Size, R&D and Technical Efficiency in the Industrial Sector of the Spanish Economy

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Abstract

Using the stochastic frontier method, technical inefficiency values are obtained for each company, with these values, the pattern of associations is built. The information analysis is carried out using a strategy based on multivariate methods of interdependence. A factorial analysis of multiple correspondences and a cluster analysis were used. The data source is that published in the Spanish Survey on Business Strategies (SBS) and collected by the SEPI Foundation. The results permit the characterizing of three groups of firms defined according to their level of efficiency/inefficiency. Companies that belong to the efficient cluster invest more in R&D, have higher labor costs, belong to the automobile (and associated) industry, and have more than 228 employees. High labor costs (in excess of 40,000 per year) are a common feature related to low technical inefficiency. The high level of inefficiency relates to small firms, companies with 54 workers or less, and firms with relatively low labor costs, presenting levels lower than 29,805.3 per employee per year; and firms without training costs and without investment in R & D. Our results obtain empirical evidence in favor of the strong correlation among size of firms, investment in R&D and labor cost per worker as determinant factor to achieve great levels of technical efficiency.

Keywords: efficiency, training, expenditure in R+D, clusters.

Introduction

The research presented in this paper aims to analyze the technical efficiency of the Spanish industrial sector. Specifically, we want to know the pattern of associations that occurs around certain levels of technical efficiency; i.e. which variables or categories of variables are associated with low/medium/high levels of technical efficiency.

It will address the relationship between the technical efficiency of Spanish manufacturing firms and the size of the firm, their annual labor costs, their expenditure on training for their workers, their investment in research and development (R & D), and the industrial sector to which each company belongs. The relationship between technical efficiency and investment in research and development (R & D) has been widely studied in the literature. Solow (1957) stressed that technological change is considered an indispensable and unquestionably decisive factor of companies' endogenous growth. Of the many studies that attest to this idea we can highlight that conducted by Hall and Mairesse (1995), which demonstrated the existence of the positive effects that product innovation has on business productivity. Moreover, Doraswzelski and Jaumandreu (2013) show a relationship between R & D and productivity with a high uncertainty and nonlinear relationship between the two variables; and taking into account the heterogeneity of the sample, demonstrate that investment in R & D is a key factor in the analysis of different levels of productivity and the development of productivity over time. Other work, in this area has been done by Ballot, Fakhfakh, Gaul and Salter (2013), where the success or failure of different innovation strategies relies heavily on nationality, resources and, especially, on the managing ability of the firm.

These authors have conducted research on the concept of organizational innovation, and have raised questions about the organization and design of companies, suggesting that the importance given by firms to process and product innovation can help explain their varying levels of performance. Innovation is also clearly related with the size of a company. Sanchez and Diaz (2013) have found that while product innovation reduces the technical inefficiency of large enterprises, it does not in the case of small businesses. Another key factor related to the technical efficiency of firms is the training of workers. Numerous studies support the idea that employee training offered and paid for by companies, and investment by firms in R & D, are the main sources of growth for businesses in the long term. Hall (2011) supports the idea that investment in training and innovative activities are important components in the productivity of firms. The main goal of a company that offers training to their employees is to increase productivity. According to the human capital theory, Becker (1964), greater human capital will be associated with increased productivity and workers will be paid according to their marginal productivity. Those workers who possess greater human capital will receive higher pay. Firms could increase the productivity of their workers by providing training. The human capital accumulated through training is one of the main factors influencing production. Training develops skills in workers, and, following the idea of Robleda (1994) training should, at this time, be the main objective of Spanish companies. Following Bartel and Lichtenberg (1991) firms whose workers accumulate the most hours of training are also those that invest most in R & D. Training enhances the skills of workers, promoting the implementation of new technologies. The work of Ballot, Fakhfakh and Taymaz (2002), studied the effect of intangible assets in wages and productivity. They showed that the benefits of investment in human capital and R & D are shared by the company and its workers, but that is the company who benefits the most. It would therefore seem reasonable to conclude that if Spanish companies invested in training to increase the knowledge of their employees then they would become more productive. In Spain, the spending of companies in employees' training presented during the period 2004-2007 negative rates of change. In 2009 spending on training experienced a sharp drop, giving a negative rate of 29.8% compared to 2008. Today spending in training by businesses continues to decline, due largely to the financial constraints faced by almost all firms, but especially the small and medium-sized businesses.

Size is another factor that contributes to a higher or lower level of technical inefficiency. Buesa and Molero (1998) correlated innovation with firm size and efficiency. They obtained data that demonstrated that among all the most innovative Spanish firms, the smaller firms were the least efficient. Diaz and Sánchez (2008) focused on the performance of small and medium-sized manufacturing firms, analyzing technical inefficiency and its determinants. Finally, the cost of labor is another factor to consider in the study of inefficiency. According to the theory of efficiency wages, the company that pays higher relative wages can improve the performance of their workers. Shapiro and Stiglitz (1984) emphasized the relationship between wages paid to workers and their level of effort in the workplace. Higher wages attract more productive workers. The work of Pisa and Sanchez (2016) highlighted the impact of labor costs related to the efficiency of Spanish manufacturing firms, showing that those companies whose salaries are above the average of the industrial sector, to which they belong, reduce inefficiency. Labor costs are used in this work as an approximation of the wages received by workers. With the inclusion of variables such as investment in R & D, expenditure in training, firm size (measured in number of employees), and the annual labor costs per worker, we will analyze the performance of Spanish manufacturing firms related with their levels of efficiency. This paper is organized as follows. Section 1 explains the data source and methodology. Section 2 focus on the obtantion of the efficiency values with the stochastic frontier approach. Section 3, explains the non-parametric test to obtain the aggrupation of firms. Section 4, introduces the main results. Finally, we present the concluding remarks.

Data Source and Methodology

The data used are obtained from the Survey on Business Strategies (SBS). The SBS stems from an agreement signed in 1990 between the Spanish Ministry of Industry and the SEPI Foundation, which was responsible for the design, monitoring and implementation of the survey. The SBS generates information with a panel structure. The reference population of the SBS is companies with 10 or more workers that are commonly known as manufacturing. The geographical scope of reference is the entire national territory. The SBS is well-known for the representativeness of its data. The initial selection of firms was made by combining the criteria of completeness with random sampling. Companies with more than 200 workers, whose participation was obligatory, were included in the first group. The second group was formed by companies with staff ranging between 10 and 200 workers, who were selected by stratified proportional restrictions and systematic sampling with random start.

In the first year, 1990, 2188 companies were surveyed using these criteria. Subsequently the SBS has made special efforts to maintain the representatively of the reference population.

All new firms with over 200 employees and a randomly selected sample representing 5 % of new companies between 10 and 200 workers enter the survey each year

Obtaining the Values of Inefficiency: The Stochastic Frontier Estimates.

We use the SFA to estimate a production frontier with inefficiency effects. Specifically, we use a panel data version of the Aigner et al. (1977) approach, following Kumbhakar et al. (2011), specification, in which technical inefficiency is estimated from the stochastic frontier and simultaneously explained by a set of variables representative of the firms' characteristics. The model is expressed as:

$$Y_{it} = f(X_{it};\beta)\exp(v_{it} - u_i) \qquad (1)$$

Where *i* indicates firms and *t* represents the period, *X* is the set of inputs; is the set of parameters, v_{it} is a two-sided term representing the random error, assumed to be *iid* $N(0,\sigma_v^2)$; u_i is a non-negative random variable representing the inefficiency, which is assumed to be distributed independently and obtained by truncation at zero of $N(\mu_{it}, \sigma_u^2)$. The mean of this distribution is assumed to be a function of a set of explanatory variables:

$$\mu_{it} = \delta_0 + \delta' Z_{it} \qquad (2)$$

Given that technical efficiency is the ratio of observed production over the maximum technical output obtainable for a firm (when there is no inefficiency), the efficiency index (TE) of firm *i* in year *t* could be written:

$$TE = \frac{f(X_{it};\beta)\exp(v_{it} - u_i)}{f(X_{it};\beta)\exp(v_{it})} = \exp(-u_i) \qquad (3)$$

The efficiency scores obtained from expression (3) takes value one when the firm is efficient, and less than one otherwise. The coefficients (β) and the inefficiency model parameters (δ) were estimated using a panel data technique to control for unobserved heterogeneity. By using the method of stochastic frontier approach, the technical inefficiency for all Spanish manufacturing firms in the sample was calculated. The results of the inefficiency of the stochastic frontier were obtained through the estimation of the trans logarithmic production function shown at the end of this section. The program provides the values for each observation of the sample. The precise definitions of the variables are available in the appendix section. The maximum-likelihood estimates of the production frontier parameters are presented in Table 1. We use the translog specification for the production function and we obtain the expected signs of the inputs estimates and both dummies representing firms' innovative activities have a positive and statistically significant coefficient.

Table1. Stochastic frontier: translog production function.

Variables	Parameters	Coefficients	t-value
Constant	β_0	6.211	48.566
T	β_1	0.157	10.384
L	β_2	1.139	27.361
K	β_3	-0.037	-2.144
K^2	β_{11}	0.033	19.182
L^2	β_{22}	0.043	6.109
T^2	β_{33}	-0.012	-7.543
KxL	β_{12}	-0.150	-10.798
LxT	β_{13}	0.029	8.292
KxT	β_{23}	-0.021	-9.718
INP	θ_1	0.031	2.256
INPR	θ_2	0.031	2.913
SEC2	θ_3	0.075	1.946
SEC3	θ_4	0.218	8.660
SEC4	θ_5	0.269	10.925
SEC5	θ_6	0.310	8.589
SEC6	θ_7	0.166	5.090
SEC7	θ_8	0.154	5.324
Inefficiency Model			
Constant	δ_1	4.409	36.967
Variance Components			
Lambda		1.063	61.867
Sigma(u)		0.372	70.355

The lambda parameter ($\lambda = \sigma_u/\sigma_v$) is positive and significant, which means that the inefficiency is stochastic and as a consequence the frontier model cannot be reduced to a mean-response wage equation (OLS estimation).

- **The Nonparametric Tests**

To analyze the behavior of the variables defined in the appendix section, we carried out a series of nonparametric analyses, in particular, test of independence tests. It was the part of variables p and q that represented mutually exclusive and exhaustive levels, whose independence we wanted to test.

The null hypothesis that we will contrast will be:

H_0: independence between two variables

Against the alternative hypothesis:

H_1: both variables presented association

The aim was to discover, if during this period, there was a relationship between technical inefficiency and the variables mentioned above (company size, training expenses, expenditure on R & D and labor costs).

The hypotheses were compared and the results are shown below in Table 2.

Table 2: Test of independence on technical inefficiency and company size, labor cost per worker

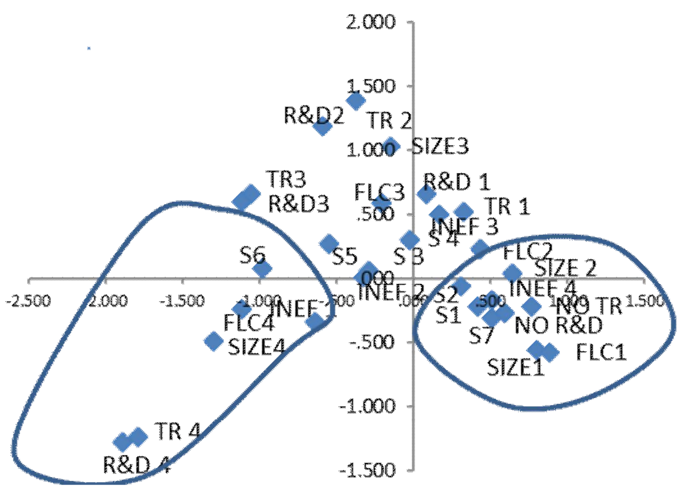
Years 2004 - 2009		Degrees of freedom	Asymptotic significance (bilateral)
size	1157,125	9	,000
Labor cost per worker	1473,625	9	,000
Expenditure in Training	1146,093	12	,000
Expenditure in R&D	859,982	12	,000

For significance level of the null hypothesis is not accepted, for any of the variables, it is concluded that there is a statistically significant relationship between technical inefficiency and the variables analyzed above. Once testing had been done, we were able to verify the relationship between technical inefficiency and the variables: firm size, labor costs, training costs and expenditure in R & D. The tests only checked the relationship between variables but did not give information about how the different types of variables were related. In order to provide a more extensive analysis of the information covered by this study, we conducted a series of studies from a multivariate perspective. Specifically, as noted in the section of methodology, the results obtained with multiple correspondences factor analysis and cluster analysis is shown in next section.

The Results

Figure 1, show the results obtained with the levels of inefficiency, training costs, investment in R & D, labor costs per worker, size and the sector of activity.

Figure 1: Graphical representation of correspondence analysis and cluster grouping for 2004-2009.



Source: Own calculation

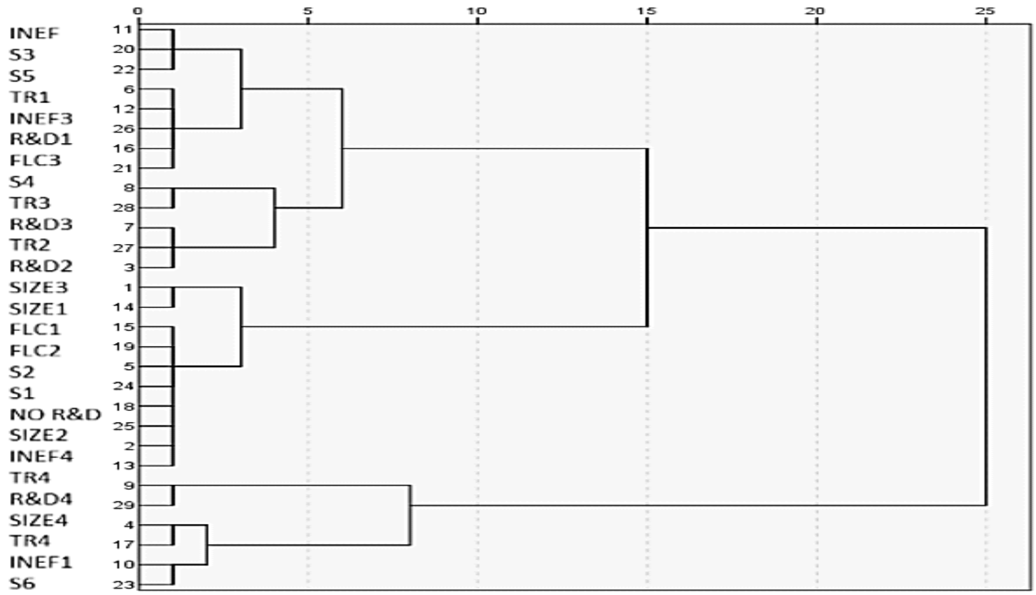
Two main clusters are formed. One composed of six variables, the most important being the lowest level of inefficiency (INEF1). The variables that make up this cluster are those related with the lowest levels of inefficiency. We call this cluster, "Efficient Cluster" with levels of inefficiency below or equal to 14.15%. In Figure 1, we find it on the left side, occupying almost entirely the lower quadrant and lower top. The characteristics of this cluster are large companies with more than 228 workers, with labor costs higher than 38,914.37 per year, companies whose training expenses exceed 60,611 per year, and whose investment in R&D exceed 1,008,261.5 per year. We can conclude that the most efficient sector, in this period of analysis, corresponds to SECTOR 6: Cars and engines and other transport equipment. The other resulting cluster is initially divided into two. In one of them we can identify the firms with the highest level of inefficiency. We will name this cluster, “inefficient cluster". In Figure 1, this cluster is found in the right lower quadrant. The high level of inefficiency (INEF 4) relates to small firms, companies with 54 workers or less, and firms with relatively low labor costs, presenting levels lower than 29,805.3 euros per employee per year; and firms without training costs and without investment in R & D. Those sectors that are associated with a high level of inefficiency are: SECTOR 1: Meat and production of meat, food and beverage industry, textiles, clothing and footwear, leather, footwear and derivatives, SECTOR 2: Wood & derivatives, paper and derivatives SECTOR 7: Other manufactured products. The firms, forming this cluster, share a number of the features outlined above, which causes them to be relatively technically inefficient when compared with the other companies in the sample.

The last cluster that remains to be analyzed is characterized by intermediate levels of inefficiency, indexes between 14.151 % and 20.11%. It is situated in the middle of figure 1. We find here firms with between 54 and 228 employees, with annual costs per worker of between 29,805.31 and 38,914.37 Euros; whose expenditure on training costs is between 42,521 and 60 611 per year; and whose investments in R & D are between 81,651.51 and 1,008,261.5 per year. This cluster contains the remainder of the firms in the sample. The differences between the most efficient companies in the sample, which are grouped in the efficient cluster, and the less efficient firms, which are grouped together in the inefficient cluster, are size, personnel costs, investment in R & D and expenditure on training. Therefore, it is reasonable to suggest that industrial policies ought to be geared towards enhancing the training of employees and increasing investment in R & D. These policies appear to be more difficult to implement for small companies than for big companies. One possible explanation for this is that small firms have greater credit restrictions than large firms. In Spain most firms are small or medium sized businesses. In our sample firms that had more than 500 employees made up only 9.45 % of the total. Therefore, if Spanish businesses increase their average size they will reduce their technical inefficiency. This result may be partially explained by the fact that large businesses invest much more in research and development than medium and small size businesses. Firms with more than 500 workers are those that receive the highest percentage for innovation in the process of production (54.60%) and in the product (43.01%), (Díaz and Sánchez, 2008).

In fact, the economic analysis of OECD for Spain 2014 showed that investment in R & D remains low, suggesting that is not effective. The government should reduce volatility of their total financial support to R & D: Innovation is a long term investment, so that the stability of funding is crucial. Apart from scholarships, loans and tax incentives, the authorities should promote and expand the use of other instruments such as venture capital.

In Spain industrial policies should be directed towards promoting access to investment in R & D and encouraging the training of workers so as to achieve higher levels of efficiency and therefore productivity, particularly in the case of small firms. For this reason, scientific parks can help in favoring small businesses, as they allow part of training expenses and R & D costs to be shared, thus improving the technical efficiency of the firms located there, as well as benefitting their staff, as higher levels of technology and training are associated with higher wages. These are the optimal factors for firms to achieve levels of inefficiency below 14 %.

Figure 2: Dendogram



Source: Own calculation

High labor costs (in excess of 40,000 per year) are a common feature related to low technical inefficiency. Firms that are characterized by making high investments in R & D and spend large amounts on training for their employees are always found lying in the efficient cluster. The social dimension of wages makes it difficult for them to carry out the equalizing role with respect to supply and demand that conventional economic theory attributes to prices in the market place. The existence of ethical norms in the labor market that state the actions of the agents operating within it inhibit purely optimizing behavior. Time plays a far more important part in the function of the labor market than is accepted by the basic, extemporal model of supply and demand. Furthermore, what is exchanged in the labor market is not the "work" that will be used in the production process, but rather the "inclination to work". The conversion of this dimensions into work effectively carried out is a problem that entrepreneurs face daily, as an integral and inseparable part of the production process. This is showed by both the habitual systems of incentives and plusses that businesses use and by the need to organize, in one way or another, the work done. While this is self-evident to social observers, it has an upsetting effect on the competitive model of the labor market.

This connection between labor costs and efficiency provides empirical evidence in favor of the efficiency wages theories. This evidence suggests that those firms that pay above average wage increase the productivity of workers and therefore their efficiency. In this sense, higher relative wages are able to attract a better group of workers within the industrial sector. Labor costs (gross wage) include not only the wage paid to workers, but also social security payments and payments in kind, among other forms of retribution. Therefore, a systematic policy of reducing labor costs may lead to a poorer selection of workers for the firm, that is, in the same way that the price of a product reflects its quality, the wage of workers ought to reflect the quality of work. It is important to distinguish between labor costs per worker and labor costs per unit of production, because what is relevant here is what firms are able to produce by paying these labor costs. These variables are the keys to achieving improved technical efficiency in Spanish companies. The cars and engines Industry is the most efficient of the sample along the whole analysis. This sector has higher levels of investment on training and R & D than other sectors.

Concluding Remarks

In the analyzed period 2004-2009, a relatively small company with less than 55 workers is a characteristic related to high levels of technical inefficiency. Everything indicates that the size of the business and technical inefficiency maintain a negative relationship. Along with size, other characteristics associated with high levels of technical inefficiency are low labor costs per worker and a lack of investment in employee training. Companies that do not offer training to their employees are located in the inefficient cluster. The same applies to investment in R & D.

The lack of investment in R & D is a feature that is always associated with high technical levels of inefficiency. The two variables mentioned previously, are key components in the long term growth of a company and consequently with its productivity. Regarding the most inefficient sectors we found them to be the food industry and those related to it, the timber industry and the group of other manufacturing companies. The introduction of new technologies and managerial decisions regarding the innovation of production processes and products are extremely important in order to guaranty a high level of competiveness and efficiency in the long term. The Spanish model of production that has been based fundamentally on construction and speculation distorted the system of business incentives that aim to achieve a greater level of technical and economic efficiency. Now there is a hurried attempt to regain competiveness by reducing labor costs, without any apparent awareness that these measures may damage our level of efficiency in the medium and long term.

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Appendix Section.

Definition of variables for the stochastic frontier:

VA: The value added in real terms. This is the dependent variable.
CAPITAL STOCK (K): Inventory value of fixed assets excluding grounds and buildings.
L: Total staff employed by the firm.
T: This is the time trend.
INP: dummy that takes value 1 if there is product innovation and 0 otherwise.
INPR: dummy that takes value 1 if there is process innovation and 0 otherwise.
Sector classification: There are seven dummy variables that take value one when the firm belongs to the corresponding sector of activity; otherwise this value is zero.
S1: Meat and manufacturing of meat; food industry and tobacco, drinks; textiles, clothing and shoes; leather, shoes and derivatives. Category of Reference
S2: Wood and derivatives, paper and derivatives.
S3: Chemical products; cork and plastic; non-metallic mineral products.
S4: Basic metal products; manufactured metal products; industrial equipment.
S5: Office machinery and others; electrical materials.
S6: Cars and engines; other material transport.
S7: Other manufactured products.

Definition of variables of the non-parametric analysis:

Once categorized, four levels for the variable technical inefficiency are obtained.

INEF 1: firms with lower levels of technical inefficiency than 14.15 %
INEF 2: Companies with technical inefficiency levels between 14.151 % and 17.27 %
INEF 3: Companies with technical inefficiency levels between 17,271 % and 20.11 %
INEF 4: Companies with higher levels of technical inefficiency than 20.11 % Size is a variable that indicates the number of employees in the firm. Here, the same operation is performed as that used in the variable of technical inefficiency
SIZE1: Firms with 22 workers or less.
SIZE2: Firms with between 23 and 54 workers.
SIZE3: Firms with between 54 and 228 workers
SIZE4: Firms with more than 228 workers
To qualify the variable annual labor cost per worker we performed the same operation done with the previous variables.
FLC1: Firms with annual labor costs lower than 22.4188, 4 euros
FLC2: Firms with annual labor costs between 22.4188, 41 and 29.805,3 euros
FLC3: Firms with annual labor costs between 29.805,31 and 38.914,37 euros
FLC4: Firms with annual labor costs greater than 38.914,37 euros

To qualify the variable annual training costs, financed by the firm, we first removed from the sample those companies which did not have training costs. Next, the values of those sampled companies that invest in training were coded. After this categorization, we created four categories for the variable training costs, plus a new category indicating the absence of investment in training.

NO TR: Firms without investment in training.
TR1: Firms that invest less than 4.052€ per year in training
TR2: Companies with training expenses between 4.052,1€ and 17.268€
TR3: Companies with training expenses between 17.268,1€ and 60.611€.
TR4: Companies with training expenses higher than 60.611€

With the variable investment in R & D we proceeded in the same way as we had done with the variable training ost.
NO R&D: Companies that do not have R & D expenses.
R&D 1: Companies investing less than 81,651.5 € per year in R & D.
R&D2: Companies investing between 81,651.51€ and 296,915€ per year in R&D
R&D3: Companies investing between 296915.1€ and 1,008,261.5€ per year in R&D
R&D4: Companies investing more than 1.008.261.5€ per year in R & D.
Industrial sectors of the NACE-CLIO classification system were grouped, in a total of seven sectors, coinciding with the same industrial classification as had been used in the stochastic frontier.
Size:
H_0: Technical inefficiency is independent on firm size or labor cost per worker or expenditure in training or expenditure in R&D
H_1: Technical inefficiency and firm size or labor cost per worker or expenditure in training or expenditure in R&D are related