# THE DETERMINANTS OF EFFICIENCY: THE CASE OF THE SPANISH INDUSTRY

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Mercedes Gumbau-Albert[a]

Joaquín Maudos[a,b]

[a] Universitat de València; Departamento de Análisis Económico; Edificio departamental oriental, Avda. de los Naranjos, s/n; 46022 Valencia (Spain); Tel. 346.382.82.46; Fax. 346.382.82.49; E-mail: Mercedes.Gumbau@uv.es

[b] Instituto Valenciano de Investigaciones Económicas (IVIE); c/ Guardia Civil, 22, Esc. 2, 1º, 46020 Valencia (Spain).

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**Joaquín Maudos**

## Abstract

The aim of this paper is to analyse the factors explaining the technical efficiency of Spanish industrial sectors during the period 1991-1994 using the Survey of Business Strategies (SBE) of the Ministry of Industry and Energy. We analyse whether efficiency can be explained by factors external to the firm such as the degree of competition in the markets in which it operates, characteristics of the firm (size, organisation, advantages of location, participation of public capital, etc.), as well as the effects of dynamic disturbances that may affect the degree of utilisation of the productive capacity.

**Key words:** technical efficiency, production frontier, determinants of efficiency.

## 1. Introduction

Technical efficiency consists of maximising the level of production that can be obtained from a given combination of factors. The concept of technical efficiency indicates the degree of success in the utilisation of productive resources. Therefore, inefficiency is simply the difference between the observed values of production and the maximum values attainable given the technology used. To estimate the differences among the economic agents it is necessary to estimate the production frontier at which the efficient agents are located. The deviations of the remaining firms from this frontier, i.e. their inefficiencies, are then calculated.

Earlier studies in the economic literature have analysed both the models and the determinants of productive efficiency using frontier approaches. Outstanding among them are the studies by Beeson and Husted (1989) and Perelman (1995). The first uses a stochastic function model to measure productive efficiency in the manufacturing sector of states of United States. Variation in productive efficiency are related to regional differences in labor-force characteristics, level of urbanization and industrial structure. The second one, estimates total factor productivity (TFP) using a parametric stochastic frontier and a non parametric production frontier (DEA). The TFP is decomposed into two components, technological progress and efficiency change and their relationship is tested with a set of potential explanatory variables that includes R&D expenditures, international competition and structural characterisitcs.

For the case of Spain, frontier estimations of efficiency have been made at major sector level in Prior (1990), Gumbau and Maudos (1996) and Maudos et al. (2000a and b). The first analyses the efficiency of the industrial sector of the regions, using a non-parametric deterministic approach, while the other three studies analyse the efficiency of the major productive sectors (agriculture, industry, energy, construction and private services) in the Spanish regions using, in Gumbau and Maudos (1996) a parametric stochastic approach, and in Maudos et al. (2000a and b) a non-parametric deterministic approach. At intra-sector level, only the study by Gumbau (1998) estimates the efficiency levels of the Spanish industrial sectors.

However, the Beeson and Husted (1989) paper have used panel data estimators to obtain a measure of the inefficiency, but the disadvantage of this models is that they assume that inefficiency is constant over time. We have used several distributional assumptions over the inefficiency to avoid this problem. Perelman (1995) uses a cross country approach while we use an intra and inter-industry approach.

In addition, to date there has been no study referring to Spanish industry which, using frontier techniques, analyses the determining factors of efficiency. The recent studies by Argimón et al. (1997) and Artola and Argimón (1998) analyse the determining factors of the efficiency of public enterprises and private firms in Spain, but use a non-frontier approach to the measurement of efficiency, constructing an efficiency index based on the productivity of labour.

Consequently, this study aims to offer, for the first time in the case of Spanish industry, empirical evidence on the factors explaining firms' degree of efficiency using , both at aggregate level for all industry and at sector level. Since economic theory does not offer us a model to explain the determinants of efficiency, the study does not aim to find causal relations but only correlations between efficiency and a set of variables that in other studies have been shown to explain efficiency.

To sum up, the aim of this paper is to analyse the determinants of the efficiency of Spanish industry, the latter being estimated using a frontier approach. The study is based on the data for a number of 1149 firms covering the whole of the industrial manufacture of the Spanish economy, captured by the Survey of Business Strategies (SBE - *Encuesta Sobre Estrategias Empresariales*) by the Ministry of Industry and Energy. The paper is structured as follows. Section 2 briefly describes the factors that the literature has pointed out as explaining differences in efficiency. Section 3 describes the sample and the variables used. Section 4 presents the empirical results of the analysis of the determinants of efficiency in Spanish industry. Finally, section 5 presents the conclusions of the study.

## 2. The determinants of efficiency

The object of this section is to identify the factors that affect the levels of efficiency of each firm. As Lovell (1993) indicates, "the identification of the factors that explain differences in efficiency is essential for improving the results of firms although, unfortunately, economic theory does not supply a theoretical model of the determinants of efficiency". However, according to Caves and Barton (1990) and Caves (1992), several studies have developed a strategy for identifying the determinants of efficiency. These determinants can be summarised as follows:

1. Factors external to the firm, such as the degree of competition existing in the markets in which they operate.

2. Characteristics of the firm itself such as size, type of organisation, greater or lesser intensity of investment and the advantages of the location of the firm.

3. Dynamic disturbances or deviations from the firm's long term equilibrium situation. These disturbances may be a consequence of the evolution of the demand faced by the firm, or a consequence of certain of the firm's production strategies such as the degree of technical innovation.

4. Public vs. private ownership of the firm. The degree of public intervention in the management of firms can affect the degree of efficiency in the use of productive factors.

With regard to competitive conditions, perfect competition reduces inefficiency since it implies that a large number of firms co-exist in the same market, using the same technology, making a homogeneous product, and furthermore both producers and consumers have perfect information on the conditions of the market. In this sense, authors such as Carlsson (1972) and Caves and Barton (1990) maintain that the presence of competitors in an economy increases the diffusion of information and technical knowledge that could be considered to be a source of experience, which can increase the efficiency of the agents participating in this economy. This effect can be valued using a measurement of the concentration of the market in which the firms carry out their activity (CONC) and a negative

relationship between degree of concentration and efficiency is therefore to be expected, as the firms with least market power will be more stimulated to develop strategies (differentiating, innovating, etc.) to modify their market conditions, whereas firms with greater market power will not feel threatened by the potential competition. However, the opposite result could be obtained if firms experience a very intense degree of competition, as in this case all stimulus to carry out these strategies disappears, since the gains from them are immediately cancelled by their rivals.

However, the effect of external competition (EC) on efficiency remains to be determined. The effect of internal competition may be reduced if the market is dominated by importing or export-oriented firms. Therefore, one way to test this aspect is to measure the degree of firms' external competition by means of international trade, the degree of openness or the propensity to export. In this case, the firms with a higher degree of openness will be forced to improve their efficiency in order to compete with foreign firms. It is therefore to be expected that the degree of foreign competition will decrease business inefficiency, and so *a priori* we would expect external competition to have a positive effect on individual efficiency.

Secondly, if we concentrate on the effect of factors of the firm's internal organisation, it is of interest to analyse whether there are differences in efficiency as a function of the size of production (SIZE). Technical efficiency can be related to the scale or size of firm if, as according to Torii (1992), it is assumed that maintaining or improving efficiency demands a cost in terms of the firm's management, or in other words, a cost of determining how much should be invested in preserving the firm's results. According to Caves (1992) this cost is not proportional to the firm's output, but on the contrary: the larger the size of the firm the lower the unit cost in terms of the firm's management.

Thirdly, differences in efficiency are also usually attributed to a higher ratio of investment to physical capital (INV) if it is assumed that new production technologies are incorporated into the new capital purchases, so that technological improvements stimulate the growth of efficiency in the industry. A positive association is therefore expected between gross capital formation and technical efficiency.

Gumbau and Maudos (1996) find substantial differences in the average levels of efficiency among regions. For this reason, in order to represent the effects caused by the location of the firm, dummy variables are constructed to represent the firm's location in one of the 17 Autonomous Communities (regions) of Spain. The aim of this is to capture the effects on the efficiency of each firm that may be caused by factors such as the greater availability of services, intermediate information channels and productive inputs which may encourage efficient use of productive resources.

Fourthly, the growth of demand - expanding market (EXPM), stable market (STAM) or market in recession (RECM) - has been pointed out as one of the factors that may influence the degree of efficiency of Spanish industry. Perelman (1995) indicates that the expansion of the market can be seen as an economic opportunity for the firm, so that it may consider carrying out projects to develop new products or production processes which would therefore improve the firm's efficiency. A positive relationship can also be expected between efficiency and expanding markets as a result of the higher degree of utilisation of the productive capacity.

We will also analyse the degree of association between innovation or occurrence of technical change (INNOV) and efficiency. According to Torii (1992) this effect is ambiguous as the effect of the innovating effort on efficiency may be of positive or negative sign. According to this author, it can be assumed that efficiency improves if a firm invests and increases its capacity to introduce new products and production processes, in which case we should expect a positive relationship between the degree of innovation or technical change and the level of efficiency. However, a high degree of technological innovation or a rapid change in the technological environment could cause unequal disturbances in the firms of a sector, therefore increasing inefficiency. In this case, it is being implicitly assumed that innovations can move upwards the production function of one firm, making non-innovating firms appear more inefficient. If this hypothesis holds good, there will be a negative association between efficiency and innovative effort.

Finally, part of the literature has concentrated on analysing the relationship between private or public ownership and the degree of efficiency attained in production. The available evidence is ambiguous[1]. We will analyse the influence of the degree of participation of the public sector in firms,

measured as the percentage of public capital in the total equity of a firm (PUBK). As pointed out by Argimón et al. (1997), "although the theory gives reasons that may explain the relatively lower efficiency of public enterprises, the results are not conclusive. The indetermination resulting from theoretical analysis therefore makes it necessary to look at the empirical evidence".

## 3. Sample and variables used

The technical efficiency of a firm is achieved by maximising production with the quantity of productive factors used. The index of technical efficiency is defined as the quotient between the level of production achieved and the maximum that a firm could achieve by being efficient. To calculate this maximum value it is necessary to estimate the so-called production frontier at which efficient firms are located, inefficiency being calculated on the basis of the distance separating a firm from the production frontier. These estimations were previously made in Gumbau (1998) using the stochastic frontier approach.

The functional form of the production function is assumed to be of the Cobb-Douglas type, supposing that the level of production -value added- (Y) depends on the quantity of labour (L) and capital (K). The production function is estimated jointly for the whole sample, though each of the sectors into which Spanish industry is divided is allowed to have its own production technology and therefore different elasticities for labour and capital. The estimations are carried out on the data of a complete panel of 1149 firms from 18 industrial sectors captured in the Survey of Business Strategies for the period 1991 to 1994.

Once the efficiency is estimated we analyse its determinants. In order to represent the importance of competition (external and internal) on productive efficiency, we construct, on the basis of the SBE data, two variables that respectively represent the importance of international trade for each firm, and the concentration of the market. The first of these variables is measured by the percentage of exports in the total sales of each firm (EC)[2], while the concentration variable (CONC) is defined as the percentage of total sales represented by the four biggest firms in the principal market in which they compete. The degree

of response to the concentration variable in the SBE is low, and an estimation of this variable has therefore been carried out for those firms that did not respond. For this purpose we proceeded to identify the markets in which these non-responding firms operate, taking into account the sector to which they belong, the geographical extent of their operations (local, regional, national ...) and the number of competitors that they claim to have in their own sector. Once the markets have been identified, they are assigned the average concentration value derived from operating with the responses from the firms working in the same market.

The size of a firm (SIZE) is quantified by the value of its sales in pesetas of 1990 using as deflator the Index of Industrial Prices of the National Statistical Institute for the 18 two-digit sectors making up the SBE, while the (INV) variable measures the firm's investments as a percentage of its physical capital. The growth of demand is quantified by two dummy variables (EXPM) and (STAM) representing, respectively, whether the firm perceives that the potential market in which it carries out its activity is in a situation of expansion or stability, the reference category being a market in recession (RECM). The degree of technological innovation is measured by the ratio of a firm's R&D costs to its sales, thus representing the effort of technical change made by each firm (INNOV).

The effect of the degree of public sector intervention is quantified by means of the percentage of the state share in the firm's capital (PUBK).

Finally, to represent the effects of the firm's location, dummy variables are constructed representing the firm's location in one of the 17 regions of Spain.

## 4. Empirical results

In order to identify the factors affecting the levels of technical efficiency of Spanish industrial firms we start from the estimation of technical efficiency levels in Gumbau (1998) for all the firms of the 18 sectors forming Spanish industry during the period 1991-1994. According to this paper, the average efficiency of Spanish industry for the period 1991-1994 oscillates around 76%. This means that, on

average, Spanish firms produce about 76% of what they could produce with the resources they use. In other words, they could increase production by about 24% if they were efficient in production. However, according to this study, no significant differences can be appreciated among sectors at the *average* levels of efficiency, although there are substantial intra-sector inequalities and also some sectors undergo substantial individual variations of efficiency over the period analysed.

Having estimated the efficiency of each firm in each year of the sample as a quotient between observed production (Y) and the efficient maximum (Y*), the model to be estimated in order to analyse the factors explaining efficiency is as follows:

$$EFIC_{it} = \frac{Y_{it}}{Y_{it}^{(}} = \frac{f(X_{it},\hat{\mathbf{a}})\exp(v_{it}-u_{it})}{f(X_{it},\hat{\mathbf{a}})\exp(v_{it})} = \exp(-u_{it}) = g(H_{it}\hat{\mathbf{a}}+\ddot{\mathbf{e}}_i+w_{it}) \qquad (1)$$

where i=1...1149, t=1991...1994, $H$ are the variables explaining efficiency, $\ddot{\mathbf{e}}_i$ are the individual effects, $w_{it}$ is a random variable, and the dependent variable ($EFIC_{it}$) is the index of technical efficiency obtained in Gumbau (1998). The explanatory variables have been defined in the previous section.

The procedure whereby the efficiency is obtained in a first stage and its determinants analysed in a second stage requires some clarification. Firstly, since efficiency is a variable ranging from one to zero it is necessary to use a non-linear specification of the functional form $g$, such as the logistic or exponential specification. Secondly, since efficiency and the explanatory variables such as concentration, size of firm or innovation are determined jointly, problems of simultaneity may occur. To avoid the biases deriving from this problem, the explanatory variables have been instrumented using for this purpose the variables' own lags. And thirdly and lastly, the variable to be explained in the second stage is an unobserved variable, as it has been estimated in the first stage. This may therefore affect the errors estimated. This possible error of measurement or uncertainty in the variable to be explained will cause the variance of the error term of the second stage to be greater, and therefore the variance of the parameters will also be greater. Thus, there is a tendency to underestimate the standard errors of the second stage.

Given the availability of a panel of data, and with the aim of eliminating the unobservable individual effects, the estimations are made in first differences[3]. In order to take into account the problems of endogeneity of the explanatory variables, we use a version of the generalised moments method (GMM) using lags of the variables as instruments. More specifically, the explanatory variables are instrumented using lags in t-2 and after. Thus, although the sample covers the period 1991-1994, the first cross section used in the estimations is 1993 because one year is lost by taking differences and another by using as instrument the first lag of the explanatory variables.

As mentioned above, it is necessary to adopt non-linear functional specifications because the variable to be explained ranges from zero to one. Using in (1) the logistic functional form, we have:

$$EFIC_{it} = \frac{e^{H_{it}\hat{a}\%\ddot{e}_i\%w_{it}}}{1\%e^{H_{it}\hat{a}\%\ddot{e}_i\%w_{it}}} \qquad (2)$$

and if we take logarithms,

$$Ln\frac{EFIC_{it}}{1\&EFIC_{it}} = H_{it}\hat{a}\%\ddot{e}_i\%w_{it} \qquad (3)$$

If we use the exponential function,

$$EFIC_{it} = e^{H_{it}\hat{a}\%\ddot{e}_i\%w_{it}} \qquad (4)$$

which, if we take logarithms, makes the estimation easier as only efficiency has to be transformed using logarithms.

Using the logistic functional form[4], the determinants of the efficiency of Spanish industrial firms are estimated as presented in table 1. It can be seen that the test of restrictions of over-identification does not reject the validity of the instruments used.

With regard to the determinants of efficiency, we would highlight, firstly, the existence of a positive association between size of firm (SIZE) and efficiency, a result which agrees with those obtained in Caves (1992) and Seong (1992). This may be the consequence of a higher level of quality in the making of internal decisions or in the organisation of the production process in firms of larger size.

Secondly, a negative correlation is obtained between the effort of innovation (INNOV) and the level of efficiency of each firm. This indicates that firms that make heavier investment in R&D increase the gap between them and the potential output. This anomalous result may be due to two causes: a) the fact that R&D activities give rise to dynamic effects so that present expenditure on R&D is sure to result in future innovations. For this reason it is possible that a firm that spends on these activities may appear to be obtaining low output at present, although it will obtain higher output in the future; and b) it may occur that some firms have incurred excessive R&D expenses compared to their competitors, so that such R&D costs may not lead to the expected innovation, which consequently does not improve the firm's degree of efficiency.

Thirdly, there is a linear relationship between the degree of concentration of the market and efficiency. The signs of the concentration variable and of its square indicate that efficiency diminishes with concentration, the square of the variable not being significant. Therefore, the firms that operate in more competitive sectors have most incentive to behave efficiently, i.e. to obtain higher levels of output for a given combination of inputs. However, the results must be interpreted with caution as high concentration does not always imply absence of competition. Thus, the theory of contestable markets shows us how the absence of barriers to the entry of potential competitors may determine competitive behaviour even in highly concentrated markets. Also, the importance of competition for efficiency is corroborated by the fact that external competition acts in favour of efficiency as shown by the variable EC.

Fourthly, we observe a positive and significant effect of the variable INV, or investments as a percentage of the firm's capital. This result shows that there exists a positive dynamic for firms that renovate their capital, and shows at the same time that the use of new machines (which presumably incorporate the latest technologies) improve the efficiency of the firm.

Fifth, the results obtained with regard to the conditions of the markets in which the firms operate are not statistically significant. So, taking into account that the reference category is the variable "markets in recession", neither the variable EXPM (markets in expansion) nor STAM (stable markets) is significant.

Six, regarding the influence of the ownership of firms, the highest levels of efficiency are associated with those sectors with least share of public capital in firms (PUBK), this result being in agreement with the evidence obtained in Argimón et al. (1997) and Artola and Argimón (1998) for a sample of firms from the Bank of Spain's Balence-sheet Register for 1994.

Finally, the dummy variables capturing the effect of firms' location in one region or another do not in general give significant results, the only exception being the significant negative differential effect in the Valencia region.

In order to find intra-sectorial differences in efficiency table 2 analyses the determinants of efficiency by sectors. As a general commentary, substantial differences can be appreciated between the results obtained for industry as a whole and the particular results for each sector of activity, which shows the heterogeneity of sectors within industry as a whole[5].

The results of table 2 show that in most sectors the size of firm (SIZE) and the investment effort (INV) affect technical efficiency positively, although in some sectors the results obtained are not statistically significant. Thus the positive effect that both variables have on efficiency at the aggregate industry level is maintained at sector level.

For innovation (INNOV) statistically significant results are obtained only in six sectors (2.- Non-metallic mineral products; 5.- Agricultural and industrial machinery; 7.- Electrical material and accessories; 9.- Other transport material; 15.- Timber and wooden furniture; and 16.- Paper, paper articles and printing), the sign of the correlation being positive in two cases (sectors 9 and 15) and negative in the rest.

Within each sector, the negative effect of concentration (CONC) on technical efficiency is not statistically significant in many of them. However, there is an opposite, positive effect in the case of sectors 9 (Other transport material) and 11 (Tobacco and food products). This is therefore a paradoxical situation in which a near-monopoly situation within the country leads to a higher level of efficiency. However it may occur that the competition for these sectors comes not from the national market but from abroad, in which case, the firm would not be in a monopoly situation. In this sense we note the positive effect exercised by external competition (EC) on efficiency in numerous sectors: 2.- Non metallic mineral products, 4.- Metal products, 5.- Agricultural and industrial machinery, 9.- Other transport material, 11.- Tobacco and food products, 13.- Textiles and clothing, 16.- Paper, paper articles and printing, and 17.- Plastic and rubber products. On the other hand, the effect of external competition increases the inefficiency of sectors such as 3.- Chemical products.

Another salient point is that the sector results show the existence of important differences among sectors with regard to the effects of the evolution of internal demand on efficiency, though at the aggregate level this effect is not significant. A positive effect of the variable EXPM (expanding market) indicates that the favourable evolution of the market in the corresponding sector has a positive effect on efficiency, and therefore on better utilisation of the firm's productive resources.

Finally, state participation in the ownership of firms (PUBK) affects efficiency negatively and significantly in sectors 1.- Ferrous and non-ferrous metals, 7.- Electrical material and accessories, 3.- Textiles and clothing, and 16.- Paper, paper articles and printing. Its effect is positive only in sector 9.- Other transport material.

Thus the results obtained at aggregate level for industry as a whole vary when the determinants of efficiency are estimated at sector level. The aggregate results "mask" important differences among sectors, and it is therefore necessary to decompose them by sectors in order to obtain more detailed knowledge of the reality of Spanish industry.

## 5. Conclusions

One of the most important economic aspects in ensuring the competitiveness of a firm or a sector is the degree of efficiency in production. Thus the empirical evidence available shows that gains in productivity, and therefore in competitiveness, depend on both technical progress and gains in efficiency.

For this reason, it is important to identify the factors explaining the differences among economic agents. The objective of this paper has been to analyse the factors explaining the technical efficiency of Spanish industry in the period 1991-1994, using the information provided by the Survey of Business Strategies. The study aims to shed light on this subject by offering empirical descriptive evidence to help towards better knowledge of the reality of Spanish industry.

Starting from the levels of technical efficiency of Spanish industry estimated in Gumbau (1998) using the stochastic frontier approach, we have attempted to identify the factors that explain the differences of technical efficiency among firms of different sectors. In order to eliminate the unobservable individual effects and thus take advantage of the availability of a panel of data, the equation explaining efficiency is estimated in first differences. Also, the generalised moments method is used to control for problems of endogeneity of the explanatory variables, using for this purpose lagged values of the variables.

The results obtained for all industry show that efficiency increases with the size of firm and with the greater volume of investment made. Also, efficiency increases in those firms that are most subjected to the pressure of external competition. At the other extreme, the lowest levels of efficiency are manifested by firms operating in more concentrated markets where there is presumably less competition, and by firms with greater public participation in the firm's capital.

The results obtained at aggregate level for all industry should not mask the fact that there are important differences at sector level regarding inequalities of efficiency and their determinants. Of all the variables explaining efficiency, the most robust results at sector level correspond to the positive effect of size and investment on firms' levels of efficiency, while among the other determinants the sector results are

much more heterogeneous. Consequently, this last result shows us the need to enter into sector detail for a better knowledge of the reality of Spanish industry.

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**Notes**

[1.] Argimón et al. (1997) review both the theoretical analysis and the empirical evidence of the ownership-efficiency relationship.
[2.] In other studies it is frequent to use the coefficient of openness, [(exports + imports) / sales], as a proxy of the degree of external competition. However, the problem that may be posed by this variable at firm level is that a large part of the imports that discipline domestic supply are not made by the producing firms themselves, but by commercial intermediaries and also directly by foreign or multinational firms. However, the results are robust when this variable is used as an indicator of external competition.
[3.] Except for the dummy variables for the region (AC) and for growth of demand (EXPM and STAM), which are introduced in levels.
[4.] As the results are robust if the exponential function is used, we only `present the results corresponding to the logistical function.
[5.] The same conclusion is reached in the study by Artola and Argimón (1994) with data from the Balance-Sheet Register of the Bank of Spain for 1994.

**References**

Argimón, I.; Artola, C. and González-Páramo, J.M. (1997): "Empresa pública y empresa privada: titularidad y eficiencia relativa", Working Paper num. 9723, Bank of Spain.

Artola, C. and Argimón, I. (1998): "Titularidad y eficiencia relativa en las manufacturas españolas", Working paper num 9824, Bank of Spain.

Beeson, E. and Husted, S. (1989): "Patterns and Determinants of Productive Efficiency in State Manufacturing", *Journal of Regional Science*, vol. 29, 15-28.

Carlsson, B. (1972): "The Measurement of Efficiency in Production: an Application to Swedish Manufacturing Industries, 1968", *Swedish Journal of Economics*, 74, 468-85.

Caves, R. and Barton, D. (1990): *Efficiency in US: Manufacturing Industries*. MIT Press.

Caves, R. (1992): "Determinants of Technical Efficiency in Australia", in Caves, R (ed.) *Industrial Efficiency in Six Nations*. MIT Press, 241-272.

Gumbau-Albert, M. and Maudos, J. (1996): "Eficiencia Productiva Sectorial en las Regiones Españolas: una Aproximación Frontera", *Spanish Economic Review*, vol. 13, 2, 239-260.

Gumbau-Albert, M. (1998): "La eficiencia técnica de la industria española", *Spanish Economic Review*, vol.15, 1, 67-84.

Lovell, C.A.K. (1993): "Production Frontiers and Productive Efficiency", in *The Measurement of Productive Efficiency: Techniques and Applications*, Harold O. Fried, C.A.K. Lovell, and Shelton S. Schmidt (eds), Oxford: Oxford University Press, 3-67.

Maudos, J.; Pastor, J.M. and Serrano, L. (2000a): "Crecimiento de la productividad y su descomposición en progreso técnico y cambio en eficiencia: una aplicación regional y sectorial en

España (1964-1993)", *Investigaciones Económicas*, vol.XXIV (1), 177-205.

Maudos, J.; Pastor, J.M. and Serrano, L. (2000b): "Efficiency and productive specialization: an application to the Spanish regions", *Regional Studies*, Vol. 34 (9), 829-824.

Perelman, S. (1995): "R&D, Technological Progress and Efficiency Change in Industrial Activities". *Review of Income and Wealth*, 41 (3), 349-366.

Prior, D. (1990): "La productividad industrial de las Comunidades Autónomas", *Investigaciones Económicas*, Vol. XIV (2), 257-267.

Seong, M.Y. (1992): "Technical Efficiency in Korea", in Caves, R (ed.) *Industrial Efficiency in Six Nations*. MIT Press, 121-157.

Torii, S. (1992): "Technical Efficiency in Japanese Industries", in Caves, R (ed.) *Industrial Efficiency in Six Nations*. MIT Press, 31-120.

**TABLE 1**
**DETERMINANTS OF THE EFFICIENCY IN THE SPANISH INDUSTRY**

| Variables | Coeficient | t-ratio |
|---|---|---|
| SIZE | 0.5226E-08 | 4.719 |
| INNOV | -1.6258 | -2.182 |
| CONC | -0.1081 | -1.971 |
| $CONC^2$ | -0.0177 | -0.821 |
| EC | 0.0309 | 2.061 |
| INV | 0.0566 | 3.258 |
| STAM | -0.5663E-03 | -0.618 |
| EXPM | 0.3746E-05 | 0.321 |
| PUBK | -0.2285E-02 | -1.885 |
| Andalusia | 0.4105 | 1.194 |
| Aragon | 0.4656 | 0.869 |
| Asturias | -0.2347 | -0.440 |
| Balearics | 0.1669 | 0.239 |
| Canaries | -0.0851 | -0.181 |
| Cantabria | 1.2731 | 1.622 |
| C-La Mancha | 0.1933 | 0.613 |
| C-Leon | -0.3376 | -1.114 |
| Catalonia | -0.0504 | -0.462 |
| Extremadura | -0.0393 | -0.0211 |
| Galicia | -0.2952 | -1.293 |
| La Rioja | 0.1545 | 0.152 |
| Madrid | 0.1193 | 1.232 |
| Murcia | 0.2183 | 0.600 |
| Navarra | 0.0832 | 0.199 |
| Basque Country | 0.0330 | 0.168 |
| C. Valenciana | -0.2406 | -1.885 |
| Num. firms | 1149 | |
| ST | 55.42 (0.33) | |

Dependent var: Ln[EFIC/(1-EFIC)]
Estimation in first differences
ST= Sargan test of overidentification; p-value in parenthesis
In parenthesis, t-ratios robust to heteroscedasticity

**TABLE 2**
**DETERMINANTS OF THE EFFICIENCY BY SECTORS**

| | SECTOR 1 | SECTOR 2 | SECTOR 3 | SECTOR 4 | SECTOR 5 | SECTOR 6 | SECTOR 7 | SECTOR 8 | SECTOR 9 |
|---|---|---|---|---|---|---|---|---|---|
| SIZE | 0.346E-08 | 0.907E-08 (2.523) | 0.846E-08 (2.145) | -0.101E-07 (- | 0.266E-07 (1.327) | | 0.370E-07 | 0.14E-09 | 0.461E-07 |
| INNOV | (0.749) | -4.1939 (-1.670) | 0.6943 (0.845) | 0.34) | -3.253 (-1.998) | | (4.063) | (0.130) | (3.970) |
| CONC | -9.9067 (-1.068) | 0.1436 (1.111) | 0.0100 (0.191) | -0.5716 (- | -0.1039 (-0.531) | | -2.4800 (-5.755) | -1.2058 (-0.871) | 7.3524 (2.639) |
| $CONC^2$ | 0.1667 (0.435) | -0.1352 (-1.743) | -0.1567 (-3.040) | 0.4743) | -0.1531 (-1.036) | | -0.14722(-1.341) | -0.3105 (-1.425) | 0.3013 (2.150) |
| EC | -0.7968 (-2.184) | 0.0656 (3.173) | -0.0758 (-2.396) | -0.0871 (-0.522) | 0.0911 (1.757) | | -0.0565 (-0.567) | -0.1099 (-0.573) | 0.6073 (3.114) |
| INV | -0.0444 (-0.493) | 0.0980 (3.717) | 0.0072 (0.261) | 0.2065 (2.652) | 0.0345 (0.591) | | -0.0090 (-0.358)) | 0.0471 (0.780) | 0.3352 (4.301) |
| STAM | 0.0983 (0.882) | 0.137E-02 (1.325) | 0.0128 (4.442) | 0.1333 (3.990) | 0.465E-02 (1.347) | | 0.0221 (0.796) | 0.1235 (2.068) | 0.4267 (3.173) |
| EXPM | -0.0154 (-3.103) | -0.158E-04 (- | -0.151E-03 (- | 0.1021 (2.902) | -0.503E-04 (- | | -0.288E-02 (- | 0.16E-02 | -0.0063 (-1.116) |
| PUBK | 0.24E-03 (3.442) | 1.196) | 4.325) | -0.178E-02 (- | 1.312) | | 2.217) | (0.258) | 0.162E-03 |
| Andalusia | -0.26E-02 (- | | -0.185E-02 (- | 1.07) | | | 0.189E-04 | -0.27E-04 (- | (2.491) |
| Aragon | 2.849) | 0.2585 (2.531) | 0.933) | 0.604E-05 | -0.0959 (-0.816) | | (0.959) | 0.36) | 0.234E-02 |
| Asturias | -0.0881 (-0.872) | 0.2599 (1.908) | 0.0210 (0.303) | (0.283) | 0.2591 (2.478) | | -0.251E-02 (- | 0.10E-02 | (3.666) |
| Balearics | | -0.0326 (0.117) | 0.1674 (1.305) | -0.215E-02 (- | -0.2487 (-1.097) | | 3.307) | (0.783) | -0.2788 (-3.005) |
| Canaries | -0.0790 (-0.645) | | 0.1124 (0.602) | 1.48) | | | 0.2349 (2.721) | | |
| Cantabria | | 0.2373 (0.701) | -0.0713 (-0.373) | 0.3802 (1.161) | | | -0.0077 (-0.084) | 0.2439 (2.526) | 0.0932 (1.297) |
| CMancha | | 0.0543 (0.449) | | -0.1213 (-0.555) | | | 0.0397 (0.185) | | |
| C-Leon | | -0.0387 (-0.670) | | 0.3674 (1.358) | -0.1367 (-0.692) | | 0.3365 (1.300) | | -0.1225 (-1.801) |
| Catalonia | | -0.2343 (-1.541) | -0.0517 (-0.480) | -0.0709 (-0.263) | 0.0149 (0.123) | | -0.0576 (-0.222) | | -0.1878 (-1.887) |
| Extrema. | 0.0529 (0.552) | -0.0276 (-0.506) | -0.0020 (-0.029) | -0.4430 (-05832) | 0.0272 (0.563) | | 0.0624 (0.214) | 0.0534 (0.355) | |
| Galicia | 0.2279 (3.286) | | 0.0103 (0.491) | 0.1141 (0.663) | | | -0.4198 (-1.058) | -0.0505 (-0.268) | |
| La Rioja | | 0.1400 (1.423) | | 0.2072 (1.563) | -0.0345 (-0.182) | | 0.0446 (0.234) | -0.0005 (-0.006) | -0.0267 (-0.541) |
| Madrid | 0.1985 (2.258) | 0.0516 (0.556) | -0.7093 (-10.083) | 0.0709 (0.298) | | | -0.1529 (-2.914) | 0.0662 (1.083) | |
| Murcia | | 0.032 (0.896) | | 0.0720 (1.697) | -0.0253 (-0.439) | | | | 0.0200 (0.335) |
| Navarra | 0.1977 (2.947) | 0.1997 (2.031) | -0.0202 (-0.522) | | | | -0.0300 (-0.213) | 0.1067 (0.739) | |
| BascqueC | | 0.0334 (0.334) | 0.3361 (1.658) | -0.3523 (-0.024) | -0.0798 (-0.393) | | | | -0.2079 (-2.979) |
| C. Valen. | 0.4110 (2.722) | 0.0400 (0.471) | -0.1810 (-1.286) | -0.514 8 (-1.632) | -0.0343 (-0.380) | | 0.0229 (0.449) | -0.2292 (-2.241) | |
| | 0.1415 (2.122) | 0.0055 (0.219) | 0.0455 (0.548) | 0.1986 (1.553) | 0.0138 (1.007) | | 0.0777 (0.600) | | |
| | -0.0171 (-0.175) | | -0.0164 (-1.951) | 0.1224 (1.053) | | | 0.0622 (0.185)) | 0.0598 (0.752) | 0.0988 (2.294) |
| | | | | -0.5480 (-1.040) | | | 0.0974 (1.463) | 0.0479 (0.450) | -0.0584 (-1.228) |
| | | | | -0.0544 (-1.240) | | | 0.0904 (0.808) | 0.0675 (0.695) | |
| | | | | -0.0666 (-0.754) | | | | | |
| Firms | 27 | 81 | 88 | 121 | 65 | 10 | 112 | 52 | 23 |
| ST | 41.89 (0.41) | 38.87 (0.56) | 47.88 (0.32) | 34.42 (0.82) | 43.82 (0.52) | | 39.52 (0.58) | 61.37 (0.07) | 34.12 (0.07) |

See notes in table 1
A white space shows that there is no firm in that sector having this variable.
The estimation in sector 6 cannot be done because the sample is too samall.

**TABLE 2 (CONTINUATION)**
**DETERMINANTS OF THE EFFICIENCY BY SECTORS**

| | SECTOR 10 | SECTOR 11 | SECTOR 12 | SECTOR 13 | SECTOR 14 | SECTOR 15 | SECTOR 16 | SECTOR 17 | SECTOR 18 |
|---|---|---|---|---|---|---|---|---|---|
| SIZE | 0.459E-07 | 0.285E-08 (1.864) | 0.441E-07 (2.136) | 0.503E-07 | -0.232E-07 (- | 0.137E-06 | 0.2185E-07 | 0.53E-07 | 0.245E-06 |
| INNOV | (2.638) | 1.3548 (0.856) | 0.9790 (0.075) | (1.727) | 0.155) | (1.32) | (8.38) | (1.856) | (1.931) |
| CONC | 1.077 (0.128) | 0.6031 (2.692) | 0.4111 (0.847) | -0.7144 (-1.240) | -0.7038 (-0.315) | 14.159 (1.694) | 4.153 (4.025) | -2.3347 (-1.027) | -2.617 (-0.274) |
| $CONC^2$ | -0.5555 (-0.960) | 0.1866 (2.022) | -0.3266 (-1.359) | -0.1977 (-1.613) | 0.3110 (0.888) | -0.2107 (- | 0.1966 (0.636) | 0.3106 (0.999) | -0.5271 (-1.507) |
| EC | -0.0293 (-0.192) | 0.0613 (1.770) | -0.0296 (-0.518) | 0.3824 (2.316) | -0.2083 (-0.902) | 0.365) | 0.0297 (0.996) | -0.1428 (-1.120) | 0.0100 (0.048) |
| INV | 0.062 (0.952) | 0.0454 (0.762) | 0.0032 (0.050) | 0.0639 (2.600) | -0.0360 (-0.434) | 0.0294 (1.198) | 0.0339 (2.525) | 0.1114 (1.791) | 0.08676 (1.5324) |
| STAM | 0.1450 (1.687) | -0.193E-02 (- | -0.348E-02 (- | 0.1103 (3.747) | 0.0431 (0.374) | -0.0287 (- | 0.0375 (1.771) | 0.0764 (1.210)) | 0.1445 (1.64445) |
| EXPM | -0.0035 (-1.018) | 0.977) | 0.615) | -0.814E-03 (- | -0.435E-02 (- | 0.432) | -0.66E-04 (- | -0.82E-02 (- | -0.588E-02 (- |
| PUBK | 0.513E-04 | 0.253E-04 (1.148) | 0.393E-04 (0.582) | 0.42) | 0.847) | -0.0623 (- | 0.059) | 2.51) | 1.10) |
| Andalusia | (1.280) | 0.170E-02 (1.551) | | 0.407E-04 | 0.717E-04 (1.204) | 0.700) | -0.114E-05 (- | 0.95E-04 | 0.170E-03 |
| Aragon | | 0.0931 (1.123) | -0.0465 (-0.644) | (1.417) | | 0.566E- | 0.084) | (1.966) | (1.777) |
| Asturias | -0.0233 (-0.600) | 0.0305 (0.167) | | -0.0101 (-4.33) | | 02(1.24) | -0.214E-02 (- | 0.12E-02 | |
| Balearics | | 0.0380 (0.612) | -0.0509 (-0.784) | -0.0050 (-0.069) | -0.0412 (-0.410) | -0.80E-04 (- | 13.44) | (0.554) | -0.3978 (-2.794) |
| Canaries | -0.1170 (-1.498) | -0.2218 (-1.325) | | 0.0475 (0.544) | -0.0949 (-0.434) | 1.40) | -0.0359 (-1.542) | -0.2046 (-0.475) | -0.0284 (-0.274) |
| Cantabria | | 0.0371 (0.511) | 0.0730 (1.098) | -0.1728 (-0.516) | 0.0396 (0.509) | | -0.1437 (-1.567) | 0.1665 (0.783) | |
| CMancha | | 0.2617 (1.518) | | -0.5807 (-2.480) | | 0.1089 (0.819)) | 0.0220 (0.210) | | -0.0681 (-0.871) |
| C-León | | 0.1774 (0.754) | 0.1389 (1.526) | | | -0.2148 (- | | 0.4291 (0.793) | 0.1196 (0.765) |
| Catalonia | -0.0039 (-0.080) | -0.0046 (-0.054) | | -0.2317 (-0.705) | 0.1032 (1.111) | 0.817) | | | |
| Extrema. | -0.1278 (-1.668) | -0.0777 (-2.702) | 0.276E-02 (0.051) | 0.1430 (-0.198) | 0.4475 (2.704) | -0.1622 (- | | | |
| Galicia | -0.0095 (-0.026) | 0.5211 (1.198) | | -0.2340 (0.950) | -0.0376 (-0.208) | 0.527) | 0.7532 (1.833) | 0.2754 (0.860) | 0.0259 (0.194) |
| La Rioja | | -0.0270 (-0.264) | 0.0170 (0.204) | -0.2633 (-0.928) | | 0.3991 (1.128) | -0.0865 (-0.772) | | 0.0759 (1.416) |
| Madrid | -0.0931 (-1.722) | 0.1583 (0.647) | | 0.0.248(0.933) | | | 0.0347 (2.268) | 0.0427 (0.636) | |
| Murcia | 0.0180 (0.220) | 0.0084 (0.076) | 0.0490 (-0.710) | 0.1810 (0.251) | | | 0.2188 (0.867) | | |
| Navarra | -0.0711 (-2.227) | 0.1843 (2.939) | -0.0437 (-0.388) | | 0.1363 (0.941) | -0.1434 (- | | 0.3745 (1.279) | |
| BasqueC | -0.0032 (-0.040) | -0.0617 (-0.239) | | 0.0778 (1.024) | 0.4157 (1.900) | 0.976) | | -0.3990 (-1.063) | -0.0135 (-0.170) |
| C. Valen. | 0.0748 (1.161) | 0.0570 (0.495) | -0.1055 (-1.058) | 0.2887 (3.778) | | 0.1061 (0.893) | 0.0260 (2.245) | 0.1692 (1.001) | |
| | -0.0541 (-0.813) | 0.0720 (0.655) | -0.0748 (-0.916) | 0.3729 (0.817) | 0.5791 (3.296) | 0.0493 | | 0.0657 (0.186) | 0.0968 (0.706) |
| | -0.0291 (-0.704) | | | 0.1014 (0.231) | -0.0545 (-1.128) | (0.425)7) | -0.1792 (-0.593) | | -0.0538 (-0.501) |
| | | | | 0.0404 (1.208) | | | -0.0213 (-0.305) | 0.1021 (0.455) | -0.1385 (-1.933) |
| | | | | | | 0.999E-02 | 0.0545 (1.515) | -0.1125 (-1.324) | |
| | | | | | | (0.09) | | | |
| | | | | | | 0.0073 (0.037) | | | |
| | | | | | | -0.0801 (- | | | |
| | | | | | | 0.527) | | | |
| | | | | | | -0.1698 (- | | | |
| | | | | | | 0.549) | | | |
| | | | | | | 0.0075 (0.136) | | | |
| Firms | 31 | 117 | 28 | 118 | 38 | 62 | 83 | 66 | 27 |
| ST | 51.70 (0.12) | 41.40 (0.41) | 51.77 (0.05) | 48.58 (0.23) | 57.22 (0.05) | 48.39 (0.29) | 37.50 (0.80) | 38.63 (0.77) | 48.22 (0.07) |

See notes in table 1