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Identifying efficiency drivers in the greek sausage industry: a double bootstrap DEA approach

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Abstract

The paper investigates technical efficiency determinants for sausage industry in Greece over the period of 1994–2007. A double bootstrap data envelopment analysis is applied in order to obtain robust estimates of efficiency scores and regression variable coefficients in the presence of serial correlation between the efficiency scores measures and explanatory variables. The primal results show that (i) the level of domestic sausage consumption, the firm's integration in a group, the knowledge and skills of employees, as well as the international expansion of firms are significant determinants for performance improvement; (ii) the firm size and productive flexibility contributes negatively to efficiency; (iii) the Greece integration in the European Economic and Monetary Union and firm age, as well as several managerial practices related to vertical integration, firm's innovation activities and capital intensity do not have a statistical significant impact on performance.

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1. Introduction

The article aims to identify the determinants of efficiencies in Greek sausage manufacturing firms during the period of 1994 - 2007 and to develop policies for efficiency improvements. The focus of the research to a single sector is needed, because the study methodology requires the use of homogenous technology among the sample firms. The specific industry has increased significance for Greece, because in the contrast to general economic climate, the sausage production is accelerated with relatively high growth rates, due to increasing demand (ICAP, 2008).

The divergences in firm's efficiency scores are examined in this study, as a result of the application of different strategies by the domestic sausage manufacturers. According to this theoretical framework the differences in strategies stems from differences in the firms themselves, firstly in terms of their available resources and capabilities (Rumelt, 1991) and secondly in terms of their structural characteristics (Porter, 1979, 1985) within the sausage industry, owing to the existence of strategy groups. So, this survey aims to identify the effect of several managerial practices and industry context on productive performance of sausage manufacturing firms. For this purpose, a two-stage bootstrap Data Envelopment Analysis (DEA) model proposed by Simar and Wilson (1998, 2000) is applied, in order to avoid the serial correlation problem between the efficiency scores measures and explanatory variables.

Many previous studies have focused on identifying the drivers of efficiency, by using the conventional two-stage DEA model. Some research projects have addressed the efficiency variation in food industry (Basu and Kumar, 2008; Dimara *et al*., 2008; Ismail, 2009), and in meat production (Lambert, 1994; Yusuf and Malomo, 2007). A few efficiency analyses have been done in meat manufacturing sector (Ali, 2007; Goncharuk, 2009), in which performance determinants have not been investigated. For example, Ali (2007) analyzed efficiency and productivity in the Indian meat processing industry, in the period of 1980-2000, by using the standard DEA and estimating the Malmquist TFP index. Also, Goncharuk (2009) evaluated the efficiency of Ukrainian and foreign meatpacking companies, by utilizing the DEA model of super-efficiency. The current survey contributes to empirical analysis of industrial economics, by examining the important factors of efficiency changes in the sausage industry, where similar studies are limited in comparison to other sectors. Contribution to the literature is also the application of the method proposed by Simar and Wilson (1998, 2007), which, to our knowledge, has not been applied in this context. Knowing the efficiency drivers should facilitate managers to find out new methods for achieving efficiency. Additionally, providing institutions with insights into factors influencing performance can serve to adopt adequate sectoral policies on a regional level. Certainly, if the subsidies provided by the government might support these policy applications, an efficient utilization of the public expenditures should be reachable.

The article is organized as follows. After the introduction, section 2 presents the institutional setting. The approach adopted in this study for measuring and identifying efficiency drivers is then described in section 3. The data are presented in section 4. Section 5 reports on the two-stage bootstrapping DEA efficiency results, and finally section 6 offers some concluding remarks.

2. Institutional Setting

To identify the contextual factors that may influence efficiency, this study begins with the description of the managerial practices and different structural characteristics in sausage manufacturing firms in Greece, over the study period. In the last two decades, radical changes took place with integrating Greece into the European Economic and Monetary Union (EMU).

During the 1990s exchange controls were abolished and capital movements were completely liberalized in the states member of the European Union (including Greece). Since 1994, Greece experienced a period of coordinating economic policy and achieving economic convergence which was accomplished by assigning of the Greek state monetary policy decisions to the European Central Bank (2001) and the adoption of the euro as its currency (2002). In this new environment, the domestic sausages production was accelerated, with an average annual growth rate of 3.4%, as a result of increasing domestic demand which has increased with an average annual growth rate of 3.7% (ICAP, 2008). The needs of the domestic market in sausage were covered by 85.3% by domestic production in 2007, from 88.7 in 1994, indicating a loss of competitiveness. The export share of sausage production ranged from 2.17% to 4.45% over the study period (ICAP, 2008).

It is noticeable that a majority of Greek sausage companies are small, private and family owned, which focuses on niche markets. The few large companies that exist have automated production processes in place, and control a significant part (approximately more than 65%) of the domestic market, through organized distribution networks that cover the whole of Greece (ICAP, 2008). Over the past years upsizing and increase of the number of firms operating, were observed in this sector (EL. STAT. 2007). Another significant point is that the sausage production is raw-material intensive; approximately 61.8 % of the total cost of an average Greek sausage firm corresponds to raw material expenditures over the study period (EL. STAT. 2007). The inherent weakness and reduced competitiveness of Greek livestock result in having about 40% of the domestic meat market covered by imports (ICAP, 2008). Thus, this sector depends on the development of the international meat market. This situation leads several companies to become vertically integrated, in order to have substantial amounts of raw material at their disposal. Additionally, in order to increase its share markets the Greek sausage companies adopted different strategies which might have affected their efficiency. Some large companies took advantage of economies of scale and/or economies of scope; others benefited from the cost economies obtained by the application of a production-flexibility strategy; while there are even firms that are at an advantage due to their commercially successful product innovations and/or their higher product quality (Fotinopoulou and Keramidou 2006). On the other hand, few large companies followed a strategy of international expansion with establishment of plants mainly into Balkan countries. Also, it is especially important to mention that emphasis is given to the product quality, by constantly monitoring the production process and quality standards (HACCP and ISO 9000).

3. Methodology

In literature technical efficiency is defined as the ability of a firm to produce, under certain technological conditions, the maximum output quantities from a given set of inputs, or several output quantities utilizing minimal inputs quantities. The performance measurement is effectuated by constructing the best practice frontier. Two methodologies have been commonly used to estimate the best practice: the nonparametric and parametric approaches. In this study it was adopted a non-parametric linear programming frontier technique compared to parametric statistical methods, because this technique overcomes the problem of incorrect specification of the production function, and mainly because the new developed bootstrapping technique proposed by Simar and Wilson (1998, 2000) enables us to determine statistical properties of non-parametric frontier estimators.

In DEA literature, two basic flavors of methods for measuring the efficiency exist. In the first one, technical efficiency ($\hat{\theta}_{CRS}$), proposed by Charnes *et al*. (1978), is appropriate for analyzing the performance when the technology exhibits constant returns to scale (CRS). On the other hand Banker, Charnes and Cooper (1984), proposed the pure technical efficiency

($\hat{\theta}_{VRS}$) which is used in the case where technology exhibits variable returns to scale (VRS). So in this study, in order to elucidate which of them is the most appropriate for analyzing the Greek sausage industry case, a non-parametric test proposed by Simar and Wilson (2002) was performed, for each year in the 14-year study period. According to these results, in all 14 cases, the null hypothesis, that the technology exhibits constant returns to scale, was rejected. Also, in the current survey, an input orientation is chosen, and the description that follows adopts this selection. Technically speaking, assuming that the activity of n production units is characterized by a set of inputs x used to produce a given set of outputs y. The VRS orientation efficiency scores of each firm ($\hat{\theta}_{VRS}$) can be obtained by solving the following linear programming problem:

$$\hat{\theta}_{VRS} = \min\{\theta > 0 \mid y \le \sum_{i=1}^{n} \lambda_i y_i, \theta x \ge \sum_{i=1}^{n} \lambda_i x_i, \sum_{i=1}^{n} \lambda_i = 1, \lambda_i \ge 0, i = 1...n\} \quad (1)$$

In Eq. (1) the efficient level of input is defined by θx, which is the projection of an observed sausage industry (x, y) on to the efficient frontier, while θ is a scalar and λ is a non-negative vector of constants specifying the optimal weights of inputs/outputs. The value of $\hat{\theta}_{VRS}$ obtained is the technical efficiency score for the ith sausage firm. In order to become efficient, pure technical efficiency gives the decrease of inputs, which an observed firm at location (x, y) could undertake. In the case where $\hat{\theta}_{VRS} = 1$, the firm is considered fully efficient (Coelli *et al.*, 2005; Cooper *et al*., 2000).

However, the standard DEA approach has come under criticism owing to the potential bias of efficiency estimates. The accuracy of DEA results may be affected by the sampling variation of the estimated frontier. This means that the distances to the frontier are underestimated in the case where the best performers in the population are not included in the sample. Another reason for the potential bias of DEA efficiency estimators is related to the non measurement of random error, and therefore to the incorrect definition of overall deviation from the frontier as inefficiency. This research project addresses these inherent limitations of DEA, by applying the smoothed bootstrap approach of Simar and Wilson (1998, 2000), which by combining the DEA model with bootstrapping techniques, enables us to provide bias-corrected estimates of DEA efficiency scores, as well as confidence intervals. The complete bootstrap algorithm applied in this study is extensively described in Simar and Wilson (1998).

The pure technical efficiency scores ($\hat{\theta}_{VRS}$) derived from the first stage bootstrapped DEA analysis are regressed, on a set of hypothesized explanatory factors. For this purpose, the following regression model is applied:

$$\hat{\theta}_{VRS\,i} = a + Z_i\delta + \varepsilon_i, \mathrm{i} = 1,..., \mathrm{n} \quad (2)$$

In Eq. (2), a is the constant term, ε_i is statistical noise, and $\mathrm{Z_i}$ is a vector of specific variables for sausage firm i that is expected to be related to the sausage firm's efficiency score. These variables may be internal and/or external to a specific firm. Internal factors include the characteristics and capabilities of firms. External factors are the characteristics of the country or industry context in which the firm operates. Further details about the independent variables used are given in a later section. Finally δ is a vector of the estimated coefficients of the explanatory factors. For estimating Eq. 2, the bootstrapped truncated regression, proposed by Simar and Wilson (2007), was implemented. In this stage of analysis, efficiency scores are left truncated by 1. This approach is preferable (Simar and Wilson 2007) to the conventional procedures of regression (Tobit estimator, OLS, etc), because the latter

have reduced reliability. This is due to the fact that the DEA efficiency estimates are serially correlated with error and explanatory factors. Thus, the basic model assumption required by regression analysis, that is independence within the sample, is violated and therefore the traditional procedures of regression cannot be used. To avoid this problem, Simar and Wilson included a generated dependent variable in the second stage of the regression by using a double-bootstrapping procedure. In this approach algorithm 2 of Simar and Wilson (2007) is used.

4. Data

Data on inputs and output were collected for 35 Greek sausage firms for the period of 1994–2007, in which all the large companies operating in this sector are included. Three inputs and one output were selected by following previous studies. The output variable is total sales (Ali, 2007; Badunenko, 2010; Kravtsova, 2008). Input variables are the cost of capital, estimated as the sum of depreciation and interest (Ali, 2007; Badunenko, 2010), the cost of raw and auxiliary materials (Ali, 2007; Goncharuk, 2009; Kravtsova, 2008) and the number of full-time employees (Lambert, 1994; Ali 2007; Goncharuk, 2009). Our dataset was compiled from both primary and secondary sources. First, a questionnaire survey was conducted from December 2009 to February 2010 by Panteion University of Athens to obtain information that wasn't readily available, such as the cost of raw and auxiliary materials and the number of employees. For the collection of data, 56 randomly selected Greek sausage manufacturing firms operating in different regions of Greece were contacted and 25 of them provided us with the relevant information (a response rate of 44.6%). At the same time, data from 10 firms, that have either been purchased or merged with other firms or have been closed, was drawn in the same time period from the annual industrial bulletin statistics of the Ministry of Development, as well as from the annual balance sheets of companies reported in the Greek Government Gazette. The descriptive statistics of the database used, in the estimation of efficiency scores, are presented in Table I. The panel data set employed here was unbalanced, including 410 observations, owing to late entries and early exits from the market. Note that the monetary variables were deflated by the producer price index and expressed in thousands of euro at constant 1999 prices.

Table I: Descriptive statistics of the data

Variables	**Mean**	**Min.**	**Max.**	**SD**
Turnover	13700	280	91894	21665
Capital Cost	1204	13	8989	2085
Cost of raw and auxiliary materials	8348	117	65645	14156
Number of employees	114	4	703	160

As outlined before, our dependent variables for the second stage of analysis were original and bias-corrected VRS orientation efficiency estimates. Variables hypothesized to affect technical efficiency were chosen by following previous studies. Thus, the model at the second stage regression takes the following form:

$$PTE_i = a_0 + a_1 MS_i + a_2 TRD_i + a_3 SIZ_i + a_4 FAG_i + a_5 GRP_i + a_6 VRI_i + a_7 INT_i + a_8 PFL_i + a_9 INV_i + a_{10} WGR_i + a_{11} CPI_i + a_{12} EMU_i + e_i \quad (3)$$

where MS_i is the Market Size measured by the logarithm of the apparent consumption of sausages. TRD_i is the annual trend (Barros *et al*., 2009). SIZ_i is firm size measured by the logarithm of total fixed asset of the firm, which is examined as a proxy of economies of scale of a firm (Lin *et al.*, 2009; Yusuf and Malomo, 2007). FAG_i is the actual years that a firm has been operating since it was established to the date of observation, which is investigated as proxy for firm learning by experience (Wadud and White, 2000; Kravtsova, 2008; Lin *et al*., 2009). GRP_i is a dummy variable, which is one for firms belonging to an economic group and zero otherwise (Barros *et al*., 2009; proxy of economies of scope). VRI_i is a dummy variable, which is one for companies vertically integrated. INT_i is a dummy variable, which applies to firms with an international expansion strategy (Barros *et al*., 2009). PFL_i is a production flexibility index, which is larger than 1 when a firm is productively flexible (Boyer and Freyssenet, 1999, 2000). INV_i captures the firm's innovation activity measured by R&D intensity (Balteiro *et al*., 2006). WGR_i indicates the average wage computed by the total cost for salaries divided by the number of employees, which is considered as proxy of human capital and employees' skills (Kravtsova, 2008). Finally, CPI_i is a proxy of the level of mechanization of the production process, that is measured by the ratio of capital rate (the sum of depreciation and interests divided to total value added) to wage rate (total remuneration of salaried employees divided by the total value added).

5. Empirical Results

The original and bootstrapped VRS technical efficiency scores are presented in Table II. These findings reveal that the original DEA average efficiency score for the entire period is equal to 0.87. The findings showed that the bias corrected pure technical efficiency of an "average" Greek sausage firm ranged from 0.83 to 0.73 from 1994 to 2007, indicating that the same output, for different years of the study, could have been produced by using 17% – 27% less than the observed inputs, if the firm was efficient. By analyzing specific years of the study period, a clear trend of decreasing efficiency was observed, when looking at both original efficiency estimates and biased corrected estimates. The distribution of bias corrected efficiency scores across firms in Table II reveals the same trend as above. The number of Greek firms with efficiency scores less than 0.70 interval increases, while the number of firms with efficiency scores more than 0.91 interval decreases.

The results of the bootstrapped truncated regression are presented in Table III. The coefficients of variables presented in the first column are bias-corrected using the method described in section 4. The associated 95% confidence intervals are presented in columns three and four of Table III. A positive sign in coefficient indicates a negative influence on efficiency, while a negative sign indicates a positive influence. Since the dependent variable is the inverse of the efficiency score, it is larger or equal to one. According to the results, seven out of twelve estimates of coefficients on the explanatory variables are highly statistically significant (at the 1% level). Four variables have a positive and high statistically significant impact on the efficiency. The market size promotes the efficiency of the Greek sausage manufacturing firms, indicating that the firm can perform better with higher demand and a higher level of sausage consumption. The international expansion with establishment of plants mainly into Balkan countries contributes positively to efficiency. This indicates that firms followed an international expansion strategy may obtain a strength negotiation power

versus the domestic and international meat suppliers, as they can buy bulks, demanding discounts, and as a result they gain a massive advantage.

Table II: Summary results of original DEA and bootstrapped efficiency estimated for the period 1994-2007

	Original DEA efficiency scores			Bias corrected estimates of VRS technical efficiency scores					Distribution			
	Mean	Min	Std. dev.	Mean	Min	Std. dev.	Confidence interval 5%		< 70	71-80	81-90	> 91
							L.B	U.B				
1994	0.91	0.68	0.10	0.85	0.64	0.08	0.77	0.91	4	9	13	4
1995	0.89	0.67	0.11	0.82	0.63	0.08	0.74	0.89	4	9	11	6
1996	0.86	0.64	0.12	0.79	0.60	0.10	0.71	0.86	8	7	16	1
1997	0.88	0.69	0.12	0.81	0.63	0.09	0.73	0.88	6	9	12	5
1998	0.85	0.54	0.15	0.76	0.49	0.11	0.68	0.85	13	2	15	2
1999	0.86	0.55	0.14	0.78	0.50	0.11	0.69	0.86	11	7	13	0
2000	0.90	0.63	0.11	0.84	0.60	0.09	0.76	0.90	4	7	16	3
2001	0.87	0.40	0.14	0.80	0.37	0.11	0.71	0.87	6	8	13	4
2002	0.86	0.60	0.14	0.77	0.55	0.11	0.69	0.86	5	4	16	4
2003	0.86	0.52	0.15	0.78	0.48	0.12	0.70	0.86	6	4	15	3
2004	0.86	0.53	0.15	0.78	0.49	0.12	0.69	0.86	10	3	12	3
2005	0.86	0.52	0.15	0.78	0.48	0.12	0.69	0.86	2	5	8	11
2006	0.82	0.44	0.18	0.72	0.40	0.14	0.63	0.82	7	4	13	2
2007	0.84	0.43	0.18	0.75	0.40	0.13	0.66	0.84	9	4	11	1
Mean	0.87	0.40	0.10	0.79	0.37	0.11	0.70	0.87				

LB=lower bound of the confidence interval, UB=Upper bound of the confidence interval.

Table III: Sources of VRS technical efficiency scores, using a bootstrapped truncated regression (number of bootstrap iterations 2000)

Variables	Bias-adjusted coefficient	Standard error	95% Bootstrap confidence intervals	
			Low	High
Constant	-0.30129	0.2359	-0.7644	0.1611
Market size	-0.00104*	0.0005	-0.0019	-0.0002
Trend	0.00128*	0.0005	0.0003	0.0023
EMU	-0.00008	0.0001	-0.0003	0.0001
Size	0.00213*	0.0003	0.0015	0.0027
Age	0.00012	0.0002	-0.0002	0.0004
Group	-0.00043*	0.0001	-0.0006	-0.0002
Vertical integration	-0.00014	0.0001	-0.0003	0.0000
International	-0.00112*	0.0002	-0.0016	-0.0006
Production flexibility index	0.00153*	0.0003	0.0010	0.0020
R&D intensity	0.00041	0.0004	-0.0004	0.0012
Wage rate	-0.00055*	0.0003	-0.0011	0.0000
Capital intensity	0.00048	0.0002	0.0001	0.0009
Total number of observations	410			

* Significance at the 5% level. All bias-adjusted coefficients that are significant at the 5% levels are also significant at the 1% level.

To be a member of a firm group contributes positively to efficiency improvements. This finding supports the view that the members of a firm group can decrease their costs

because of scope economies and/or of internal benchmarking. A high level of employees' skills calculated by the total cost for salaries divided by number of employees, and it is a favourable factor in terms of technical efficiency. This indicates that a greater stock of competences, knowledge and personality attributes increases the ability to perform labour. The Greece integration to the European Monetary Community, since 2001, is also found to contribute positively to efficiency. The rationale for this is based on decrease of interest rate and hence the cost of capital use. However, the estimates are statistically insignificant. Additionally, vertically integration has a positive statistical insignificant effect on efficiency.

It is important to note that half of variables contribute negatively to the efficiency. This leads, as the time trend indicates, to a statistically significant decrease in technical efficiency during the study period. Another two variables also had a negative and high statistically significant impact on the efficiency, as they have a positive sign, which denotes a negative influence on efficiency. To be a large firm, which is measured by the logarithm of total fixed asset of the firm, contributes negatively to efficiency, indicating the evidence of diseconomies of scale in the sample firms and/or of underutilization of production capacity. Productive flexibility is also an unfavourable factor and highly statistically significant. An explanation for this is the fact that productive flexible capability of firms permits to meet the market needs, by diversification of products, having a negative effect on average total cost. In addition, capital intensity was another unfavourable factor. This may imply an overcapitalization of sample firms, due to incorrect management decisions regarding to quantities of machinery, equipment and buildings that are needed. On the other hand it may indicate the existence of old and no longer in use capital stock, the maintenance of which often requires expenditures (e.g. payment of interest). Moreover, the firm innovation activity measured by R&D intensity, contributes negatively to efficiency of sample firms. This implies that firm innovation activity do not lead always in commercially successful innovative product or process and hence in higher return. This negative impact on technical efficiency is also statistically insignificant[1]. Lastly, the age variable proved to be negatively related to technical efficiency, meaning that older companies are less likely to be technically efficient. Therefore, the firm's accumulated experience and knowledge through time does not obtain a superior level of efficiency. However, the estimates are statistically insignificant.

Thus, being a member of a firm group, adopting an international expansion strategy and having high level of human capital is all associated with a firm being technically efficient. The variables that are significantly negative and hence prevent firm performance are firm size and the capacity to be productively flexible.

6. Concluding Remarks

This article provides an application of the double bootstrapping DEA procedure in the sausage industry. The analysis of efficiency began by measuring the DEA-bootstrapped efficiency scores for a sample of sausage manufacturing firms in Greece over the period of 1994 - 2007. The findings showed that managers have substantial margin to enhance their efficiency by decreasing the waste of productive factors and by adopting similar practices to those of the best performers in the sample. In order to determine the inefficiency sources, technical efficiency scores are related to different managerial practices and some elements of industry context. For this purpose, the use of the standard regression model that is commonly

[1] A positive relationship between year trend and efficiency has been identified by previous studies in other areas (Barros *et al*., 2009). In addition Yusuf and Malomo (2007) found a negative impact of firm size on efficiency. On the other hand Balcombe *et al*., (2005) described a positive impact of capital intensity on efficiency of farms in Central Europe. Wadud and White, 2000 indentified a negative impact of firm age on efficiency.

applied is inappropriate and instead, in this study, a bootstrap truncated regression model is implemented. The motivation for employing this approach is to overcome the problem of serial correlation among efficiency scores and explicative factors. From the analysis of regression, it is concluded that the Greek sausage companies adopted different strategies and that have affected their efficiency. An important result is that members of a firm group and firms with international expansion or high level of human capital have an efficiency advantage when compared to the sample firms that present different capabilities. Large firms, and productively flexible are associated with being technically inefficient. Another interesting result is that the firms' age and innovation activities do not have a statistical significant impact on performance. This is also the case for the vertical integration, the capital intensity, and the Greece integration in EMU. From a policy perspective, the above results can serve as a guideline for improving efficiency in the sausage industry in Greece.

To summarize, this survey could be considered as applying an advanced approach of identifying the inefficiency sources. It shows a DEA approach which is combined with bootstrapping techniques to obtain robust estimates of efficiency scores and truncated regression model coefficients. Therefore, this analysis contributes to knowledge about the efficiency sources of Greek sausage manufacturing firms. Policy makers and managers can use these results with increasing confidence in order to develop ways to improve performance of separate firms and of the whole industry.

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