Are large innovative firms more efficient?

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Abstract.

One of the characteristics of the Spanish economy is the high percentage of small and medium-sized firms. Size is one of the factors that condition the managerial organization of the firms and their efficiency and productivity. Moreover size has been found a highly significant variable in explaining differences in firm's innovative activities and the returns of R&D expenditures, and it is a well-established connection between productivity and innovative activities. This paper analyses the relationship between innovative activities and size and their effect over firms' technical efficiency and then over their productivity. We also take into account other variables that could affect the relationship between productivity and innovative activities: industrial sector, market structure, or firms' financial conditions. The analysis could help to design political economic measures to encourage small firms' innovation and then contribute to improve their competitiveness. We use a micro panel data set of Spanish manufacturing firms, during the period 2004–2009, to simultaneously estimate a stochastic frontier production function and the inefficiency determinants. The data source is published in the Spanish Industrial Survey on Business Strategies (Encuesta sobre Estrategias Empresariales, ESEE), collected by the Fundación SEPI. Our preliminary results show that innovative firms are more efficient than non-innovative firms; and that small and medium-sized firms' tent to be more efficient than large firms are.

Key words: small firms, technical efficiency, innovative activities.
JEL: C23, J21, J29, L60

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1. Introduction

This paper analyses the performance of the small and medium-sized manufacturing firms during the period 2004–2009, focusing on the degree of technical inefficiency and its determinants. We centre our analysis in the relationship between innovative activity and firm size.

There is an extensive literature that analyses the effect of innovation on productivity[2]. Also, the effect of size on innovation activities has been largely analysed by the literature. Size has been found one of the factors that explain firms' differences in innovation activities and in the returns on R&D expenditures[3]. Most studies found that large firms are more innovative than the small and medium sized firms. Large firms could benefit from scale economies, more qualified work force, and better access to external financial funds and better capacity to exploit an innovation and expand the new production. Some empirical papers showed that, to a threshold point, there is a linear relationship between R&D expenditures and size. Large firms innovate more and obtain higher returns from their investment. Other studies consider that new small firms are more innovative, as a way to quickly raise their size and survive. The Winter's (1984) hypothesis, that innovation activities respond to different technological regimes and differences in the economic environment, has obtained empirical support as in Acs & Audretsch (1990)

This paper analyses the relationship between innovative activities and size, and their effect over firms' technical efficiency and then over their productivity. We are interested in analysing the determinants of technical efficiency in Spanish manufacturing firms. We focus on firms' specific factors related to R&D activities and try to provide an explanation of the differences in technical efficiency among different sized manufacturing firms. It is expected that innovation help firms to be more efficient and more productive. Then, we expect that our empirical analysis show that innovative firms present a higher efficiency than not innovative firms. Our objective is to analyse if differences in efficiency could be explained by differences in

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[2] Griliches (1979), Crépon et al. (1998),Griliches and Regev (1995) and Huergo and Jaumandreu (2004a). See Griliches (1995) for a survey.

[3] See Acs and Audretsch (1988), Cohen and Klepper (1996).

innovative activities and if size have a significant impact on the returns of R&D expenditures. One of the characteristics of the Spanish economy is the high percentage of small and medium-sized firms. So, it is important to understand if size has a significant effect on the effectiveness of the R&D expenditure and then, on the effectiveness of undertaken product or process innovation. Our analysis could help to design political economic measures to encourage small firms' innovation and then contribute to improve their competitiveness.

We use a micro panel data set to simultaneously estimate a stochastic frontier production function and the inefficiency determinants using an unbalanced panel of manufacturing firms. We analyse, firstly, if innovative firms are more technical efficient than not innovative firms and finally if large firms obtain more returns from their investment on R&D. We also take into account other variables that could affect the relationship between productivity and innovative activities: industrial sector, market structure, or firms' financial conditions.

We follow the frontier approach, first developed by Farrell (1957) and widely used in empirical works. This approach measures the technical inefficiency of a production unit as the ratio of a firm's production over its optimal level. The optimal behaviour, the technically efficient result of the production process, is represented by a production function, a frontier, which shows the maximum level of output a firm could achieve, given the technology and a given level of inputs. The first step of this approach is to estimate the practice frontier obtained from the sample information, using their best observations. If a firm produces this optimal level of output, it is technically efficient and it will be on the frontier. If a firm produces less than is technically feasible, given both, the technology and a level of inputs, it is inefficient and we can measure the degree of technical inefficiency as the distance from each individual observation and a corresponding point on the frontier.

Using frontier techniques, several studies have analysed which are the sources of technical inefficiency. Caves and Barton (1990) examine technical inefficiency of the manufacturing industry in United States, while Green and Mayes (1991) analyse technical inefficiency for United Kingdom firms. Caves et al. (1992) compare inefficiency and its determinants between developed countries. Other studies focus on particular determinants of inefficiency, such as the Hay and Liu study

(1997), which focuses on the relevance of a competitive environment on efficiency; Patibandla (1998), who shows the relevance of capital market imperfections on the structure of an industry; and Dilling-Hansen et al. (2003), who analysed whether relative efficiency is due to R&D investment. Díaz and Sánchez (2008) obtain that small and medium-sized firms tend to be more efficient than the large firms are.

2. Stochastic frontier and the inefficiency model

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 and Lovell (2000), and Wang (2002) specification, in which technical inefficiency is estimated from the stochastic frontier and simultaneously explained by a set of variables representative of the firms' characteristics. This approach avoids the inconsistency problems of the two-stage approach used in previous empirical works when analysing the inefficiency determinants[4].

The model can be expressed as:

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

Where *i* indicates firms and *t* represents the period, *X* is the set of inputs; β 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 $N(0,\sigma_u^2)$.

We introduce some explanatory variables to explain inefficiency assuming that,

$$\sigma^2_{(u)_i} = \sigma^2_{(u)}\exp(\delta' Z) \tag{2}$$

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[4] In a two-stage procedure, first of all a stochastic frontier production function is estimated and the inefficiency scores are obtained under the assumption of independently and identically distributed inefficiency effects. But in the second step, inefficiency effects are assumed to be a function of some firm-specific variables, which contradicts the assumption of identically distributed inefficiency effects.

Where Z is a (Mx1) vector of variables that may have effects over firm efficiency, δ is a (1xM) vector of parameters to be estimated. We also control for heteroscedasticity, allowing the noise term to reflect differences between firms related to size.

$$\sigma^2_{(v)_{it}} = \sigma^2_{(v)} \exp(\gamma' w) \tag{3}$$

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 as[5]:

$$TE = \frac{f(X_{it};\beta)\exp(v_{it} - u_i)}{f(X_{it};\beta)\exp(v_{it})} = \exp(-u_i) \tag{4}$$

The efficiency scores obtained from expression (3) take value one when the firm is efficient, and less than one otherwise.

3. Data and variables

The Data source is published in the Spanish Industrial Survey on Business Strategies *(Encuesta sobre Estrategias Empresariales, ESEE).* The data is collected by the *Fundacion Empresa Pública* (FEP) and sponsored by the Spanish Ministry of Industry. This is supplied as a panel of firms' representative of twenty manufacturing sectors. A characteristic of the data set is that firms participating in the survey were chosen according to a selective sampling scheme. The sample of firms includes almost all Spanish manufacturing firms with more than two hundred employees. Firms employing between ten and two hundred employees were chosen according to a stratified random sample representative of the population of small firms. Given the procedure used to select firms participating in the survey, both samples of small and large firms can be considered as samples that allow us to estimate the distribution of

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[5] Individual efficiency scores u_i, which are unobservable, can be predicted by the mean or the mode of the conditional distribution of u_i given the value of $(v_i$-$u_i)$ using the technique suggested by Jondrow et al (1982).

any of the characteristics of the population of Spanish manufacturing firms with information available from our data set. Each year a number of additional firms were selected according to a random sampling procedure among the whole population of firms. This selection is conducted using the same proportion as in the original sample (see Fariñas and Jaumandreu (2004) for technical details of the sample)

From the original sample, a number of firms have been eliminated, most of them due to a lack of relevant data. Others were eliminated because they reported a value-added annual growth rate per worker in excess of 500% (in absolute value), and some were rejected because they have fewer than ten workers and, in both cases, they would distort the analysis. Also, we do not include firms after a merger or division process in our sample data. Our sample includes 2,247 firms from the ESEE Survey and refers to an unbalanced panel where we have eliminated those firms for which we do not have two consecutive years of data. Our period of analysis runs from 2004 to 2009. Summary statistics of the data are presented in Table I.

[Insert Table I]

We estimate a stochastic translog production function adding a term of inefficiency, whose variance is the function of a set of inefficiency determinants.[6]

$$\ln Y_{it} = \beta_0 + \sum_{j=1}^{J} \beta_j \ln X_{ijt} + \frac{1}{2} \sum_{j=1}^{J} \sum_{k=1}^{K} \beta_{jk} \ln X_{ijt} \ln X_{ikt} + \sum_{m=1}^{M} \varphi_m S_{im} + \theta_1 INP + \theta_2 INPR + v_{it} - u_i \qquad (5)$$

$$\sigma^2_{(u)_i} = \sigma^2_{(u)} \exp(\delta^{'} Z)$$

The variables used for estimation of the production frontier are the value-added, such as the output variable, and the number of employees in the firm, capital stock and trend, as input variables (X_{it}), the industrial sector dummies (S_i) and two dummies that indicate if firms have undertaken process (INPR) or product innovation (INP). Here we present a more precise definition of the variables used for estimation and the definition of the inefficiency determinants considered:

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[6] We imposed the usual symmetry conditions to the translog function

Variables of Stochastic Frontier estimations:

VA: The value added in real terms. This is a dependent variable.

CAPITAL STOCK (K): Inventory value of fixed assets excluding grounds and buildings.

L: Total employment by 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.

SEC1: Meat and manufacturing of meat; food industry and tobacco drinks; textiles, clothing and shoes; leather, shoes and derivatives. SEC2: Wood and derivatives, paper and derivatives.

SEC3: Chemical products; cork and plastic; non-metallic mineral products.

SEC4: Basic metal products; manufactured metal products; industrial equipment.

SEC5: Office machinery and others; electrical materials.

SEC6: Cars and engines; other material transport.

SEC7: Other manufactured products.

Determinants of efficiency:

PROPORTION OF TEMPORARY: This is the proportion of temporary workers on total employment

INVESTMENT OVER CAPITAL: This is the ratio between investment in capital goods over capital.

INNOVATION INVESTMENT OVER CAPITAL: This is the ratio between cost of purchase of capital goods for product improvement over capital.

R&D INTENSITY: This is the ratio between R&D expenditures over Value added

LEVERAGE: This is the ratio between external total funds over added value.

SIZE: There are six dummy variables that take value one when the firm belongs to the corresponding interval of workers, zero otherwise:

- SIZE 1: Firms with no more than twenty workers.
- SIZE 2: from 21 up to 50.
- SIZE 3: from 51 up to 100.
- SIZE 4: from 101 up to 200.
- SIZE 5: from 201 up to 500.
- SIZE 6: Firms with a number of workers higher than 500.

4. Results.

From the frontier approach, we obtain a measure of a firm's technical inefficiency compared with the best observations of the sample. The value of the estimates allows us to explain the differences in the inefficiency effects among firms. As technological and market conditions can vary over sectors, we have included sector dummy variables in the production function in order to be able to control them.

The maximum-likelihood estimates of the production frontier parameters, defined in equation (4), given the specification for the inefficiency effects, defined in equation (5), are presented in Table II. We use the translog specification for the production function and we obtain the expected signs of the inputs estimates. We also obtain that both dummies representing firms' innovative activities have a positive and statistically significant coefficient.

[Insert Table II]

Respect to the inefficiency determinants, our results show that inefficiency tends to be larger for firms with a high ratio of external financial funds over total assets. As higher is the leverage more difficult is for firms to be close to the frontier. The ratio of temporary over total employment shows, also, a negative impact over efficiency. Díaz and Sánchez (2004) obtained that a higher number of temporary workers in manufacturing firms affects negatively their technical efficiency because firms do not invest in training in this type of workers.

We find a negative and significant relationship between size and technical efficiency. There are at least two reasons for expecting a negative relationship between size and efficiency. First, large firms may suffer more from bureaucratic frictions, lack of motivation of workers, and difficulty in monitoring than smaller firms. Second, large firms are more able to remain in the market, even if they have economic problems due to a low technical efficiency, than small firms because of the existence of market imperfections. Due to this effect of market selection, the surviving small firms that we observe may on average show a higher level of technical efficiency than the larger firms do.

The R&D intensity, affects positively the firm's efficiency, that is, innovative firms tend to be closer to the frontier than those firms that do not perform R&D spending. We obtain the same significant effect for variables representing the degree of investment. These results allow us to conclude that the most innovative companies are closer to the efficient frontier than those that are not innovative.

When we estimate two separate frontiers, for small and large companies we observe interesting differences. R&D intensity is a relevant determinant of efficiency for large firms but not for small companies. Moreover, capital intensity is more relevant for small firms than innovative activities. Then, it seems that for small firms it is more difficult to obtain benefits from their R&D expenses than for large firms.

[Insert Table III]

[Insert Table IV]

To sum up, the impact of the investment in R&D over efficiency and consequently over production has been positive and statistically significant. Our results indicate that innovative firms produce more efficiently than non-innovative firms. This implies that all policies conducted to incentive this kind of investment will contribute to a productivity growth in the long run.

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Table I: Descriptive statistics

	Min.	Max	Mean	Standard Deviation
VA*	110.29	10689161.42	162610.05	553841.99
K*	10.94	33091212.35	357083.77	1609312.16
L	10.00	14400.00	236.90	724.36
INP	0.00	1.00	0.20	0.40
INP	0.00	1.00	0.32	0.47
INVEST/K	0.00	4.58	0.07	0.14
LEVERAGE	0.00	209.39	2.31	5.82
TEMP	0.00	0.97	0.13	0.17
INNOV EXP/K	0.00	3.64	0.02	0.10
R&D EXPEND.*	0.00	4152551.57	11367.04	122314.54

(*) Euros

Table II: Stochastic Frontier Analysis

Translog Production function estimates.

Variables		Coefficient	Standard- Error	T- Student
Constant	β_0	5.883	0.142	41.302
T	β_1	0.146	0.018	7.971
L	β_2	1.074	0.050	21.592
K	β_3	-0.110	0.020	-5.508
K^2	β_{11}	0.042	0.002	23.894
L^2	β_{22}	0.076	0.007	11.661
T^2	β_{33}	-0.013	0.002	-6.824
KxL	β_{12}	-0.195	0.0130	-14.939
LxT	β_{13}	0.025	0.004	6.348
KxT	β_{23}	-0.019	0.003	-7.305
INP	θ_1	0.025	0.015	1.681
INPR	θ_2	0.034	0.012	2.980
Wood and derivatives, paper and derivatives.	φ_1	-0.066	0.025	-2.651
Chemical products; non-metallic mineral products.	φ_2	-0.192	0.0045	-4.301
Basic metal products; industrial equipment.	φ_3	0.044	0.029	1.541
Office machinery and others; electric materials.	φ_4	0.095	0.025	3.754
Cars and engines; other material transport.	φ_5	0.177	0.034	5.167
Others manufactured products.	φ_6	0.053	0.041	1.301

Table II(cont.)

Inefficiency model				
Variables		Coefficient	Standard-Error	T- Student
Gross investment over capital	δ_1	-1.643	0.228	-7.197
R&D intensity	δ_2	-0.186	0.039	-4.818
External funds over VA	δ_3	0.021	0.023	9.058
Temporary workers proportion	δ_4	0.376	0.165	2.282
New products investment over capital	δ_5	-2.682	0.658	-4.078
Size1: Up to 20 workers	δ_7	-0.917	0.142	-6.473
Size2: From 21 to 50	δ_8	-0.924	0.148	-6.227
Size3: From 51 to 100	δ_9	-1.008	0.135	-7.488
Size4: From 101 to 200	δ_{10}	-0.930	0.133	-7.015
Size5: From 201 to 500	δ_{11}	-0.800	0.140	-5.719
Heteroscedasticity				
L	γ_1	0.000	0.000	0.324
INP	γ_2	-0.033	0.227	-1.209
INPR	γ_3	0.009	0.020	0.462

Table III: Large firms' inefficiency model

	coefficient	Standard error	t-Student
Gross investment over capital	-3.727	0.564	-6.613
R&D intensity	-0.237	0.057	-4.190
External funds over VA	0.020	0.004	4.587
Temporary workers proportion	-0.904	0.191	-4.726
New products investment over capital	2.681	1.634	1.641

Table IV: Small firms' inefficiency model

	coefficient	Standard error	t-Student
Gross investment over capital	-1.800	0.618	-2.913
R&D intensity	-0.128	1.088	-0.117
External funds over VA	0.050	0.008	6.039
Temporary workers proportion	0.589	0.512	1.149
New products investment over capital	-1.835	2.035	-0.902