Drawing the Profile of Efficient Food Industries—Vertical Integration, Economies of Scale, and Location Advantages in the Distribution of Products: A Case Study from the Greek Food Industry

Ioannis Kaltsas and Bobby Beamer

A stochastic frontier production function that incorporates a model for technical inefficiency effects is used to investigate the industrial production of Greek food industries. Panel data comes from 29 Greek firms in 1988 through 1992. Parameters considered in the model for inefficiency effects include the degree of vertical integration, capital intensity, location, and time. A translog stochastic frontier function is estimated simultaneously with those variables in the model for inefficiency effects. The results indicate that technical efficiency among the firms ranges from 42 percent to 99 percent. More efficient firms are those with a higher degree of vertical integration that are located in rural areas and have sufficient investment in human capital to exploit the economies of scale obtained through investment in fixed capital. Most firms improve their performance over time, reducing the efficiency gap.

Introduction

The food manufacturing industry appears to be one of the most profitable industrial sectors of the Greek economy (OECD, 1997). However, increased international competition, especially from the neighboring Balkan countries, will introduce new challenges that will require increasingly efficient performance for firms to successfully compete in both foreign and domestic markets. The purpose of this study is to identify determinants of technical inefficiencies within the food manufacturing industry. Results should suggest managerial and industrial policy remedies that can be applied to overcome these inefficiencies.

The measurement of technical efficiency can provide useful insights into the competitiveness of firms and their potential for superior productivity and resource use. Farrell (1957) provided a method of measuring technical and economic inefficiencies, and his work has been extended and applied by many others. This investigation follows the approach initially proposed by Kumbaharak, Ghosh, and McGuckin (1989), and extended by the work of Battese and Coelli (1996), whereby a stochastic frontier production function incorporates a model of inefficiency effects.

The single-stage approach seems less objectionable from a statistical point of view than the traditional two-stage approach followed by Kalirajan (1981), and Parikh and Shah (1994). There are two main disadvantages of the two-stage approach. In the first stage, it is assumed that the inefficiency effects are independently and identically distributed while in the second stage we neglect this assumption by regressing the inefficiency effects to a number of firm-specific factors. Additionally, the one-stage approach is expected to lead to more efficient inference with respect to the firm-specific variables involved (Coelli, 1995).

The Empirical Model

The stochastic frontier production function for the food firms in Greece is assumed to be

$$(1) \qquad \ln y_i = A_0 + \sum_{i=1}^{k} A_i \ln x_{it} + \frac{1}{2}\sum_{i=1}^{k}\sum_{j=1}^{k} A_{ij}\ln x_{it}\ln x_{jt} + A_i T_{it} + \epsilon_i ,$$

Ioannis Kaltsas is a Ph.D. student, and Bobby Beamer is adjunct professor, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0401. Email: ikaltsas@vt.edu; bgbeamer@vt.edu.
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where the subscripts i refer to the i[th] firm, ln denotes logarithms to base e, y is the output of the firm, x is the amount of inputs, and ϵ_i is a stochastic error term consisting of two independent elements,

(2) $$\epsilon_i = u_i + v_i .$$

The stochastic component, v_i, is assumed to be independent and identically distributed as $N(0,\sigma_v^2)$. It accounts for random variation in output due to factors outside of the firm's control, such as random shocks in supply and demand. A non-negative component, u_i, reflects technical inefficiency effects relative to the stochastic frontier. It is assumed to be independently distributed and to arise from the truncation of the normal distribution with variance σ^2 and mean μ_i defined by

(3) $$\mu_i = B_0 + \sum_{i=1}^{k} B_i z_{it} + B_{i+1} T_{it} ,$$

where the zs are the inefficiency factors and T is a trend variable to allow for systematic changes over time.

The functional form for the stochastic frontier, defined by equation (1), is a translog model. While not as flexible as the Zellner-Revankar generalized production function, the translog has the advantage of being less complex in the estimation of parameters (Coelli, 1995).

The A- and B-coefficients are unknown parameters to be estimated together with the parameters of the variance that is expressed in terms of

(4) $$\sigma^2 = \sigma_u^2 + \sigma_v^2 .$$

(5) $$\gamma = \sigma_u^2 / \sigma^2 .$$

According to Jordow et al. (1982), measures of technical efficiency of a production unit at a given period of time can be obtained from the error terms $\epsilon_i = u_i + v_i$. For any firm i, the measure is the expected value of u_i, conditional on ϵ_i, which is

(6) $$E(u_i | \epsilon_i) = \sigma_u \sigma_v / \sigma \;\; [\varphi(\epsilon_i \lambda / \sigma) / [1 - \phi(\epsilon_i \lambda / \sigma)]] - \epsilon_i \lambda / \sigma \qquad i = 1,...,n$$

where $\varphi(.)$ is the standard normal density function (PDF) and $\phi(.)$ is the standard normal distribution (CDF). For ϵ, λ, and σ, the estimated values are used to evaluate the density and the distribution function. Thus, the measure of technical efficiency (TE_i) for any farm i can be calculated as

(7) $$TE_i = \exp(-E[u_i | \epsilon_i]) \qquad i = 1,...,n .$$

Thus, the technical efficiency of the firm is between 0 and 1, and it is inversely associated with the inefficiency effect. The parameters and the stochastic frontier model (1)–(3) are estimated by the method of the maximum likelihood, using the *Frontier 4.1* computer program (Coelli, 1994).[1]

The above model, which accounts for the inefficiency effects, can only be estimated if the inefficiency effects are stochastic and have a particular specification of their distribution. Thus, it is important to test the following null hypotheses: Whether the inefficiency effects are not present, H_0: $\gamma = B_0 = ... = B_{i+1} = 0$, and whether the inefficiency effects are not stochastic, $H_0 : \gamma = 0$. The generalized likelihood-ratio statistic, λ, is used to test the above and other interesting null hypotheses.

(8) $$\lambda = -2\ [\ln L(H_0) - \ln L(H_E)],$$

where $L(H_0)$ and $L(H_E)$ are the values of the likelihood function under the specifications of the null hypothesis, H_0, and the alternative hypothesis, H_E. On the condition that the null hypothesis is true, λ follows a mixed Chi-square or an approximate Chi-squared distribution. According to Coelli (1995), if the null hypothesis involves γ=0, the model reduces to a traditional average response model.

Data Description

The basic information for this study was obtained from the Statistic Office of the Greek Ministry of

[1] Thanks to Tim Coelli for the provision of the program.

Industrial Affairs as well as from the annual budgets of the firms. Some additional information was collected by telephone interviews. The firms included in the study belong to the 311 food manufacturing category from the International Standard Economic Classification. Data for the study cover the years 1988 through 1992.

Output for each firm is measured by total production in terms of drachmas (Dr) of sales. The two inputs of interest for the primary production function are fixed capital and labor. Fixed capital is the total value of all fixed capital in drachmas. Labor is measured by the total payroll in drachmas. While the impact of labor and capital on the level of production is not the primary focus of this investigation, prior expectations are that either could have a positive impact on the level of production, depending on the stage of production and the interaction of the factors. Given the flexibility of the model utilized in the investigation, this issue becomes an empirical question.

Three factors are considered to affect the efficiency of firms: vertical integration, capital intensity, and location in rural areas. Value-added is used as a proxy for vertical integration of the firm. Value-added is measured as gross output minus the costs of materials, fuels and other supplies, goods shipped in the same condition as received, and electricity purchased. Note that the cost of the non-industrial services is not deducted. Vertical integration is then defined as value-added divided by total production. Vertical integration, if significant, is expected to reduce technical inefficiencies by bringing more factors of production under the manager's control.

Capital intensity is defined as the drachmas of wages for the firm divided by the drachmas of fixed capital. The impact of the location of firms in rural versus urban areas is measured with a dummy variable that takes a value of 1 if a firm locates at the industrial zone of a major city and 0 otherwise. Food manufacturing firms that are located in rural areas experience the advantages of close proximity to raw input supplies, lower cost labor, and tax incentive programs. On the other hand, they are farther from the major consumer centers and may face a less-skilled labor pool when compared with urban areas.

The specific form for the stochastic production function frontier model is assumed to be:

$$
\begin{aligned}
\text{n}Y_{it} &= A_0 + A_1\ln(L_{it}) + A_2\ln(C_{it}) \\
&+ \tfrac{1}{2}[A_{11}\ln(L_{it})\ln(L_{jt}) + A_{12}\ln(L_{it})\ln(C_{it} \\
&+ A_{22}\ln(C_{it})\ln(C_{jt})] + B_1\ln(VI_{it}) \\
&+ B_2\ln(CI_{it}) + B_3\ln(R_{it}) + V_{it} + U_{it},
\end{aligned} \tag{9}
$$

where

$$V_{it} \sim N(0,\sigma_v^2), \tag{10}$$

and

$$
\begin{aligned}
(U_{it}|B_0 &+ B_1\ln(VI_{it}) + B_2\ln(CI_{it}) \\
&+ B_3\ln(R_{it}) + B_4T,\ \sigma_u^2),
\end{aligned} \tag{11}
$$

where

Y is total value of firm production (Dr);

L is total firm expenditure for wages (Dr);

C is total value of fixed capital (Dr);

VI is degree of vertical integration (value added over Y);

CI is capital intensity (L over C);

R is dummy variable for location (rural versus urban);

T is time trend.

Descriptive statistics of the primary variables used in the analysis are presented in Table 1.

Empirical Results

The formal tests of the hypotheses associated with inefficiency effects are presented in Table 2. The hypotheses are strongly rejected. Rejection of the first hypothesis (H_0: $g=B_0=B_1=B_2=B_3=B_4=0$) suggests that the inefficiency factors tested do impact the production of output. More importantly, rejection of the second null hypothesis indicates that the inefficiency factors are not merely components of the production and requires that we accept the alternative hypothesis of the inefficiency model. If γ equals zero, then the model reduces to a

Table 1. Summary Statistics of Output and Inputs for 39 Greek Food Manufacturing Firms, 1988–92.

Inputs/Outputs	Mean	Std Dev.	Min	Max
Total Production (drachmas)	417.8	469.5	21.5	2,756.1
Fixed Capital (drachmas)	436.3	480.6	18.2	3,188.8
Wages for employees (drachmas)	201.6	273.3	8.93	2,184.4
Degree of Vertical Integration	0.51	0.22	0.19	0.87
Capital Intensity	0.053	0.04	0.0001	0.254
Location in Rural Area		29 percent of the firms		
Location in Suburban Area		71 percent of the firms		

Table 2. Tests of Hypotheses Associated With Inefficiency Effects in the Stochastic Frontier Production Function for the Greek Food Manufacturing Industry.

Null Hypothesis	Log-L	λ	Critical Value	Decision
H_0: $\gamma = B_0 = B_1 = B_2 = B_3 = B_4 = 0$	62.308	18.47	11.07	Reject H_0
H_0: $\gamma = 0$	57.245	8.88	5.991	Reject H_0

traditional response model involving two less parameters. Thus, the traditional average response model is not adequate to explain the production of the food industry, given the specification of the stochastic frontier and inefficiency function, defined by equations (1) and (3).

Given the results of the hypothesis tests, explanatory variables for the inefficiency model bear further inspection. Table 3 contains the maximum likelihood estimates for the parameters in the stochastic frontier and the inefficiency model. The values and the sizes of the coefficients of the stochastic frontier are consistent with expectations. The degree of vertical integration of the firms (B_1) clearly has a negative impact upon the inefficiency effects. More simply stated, vertically integrated firms tend to be more efficient in food production.

The coefficient of the capital intensity (B_2) variable is negative but significant only at the 10 percent level. While less significant than the other inefficiency factors, this result is still worthy of some comment and interpretation. Capital intensity here was measured as the total firm expenditure for wages divided by the total value of the firm's fixed capital. Under the assumption that more qualified workers are more highly paid, the results suggest that firms could reduce inefficiency by increasing expenditures on workers. This could be accomplished by either hiring more workers or by improving the quality of workers hired. A further implication is that, if a firm increases its investment in capital, it must also increase its expenditure on wages or suffer increased inefficiency. While not directly considered here, this result is also consistent with the estimated coefficients for labor (A_1) and capital (A_2) in the production function portion of the model.

Location of the firms (B_3) close to the urban center seems to be associated with lower technical efficiency. Establishment of the food production units in the rural areas give them a significant efficiency advantage. This result suggests that the advantages of close proximity to raw input supplies, lower-cost labor, and tax incentive programs outweigh the disadvantages of a less-skilled labor pool and distance from major market centers.

Finally, firms do improve their efficiency over time (B_4). Using the results estimated above, the technical efficiencies can be calculated for each of the firms in the sample. Table 4 provides the frequency distribution of the firms in each of the five years of the study. Clearly, the food

Table 3. Maximum Likelihood Estimates of the Stochastic Frontiers and Inefficiency Models for the Greek Food Industry.

Parameter	Coefficients	Standard Error	t-ratio
A_0	-5.87	1.05	5.56*
A_1	2.83	0.23	11.99*
A_2	-1.58	0.45	3.48*
A_{11}	-0.29	0.03	8.28*
A_{12}	0.29	0.05	5.05*
A_{22}	-0.36	0.08	4.47*
Results for the Inefficiency Model			
B_0	0.88	0.27	3.24*
B_1	-1.41	0.60	2.33*
B_2	-4.44	2.68	1.65**
B_3	0.53	0.16	3.25*
B_4	-0.13	0.04	2.87*
σ^2	0.139	0.023	5.953*
γ	0.178	0.176	1.013
	Ln(likelihood)	-52.869	
	Number of Iterations	22	

*Significant at the 5% level.

**Significant at the 10% level.

Table 4. Frequency Distribution of Technical Efficiencies of the Stochastic Production Frontier for the Greek Food Industry.

Efficiency Index	**Year**				
	1	**2**	**3**	**4**	**5**
90 to 100%	10 (34.5%)	16 (55.2%)	23 (79.3%)	24 (82.8%)	26 (89.7%)
80 to 89%	10 (34.5%)	7 (24.1%)	3 (10.3%)	1 (3.4%)	0 (0.0%)
70 to 79%	3 (10.3%)	2 (6.9%)	2 (6.9%)	4 (13.8%)	3 (10.3%)
60 to 69%	2 (6.9%)	2 (6.9%)	1 (3.4%)	0 (0.0%)	0 (0.0%)
50 to 59%	3 (10.3%)	2 (6.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
0 to 49 %	1 (3.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

manufacturing firms in the study were able to reduce inefficiencies during the period from 1988 through 1992. Estimated efficiencies in 1988 ranged from a minimum of 42 percent to a maximum of 96 percent but had improved by 1992 to a minimum of 62 percent and a maximum of 98 percent. It should be noted that the measures of technical efficiency calculated here are ordinal and not cardinal and, as such, are only appropriate for ranking one firm relative to another. The fact that one firm has an estimated technical efficiency of 98 percent with this model does not imply that they are operating near perfect efficiency but rather means that they are more efficient than a firm with a technical efficiency of 90 percent.

Conclusions

This paper employed a single-stage approach to the estimation of the inefficiency model for 29 Greek food manufacturing firms. The production frontier was estimated as a function of the inputs of labor and fixed capital while the inefficiency effects in the stochastic frontier included the degree of vertical integration, capital intensity, area of location, and time. Results suggest that increased vertical integration and increased investment in labor both reduce inefficiencies with the firm while locating firms within the urban industrial center's increased inefficiencies. Food manufacturers improved efficiency over the sample period as indicated by both the significance of the time variable in the model and the reduced disparity between efficient and inefficient firms. That the less efficient firms have managed to close the gap with the more efficient firms may be the result of an increased awareness of the inefficiencies with increased competition in international markets. Incentive programs may also have helped to prompt the increase in efficiency.

It would be difficult to draw policy conclusions from this small sample of panel data. A more extended data set would offer the chance to estimate and study technical change and changes in the inefficiency effects in more detail over time. However, the results indicate that there is an evident potential for further exploitation for increasing the technical efficiency without additional investment in the food industry. Policies should take into account the relative low level of vertical integration and perhaps become more lenient in the issues of mergers and acquisitions. Capital intensity should also be combined with better quality of human capital to give more striking results. Finally, both policymakers and firms should take into consideration the efficiency advantage that firms obtain in the rural areas and more carefully design their long-term policy.

References

Battese, G.E. and T.J. Coelli. 1996. "Indication of Factors Which Influence the Technical Efficiency of Indian Farmers." *Australian Journal of Agricultural Economics*. 40:103B128.

Coelli, T.J. 1994. "A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation." Mimeo, Department of Econometrics, University of New England, Armidale.

Coelli, T.J. 1995. "Recent Developments in Frontier Modelling and Efficiency Measurement." *Australian Journal of Agricultural Economics*. 39:219B245.

Farrell, M.J. 1957. "The Measurement of Productive Efficiency." *Journal of Royal Statistical Society*. Series A(120):253B290.

Jordow, J. et al. 1982. "A Survey of Frontier Production Function and Their Relationship to Efficiency Measurement." *Journal of Econometrics*. 13:25B34.

Kumbaharak, S.C., S. Ghosh, and J.T. McGuckin. 1989. "A Generalized Production Frontier Approach for Estimating Efficiency in U.S. Dairy Farms." *Journal of Business and Economic Statistics*. 9:279B286.

National Statistic Service of Greece. 1995. *Annual Industrial Survey*. Athens, Greece.

OECD (Organization for Economic Cooperation and Development). 1997. *Industrial Structure Statistics, 1995*. Paris, France.

Parikh, A. and K. Shah. 1994. "Measurement of Technical Efficiency in the North West Frontier of Pakistan." *Journal of Agricultural Economics*. 45:132B138.