fewer members: continually subsidised firms (6.57%), incoming firms (7.96%) and outgoing firms (6.92%).

Figure 4 shows the evolution of the mean efficiency values dividing the sample according to this classification with respect to the subsidies received or otherwise. As can be seen, the non-subsidised firms differ notably[10] in their mean values from the other types of firm throughout the whole period of analysis, particularly compared to the continually subsidised (or stable) firms.

Figure 4

The incoming, outgoing and alternating firms behave dynamically throughout the period, although the outgoing firms tend to converge with the non-subsidised firms. The analysis carried out up to now has proved very instructive about the relation of interest here between efficiency and R&D subsidies, but the weight of the analysis refers to just one moment in the distribution, namely its mean value. For this reason, we also need to analyse the efficiency distribution by means of density functions, carrying out a non-parametric approximation[11] by using the kernel method, and in particular estimating a Gaussian kernel with optimal bandwidth[12]. The purpose of density estimations is to determine whether convergence or divergence has occurred in the period of analysis. The former would be evident if the probabilistic mass tended to concentrate around certain values. For example, if this point of concentration was greater than 0.9, it would be indicating a convergence process towards values close to the frontier. In contrast, a divergence process would be reflected in a shifting of the probabilistic mass within the distribution. range of the distribution.

Figure 5 shows the density functions of the efficiency for the years 1993, 1996, 1999 and 2002. The results obtained reveal the changes that have taken place in the external shape of the distribution for all the types of subsidy behaviour, changes which confirm convergence processes towards upper efficiency levels. In this respect, the external shape of the efficiency distribution appears to be maintained in a single mode, but one that is shifting over time.

Figure 5

We should stress that in some subsamples of this classification the number of observations is low, and so the distribution appears incomplete in such cases. As was mentioned, examining Figure 5 from the top to the bottom graph, the distributions can be seen to shift towards higher values, particularly for the non-subsidised firms compared to the continually subsidised firms. Meanwhile, examining each graph from left to right, there is a greater spread in the distributions in the case of the firms continually receiving subsidies (stable firms), or those that start receiving them and continue to be subsidised (incoming firms), compared to the other groups, particularly the unsubsidised firms.

In short, whether from the perspective of the mean efficiency values or applying kernel distributions to observe the whole distribution, the analyses indicate that the non-subsidised firms are more efficient than the firms that continually receive subsidies. Even the firms that stop receiving subsidies appear to behave better.

5. CONCLUSIONS AND FINAL RECOMMENDATIONS

This work provides new evidence about the effects of subsidies for research and development on the technical efficiency of a sample of Spanish manufacturing firms from the ESEE survey on business strategies during the period 1993-2002. We have estimated the Cobb-Douglas stochastic production frontier following Battese and Coelli's (1995) model to analyse an incomplete panel of innovative firms, introducing the subsidies received by the firms as explanatory variable of their inefficiency.

Although subsidies form only a part of the assistance obtained by Spanish manufacturers (they also receive tax relief, soft loans, etc.), they are a very important part of such aid. In this respect, one of the conclusions of this work relates to the curvilinear relation between inefficiency and subsidies. In other words, as the size of the subsidy increases, so does the inefficiency up to a certain point, after which the inefficiency begins to decline. Despite this behaviour, more than 85% of the sample firms are in the growth part of this relation, and 78% are in the part with the steepest slope. This finding suggests that economic policymakers should be extremely cautious about using subsidies to incentivise R&D activities among Spanish manufacturing firms.

On the other hand, the results of the classification of the firms in function of their receipt of subsidies for research and development (continually subsidised, incoming, outgoing, alternating and non-subsidised firms) with respect to the efficiency show that during the period under analysis the non-subsidised firms are more efficient than the firms receiving subsidies every year in the period. In addition, a full analysis of the distribution by means of kernel distributions allows us to confirm the relatively stronger convergence towards higher efficiency levels over time among non-subsidised firms.

The Spanish firms analysed here experience a small level of technical progress over time. Analysis of their efficiency at the sectorial level shows that the mean efficiency of Spanish industrial firms ranges from 94% to 99%. This finding indicates that on average, Spanish firms could produce at higher levels. These results are quite different to those of other works using data from the same survey. The differences could be due to two reasons: i) the sample of firms analysed in this work is limited to those that carry out innovation activities, and the time period is longer; and ii) although the current study uses a Cobb-Douglas model, like Martín and Marcos (1997), Gumbau (1998), and Gumbau and Maudos (2002), it applies an estimation model in one single stage, introducing the variable subsidies as determinant of the efficiency. Nevertheless, the efficiency measure refers to a judgment about the relation between the resources used (inputs) and a measure of the results obtained (output), so that the idea of opportunity costs underlies both concepts (Bosch et al., 1998).

The absence of other work in this line of research relating efficiency and subsidies, at the national or international levels, has prevented us from comparing the results obtained here in this specific context. Possible extensions of this work could focus on comparing the results obtained here with those of firms from other countries. The findings of this work could also suggest some interesting reflections, for example: it appears to be inefficient to continue subsidising Spanish manufacturing firms as is being done at present. This may have something to do with the size of the subsidies, the time it takes for the subsidies to reach the firms, or the process of selecting which firms to subsidise. In this respect, larger firms probably obtain subsidies for projects that they could have undertaken without such assistance, while smaller firms may not be obtaining subsidies, making it impossible for them to undertake larger-scale projects.

Notes

1.The author is grateful for comments and suggestions from Vicente Salas Fúmas and Sergio Perelman. All remaining errors or failings are the sole responsibility of the author.

2 The author of this work recognise the support received from the Regional Government of Castille-La Mancha(Spain).

3. A description of this database can be seen in Fariñas and Jaumandreu (1999).

4. The formula of permanent inventory is $KNR_t = I_t + KNR_{t-1}(1-\delta_t)\ p_t/P_{t-1,}$ where KNR is the net capital at replacement cost, It the investment in capital assets, δ_t the depreciation rate of the capital assets, and Pt the price indexes for capital assets published by the National Statistics Institute (INE).

5. The Cobb-Douglas production function was chosen because of its simplicity and validity in different works (Zellner et al., 1996). Nevertheless, we also tried to use the trans-log function, but the likelihood function had problems of convergence.

6. Nevertheless, we estimated different models lagging the variable R&D spending by more than one year. The results barely changed.

7. Using ESEE data, authors such as Gumbau (1998) and Martín and Suarez (1997) use this same specification.

8. In Gumbau's (1998) comparative study for the period 1991-1994, these values are lower, ranging from 76% to 83%. In the current study, the model follows Battese and Coelli's (1995)

approach, the time period is much longer and the sample of firms is different, since the firms carry out innovation and development.

9. These authors use the same criterion applied to firms carrying out R&D, the idea being to avoid sample selection bias.

10. A comparison of means was conducted through the Kruskal-Wallis test, which was found to be statistically significant at the 5% level. This type of test was chosen rather than an ANOVA due to the non-normality of the sample, it being truncated at value 1.

11. This type of approach does not impose, a priori, any functional form on the distribution. As is commonly said, non-parametric estimation "lets the data speak for themselves".

12.A kernel can be regarded as a smoothed version of a histogram. The bandwidth of the kernel measures the degree of smoothness employed in estimating the density function. The value of the smoothing parameter is determined following Silverman's (1986) approach.

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Table 1: Distribution by size of firms investing in R&D and of firms receiving public R&D subsidies (as % of total) 1993-2002. (Standard deviation in brackets).

	Firms investing in R&D		**Firms receiving R&D subsidies**	
Year	≤ 200 workers	> 200 workers	≤ 200 workers	> 200 workers
1993	24.62 (2.05)	75.71 (3.09)	5.34 (2.34)	26.57 (3.21)
1994	24.18 (3.83)	77.4 1(3.21)	4.87 (3.21)	22.58 (4.01)
1995	22.85 (4.23)	72.23 (4.00)	4.70 (3.05)	21.86 (3.78)
1996	23.36 (2.23)	72.54 (2.67)	5.14 (3.12)	22.92 (2.89)
1997	23.08 (3.23)	74.06 (3.12)	5.02 (2.89)	22.69 (3.56)
1998	26.39 (2.22)	76.36 (3.89)	4.79 (3.00)	25.87 (4.03)
1999	25.64 (2.35)	78.53 (4.11)	5.04 (3.45)	23.48 (3.25)
2000	28.82 (4.01)	75.28 (3.45)	5.64 (2.78)	27.48 (3.07)
2001	22.70 (3.33)	73.19 (3.49)	4.54 (4.01)	23.34 (4.89)
2002	22.35 (3.05)	75.69 (4.01)	5.18 (3.33)	24.00 (3.12)

Source: The Authors, from ESEE data.

Table 2: Means of relevant variables 1993-2002

Year	**All firms** R&D effort (% spending/sales)	**Subsidised firms** R&D effort (% spending/sales)	**All firms** Mean subsidy/total R&D spending (%)	**Subsidised firms** Mean subsidy/total R&D spending (%)
1993	2.13(3.52)	3.41(5.23)	6.92(19.2)	27.0(30.0)
1994	1.96(3.02)	3.18(4.65)	9.80(35.4)	39.3(63.7)
1995	1.95(3.40)	3.69(4.83)	8.11(29.2)	30.3(51.8)
1996	1.88(3.13)	3.33(4.72)	8.35(29.0)	31.2(50.5)
1997	1.88(2.79)	3.21(4.32)	7.78(24.1)	28.7(40.1)
1998	1.89(2.79)	3.16(3.78)	8.63(29.5)	31.8(47.4)
1999	2.04(3.30)	3.81(4.47)	7.33(25.7)	27.4(41.5)
2000	2.07(4.19)	3.35(4.18)	11.5(35.9)	36.8(58.7)
2001	1.98(2.95)	3.23(3.08)	9.96(27.6)	34.1(43.2)
2002	1.85(2.67)	3.26(3.53)	12.2(41.3)	37.1(55.6)

Source: The Authors, from ESEE data.

Table 3: Descriptive statistics of variables of production frontier model, 1993-2002

Variable	No. obs.	Mean	SD	Minimum	Maximum
Lnsales	5461	10.1503	1.6536	4.8548	15.6072
Lncapital	5461	8.3446	1.9146	0.7662	14.0385
Lnspending	5429	9.4280	1.7831	2.3116	15.4279
Lnemployment	5452	5.0827	1.4326	0	9.5369
LnRDspending	5360	5.3608	2.0361	-3.3233	12.5396
Subsidies	5360	445.64	1585.6	0.0420	28313.6

Source: The Authors, from ESEE data.

Figure 1

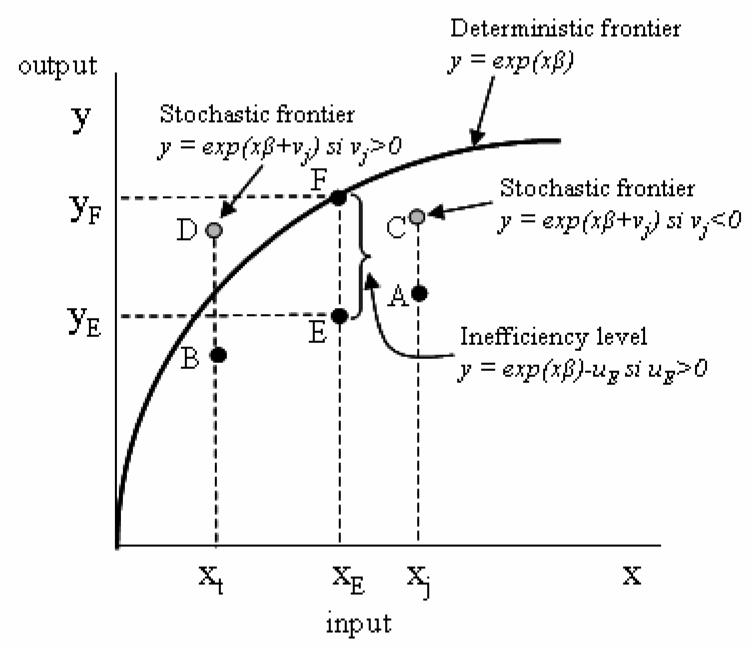

Figure 1. Calculation of technical inefficiency using stochastic production frontiers

Table 4

Results of estimation	Estimated Coefficient	Std. Error
Production frontier		
B_0	-8.793**	4.508
β_1 *(Capital)*	0.122***	0.004
β_2 *(Purchases)*	0.600***	0.004
β_3 *(Employment)*	0.247***	0.005
β_4 *(R&D spending)*	0.019***	0.002
β_5 *(trend)*	0.005***	0.022
sector dummies		
β_{6_2} *(Food and tobacco products)*	0.006	0.025
β_{6_3} *(Beverages)*	0.147***	0.032
β_{6_4} *(Textiles and clothing)*	-0.171***	0.025
β_{6_5} *(Leather and footwear)*	-0.207***	0.032
β_{6_6} *(Wood industry)*	-0.205***	0.039
β_{6_7} *(Paper industry)*	-0.134***	0.031
β_{6_8} *(Publishing and graphic arts)*	-0.041	0.035
β_{6_9} *(Chemical products)*	0.035	0.024
β_{6_10} *(Rubber and plastic products)*	-0.121***	0.026
β_{6_11} *(Non-metallic mineral products)*	0.093***	0.026
β_{6_12} *(Ferrous and non-ferrous metals)*	-0.028	0.026
β_{6_13} *(Metal products)*	-0.064***	0.026
β_{6_14} *(Agricultural and industrial machines)*	-0.148***	0.024
β_{6_15} *(Office machinery)*	-0.050	0.030
β_{6_16} *(Electrical machinery and material)*	-0.093***	0.025
β_{6_17} *(Motor vehicles)*	-0.138***	0.025
β_{6_18} *(Other transport material)*	-0.161***	0.030
β_{6_19} *(Furniture industry)*	-0.085***	0.029
β_{6_20} *(Other manufacturing industries)*	-0.038	0.033
Equation u_{it}		
δ_{uo}	763.04***	300.08
δ_1 *(Subsidy)*	0.003***	0.001
δ_2 *(Subsidy)^2*	$-9.10 \cdot 10^{-7}$**	$-3.96 \cdot 10^{-7}$
δ_3 *(trend)*	-0.385***	0.150
Equation v_{it}		
δ_{vo}	-2.964***	0.020
σ_v	0.227	0.002
Log-likelihood	317.65	
No. observations	5329	

β_{6_1} =sector omitted: Meat industry; Significance levels= ***1%, **5%, *10%

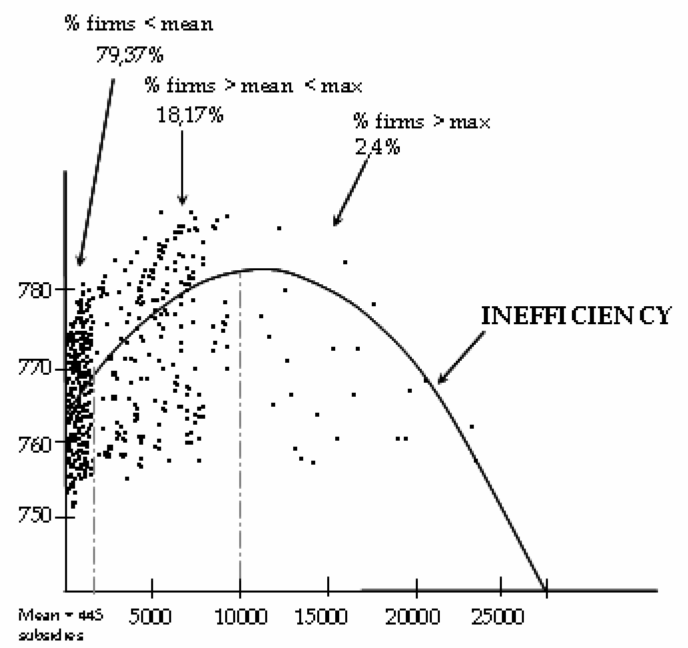

Figure 2. Distribution of firms with respect to subsidies and inefficiency

Table 5

Sector	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Meat industry	0.964	0.969	0.973	0.980	0.983	0.986	0.989	0.986	0.989	0.993
	0.003	*0.005*	*0.008*	*0.001*	*0.001*	*0.002*	*0.000*	*0.015*	*0.006*	*0.002*
Food and tobacco	0.965	0.971	0.976	0.980	0.983	0.985	0.988	0.990	0.992	0.992
	0.004	*0.004*	*0.002*	*0.002*	*0.001*	*0.008*	*0.002*	*0.003*	*0.001*	*0.006*
Beverages	0.966	0.971	0.976	0.980	0.983	0.987	0.989	0.991	0.991	0.993
	0.004	*0.003*	*0.002*	*0.001*	*0.001*	*0.001*	*0.000*	*0.000*	*0.004*	*0.002*
Textiles and clothing	0.965	0.971	0.975	0.980	0.982	0.985	0.989	0.990	0.992	0.993
	0.005	*0.004*	*0.003*	*0.002*	*0.006*	*0.005*	*0.002*	*0.002*	*0.003*	*0.002*
Leather and footwear	0.962	0.968	0.975	0.980	0.983	0.986	0.987	0.989	0.993	0.994
	0.008	*0.009*	*0.003*	*0.001*	*0.001*	*0.001*	*0.007*	*0.006*	*0.000*	*0.000*
Wood industry	0.965	0.972	0.978	0.981	0.984	0.987	0.989	0.988	0.989	0.992
	0.001	*0.002*	*0.003*	*0.001*	*0.000*	*0.000*	*0.000*	*0.009*	*0.008*	*0.005*
Paper industry	0.959	0.964	0.976	0.980	0.983	0.986	0.988	0.989	0.992	0.994
	0.011	*0.016*	*0.003*	*0.002*	*0.003*	*0.002*	*0.001*	*0.007*	*0.002*	*0.000*
Publishing and graphic arts	0.967	0.971	0.976	0.979	0.984	0.987	0.989	0.988	0.992	0.992
	0.004	*0.003*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.005*	*0.000*	*0.003*
Chemical products	0.961	0.969	0.974	0.979	0.981	0.984	0.987	0.987	0.990	0.989
	0.013	*0.006*	*0.004*	*0.004*	*0.013*	*0.009*	*0.005*	*0.010*	*0.010*	*0.010*
Rubber and plastic products	0.964	0.971	0.976	0.980	0.983	0.986	0.989	0.990	0.990	0.994
	0.003	*0.002*	*0.001*	*0.001*	*0.001*	*0.002*	*0.001*	*0.002*	*0.009*	*0.000*
Non-metallic mineral p.	0.963	0.970	0.975	0.979	0.982	0.985	0.987	0.988	0.992	0.993
	0.004	*0.004*	*0.004*	*0.005*	*0.006*	*0.003*	*0.007*	*0.008*	*0.001*	*0.003*
Ferrous & non-fer. metals	0.959	0.965	0.973	0.976	0.982	0.984	0.984	0.987	0.992	0.993
	0.023	*0.016*	*0.012*	*0.013*	*0.008*	*0.006*	*0.016*	*0.012*	*0.002*	*0.003*
Metal products	0.958	0.964	0.972	0.978	0.979	0.984	0.988	0.989	0.992	0.993
	0.023	*0.020*	*0.020*	*0.008*	*0.020*	*0.009*	*0.005*	*0.005*	*0.002*	*0.003*
Agric. & ind. machines	0.963	0.964	0.970	0.978	0.982	0.984	0.986	0.989	0.991	0.991
	0.008	*0.049*	*0.028*	*0.008*	*0.009*	*0.012*	*0.013*	*0.009*	*0.006*	*0.007*
Office machinery	0.950	0.962	0.971	0.972	0.968	0.980	0.984	0.991	0.992	0.993
	0.032	*0.024*	*0.019*	*0.023*	*0.030*	*0.016*	*0.016*	*0.003*	*0.001*	*0.001*
Elec. machinery & material	0.959	0.965	0.969	0.976	0.981	0.984	0.986	0.989	0.988	0.992
	0.015	*0.018*	*0.018*	*0.011*	*0.006*	*0.006*	*0.007*	*0.006*	*0.010*	*0.006*
Motor vehicles	0.958	0.967	0.972	0.975	0.982	0.983	0.986	0.987	0.990	0.992
	0.019	*0.018*	*0.012*	*0.015*	*0.010*	*0.008*	*0.012*	*0.010*	*0.009*	*0.007*
Other transport material	0.944	0.953	0.954	0.967	0.966	0.968	0.981	0.972	0.985	0.989
	0.024	*0.024*	*0.046*	*0.041*	*0.034*	*0.028*	*0.015*	*0.028*	*0.019*	*0.018*
Furniture industry	0.967	0.971	0.976	0.980	0.984	0.987	0.989	0.989	0.992	0.994
	0.003	*0.001*	*0.002*	*0.001*	*0.000*	*0.001*	*0.000*	*0.006*	*0.001*	*0.000*
Other manuf. industries	0.965	0.969	0.976	0.979	0.984	0.987	0.988	0.989	0.992	0.994
	0.006	*0.011*	*0.002*	*0.002*	*0.001*	*0.000*	*0.002*	*0.004*	*0.000*	*0.001*
Max.	0.967	0.972	0.978	0.981	0.984	0.987	0.989	0.991	0.993	0.994
Min.	0.944	0.953	0.954	0.967	0.966	0.968	0.981	0.972	0.985	0.989
Mean	0.961	0.967	0.973	0.978	0.981	0.984	0.987	0.988	0.991	0.992

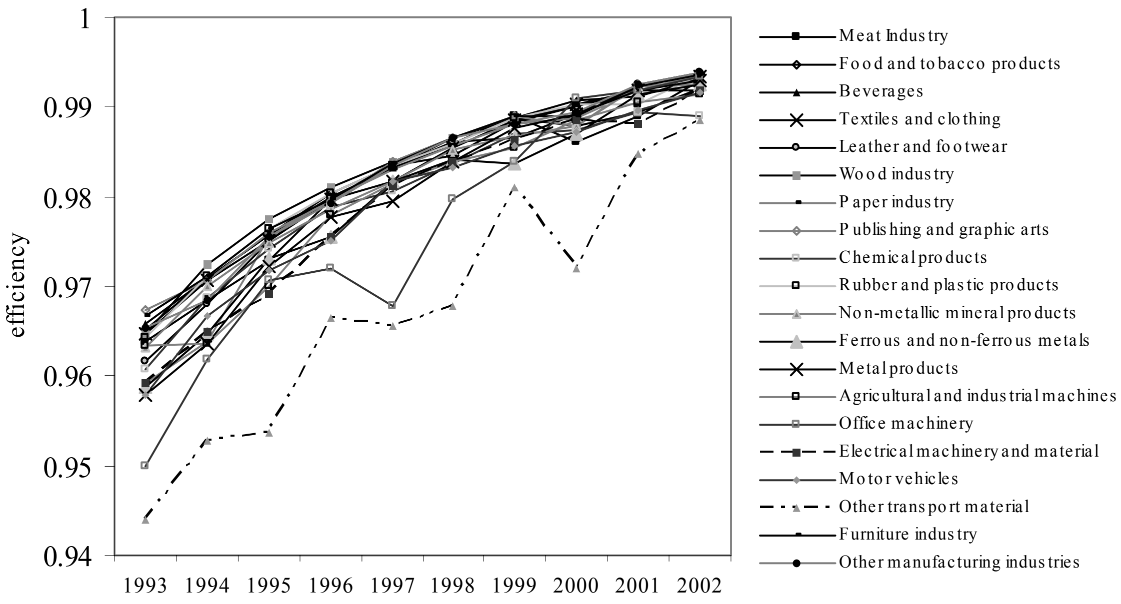

Figure 3. Evolution of mean efficiency by sector of activity

Table 6

Trend			Years									
	Obser.	%	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Con. subs.	350	6.57	33	36	37	30	34	34	33	45	35	33
Incoming	424	7.96	37	44	44	37	41	38	42	53	43	45
Outgoing	369	6.92	41	39	35	34	39	42	43	41	30	25
Alternating	1712	32.13	136	160	162	178	186	195	201	191	154	149
Non-subs.	2474	46.43	227	257	238	236	270	294	285	263	204	200
	5329	100%	474	536	516	515	570	603	604	593	466	452

Source: The Authors from ESEE data.

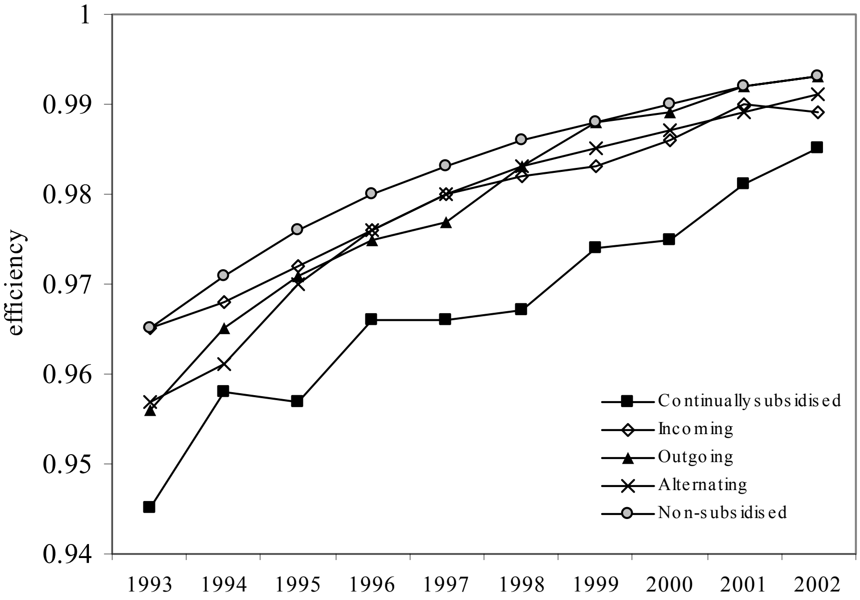

Figure 4. Distribution of mean efficiency values with respect to subsidy behaviour

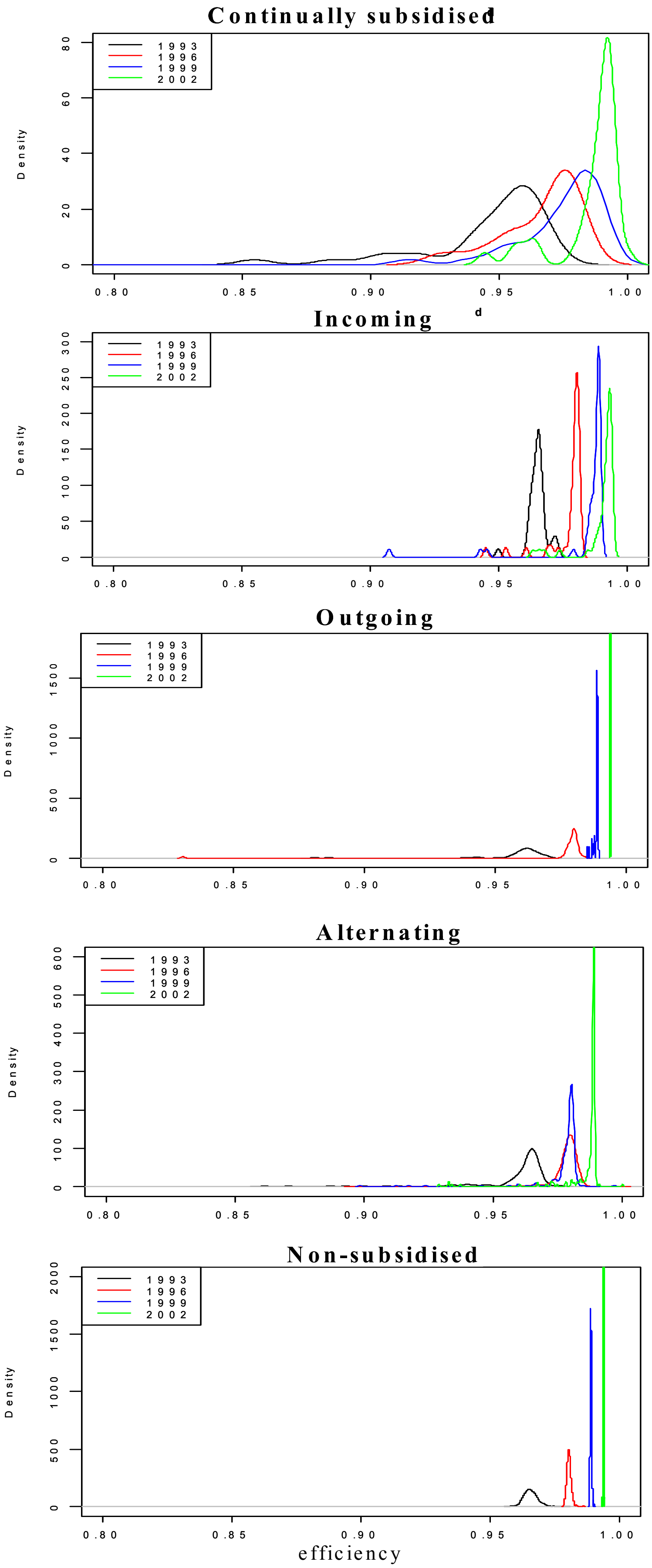

Figure 5. Kernel distributions of efficiency by subsidy behaviour