

Assessing the Efficiency of Sheep Farming in Mountainous Areas of Greece. A Non Parametric Approach

Panos Fousekis, Pavlos Spathis and Konstantinos Tsimboukas*

Abstract

The objective of this paper is the measurement and decomposition of the overall efficiency of sheep farming in mountainous areas of Greece. To this end, both a Constant Returns to Scale (CRS) and a Variable Returns to Scale (VRS) DEA model has been applied to a sample to 101 farms located in the mountainous areas of Epirus, Sterea, and Thessaly. The empirical results suggest: a) the average overall efficiency ratio in the sample is about 80 percent; b) the pure technical and the scale efficiency are of almost equal importance in the determination of the overall efficiency. Therefore, CRS DEA models will tend to underestimate systematically the level of pure technical efficiency; c) there are differences in the overall efficiency ratios across the three regions stemming mainly from differences in pure technical efficiency.

Key Words: *Sheep Farming, Mountainous Areas, Greece, DEA*

Introduction

The neoclassical theory of the firm suggests that market competition will force optimizing producers to utilize resources in the most efficient way. In reality, however, a process such as this works slowly and, thus, there may be some opportunity for “free lunch”, that is, opportunity for input savings without output reduction. This explains why the measurement of efficiency has been the focal point of numerous theoretical and empirical works in economics (e.g. Charnes, Cooper, and Rhodes, 1978; Kopp, 1981; Battese and Coelli, 1988; Bauer, 1990; Bera and Sharma, 1999).

There are two general approaches to measuring efficiency, namely, the parametric and the non parametric. The former require explicit assumptions about the functional form which relates inputs and outputs and about the distribution of the error terms (Jondrow et al., 1982). The non parametric methods, in general, and the Data Envelopment Analysis (DEA), in particular, do not impose any functional form and can handle easily multiple input and multiple output cases. Moreover, in DEA applications inputs and outputs can have very different units

* Lecturer, Associate Professor, and Assistant Professor at the Agricultural University of Athens. Address Correspondence to: Dr. Panos Fousekis, Department of Agricultural, Economics and Development, Agricultural University of Athens, Iera Odos 75, Athens 118 55, Greece, Tel: + 30 – 1- 5294725, Fax: + 30 – 1- 5294786, E-mail: p.fousekis@aua.gr
No senior authorship has been assigned.

of measurement without requiring any *a priori* tradeoffs or any input and output prices. Given these highly desirable features of the non parametric methods, it is not surprising that they have recently become very popular among researchers (e.g. Neff, et al., 1993; Sharma, et al., 1997; Piot-Lepetit, et al., 1997; Townsend, et al., 1998; Shafiq and Rehman, 2000).

It appears that, to date, there have been only two applications of DEA to the agricultural sector in Greece. Phychoudakis and Dimitriadou (1998) estimated technical efficiency (TE) for dairy farms located in Central and Western Macedonia, during 1990-91. Karagiannis and Galanopoulos (2000) estimated technical efficiency (TE) for sheep farms located in Epirus, during 1998-99. Both studies reported high rates of TE (above 89 percent).

A potential limitation of the two aforementioned works is that they assume constant returns to scale (CRS). If that assumption is true, the application of the CRS DEA model will lead to correct estimates of technical efficiency. However, if returns to scale are increasing or decreasing the CRS DEA model will actually yield estimates of the overall efficiency (which is the product of pure technical and scale efficiency). In other words, the CRS DEA will underestimate the true pure technical efficiency (Thanassoulis, 2000). At the same time, the CRS DEA will provide no information on scale inefficiency and its causes (increasing or decreasing returns). Such information is certainly necessary for policy formulation.

The objective of the present paper is the measurement of technical and scale efficiency of sheep farming in mountainous areas of Greece. To this end, a modified DEA approach is applied to 101 farms located in mountainous areas of Epirus, Sterea, and Thessaly during 1997. In what follows, Section 2 describes the DEA method, and Section 3 discusses the data. Section 4 presents the empirical results, while Section 5 offers conclusions.

Mathematical Formulation

Suppose that there are n firms to be evaluated. Each firm produces s different outputs using m different inputs. Let x_{ij} be the observed level of the i th input ($i = 1, 2, \dots, m$), and y_{rj} be the observed level of the r th output ($r = 1, 2, \dots, s$) for the j th firm ($j = 1, 2, \dots, n$). Charnes, Cooper, and Rhodes (1978) suggested that the technical efficiency for firm j_0 can be obtained as the solution to the following mathematical programming problem (known as CCR primal)

$$(1) \text{ Min } w_0$$

subject to

$$(2) w_0 x_{i0} \geq \sum_{j=1}^n \lambda_j x_{ij}, \quad i = 1, 2, \dots, m$$

$$(3) \sum_{j=1}^n \lambda_j y_{rj} \geq y_{r0}, \quad r = 1, 2, \dots, s$$

$$(4) \lambda_j \geq 0.$$

In above, w_0 is the measure of TE. Hence, the maximum possible radial reduction in all inputs while keeping at least the same level of output, is $1 - w_0$. λ_j are *intensity variables* identifying the *peer group* for the firm, that is, other firms in the sample which for the same set of virtual weights are more efficient than j_0 (Charnes and Cooper, 1985).

Model (1) to (4) is based on the assumption of constant returns to scale (CRS), implying that firm size does not matter for efficiency. The CRS assumption, however, is only appropriate when all firms are operating at the optimal scale. Using the CRS specification when a number of firms experience variable returns to scale (VRS) results in TE measures which comprise both *pure technical efficiency* and *scale efficiency* (Coelli, et al., 1998).

Banker, Charnes, Cooper (1984) and proposed a modification of the CRS DEA to account for VRS. This involves adding the convexity constraint

$$(5) \sum_{j=1}^n \lambda_j = 1$$

to the CCR primal model. The proposed approach forms a convex hull of intersecting planes which envelop the data points more tightly than the CRS conical hull providing, thus, technical efficiency scores which are greater than or equal to those obtained using the CRS DEA. In essence, the convexity constraint ensures that an inefficient firm is only “benchmarked” against firms of similar size, while in the CRS DEA a firm may be benchmarked against firms which are substantially larger (smaller) than it.

Figure 1 illustrates the CRS and the VRS DEA boundaries using a one input-one output technology example. Under the CRS, the technical inefficiency for point P is the distance PC, while under the VRS it is the distance PV. The difference between the two is due to scale inefficiency.

Let w_0^* be the solution of the VRS DEA model. Then, scale efficiency measure is

$$(6) \quad SE = \frac{w_0}{w_0^*}$$

which implies

$$(7) \quad w_0 = (w_0^*)(SE)$$

(Thanassoulis, 2000).

The last relation decomposes the overall efficiency (w_0) into pure technical efficiency (w_0^*) and scale efficiency (SE). The scale efficiency measure, in turn, can be roughly interpreted as the ratio of the average productivity at the point on the VRS boundary to the average productivity at point of the technically optimal scale (Coelli et al., 1998). In terms of Figure 1, scale efficiency is the ratio of the average productivity at V to the average productivity at R.

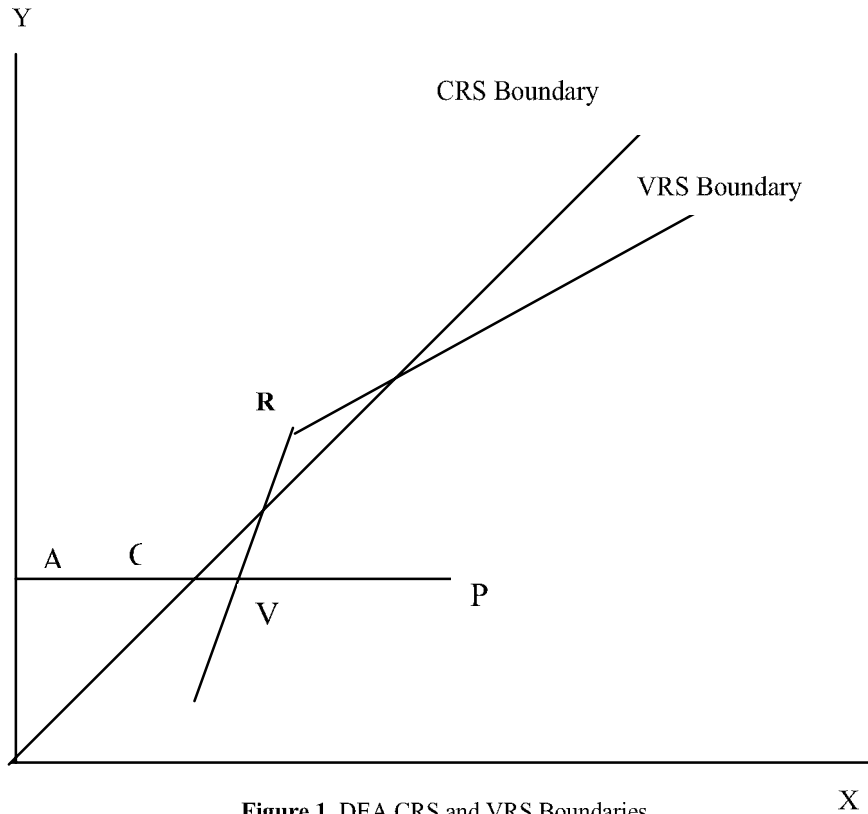


Figure 1. DEA CRS and VRS Boundaries

X

The nature of scale inefficiency can be of two types. First, a firm is too small and belongs to the section of the frontier where increasing returns to scale prevail; second, a firm is too large and belongs to the section where decreasing returns to scale prevail. The type can be identified from the solution of the CRS

DEA model. Specifically, when $\sum_{j=1}^n \lambda_j \geq 1$ the scale for a firm is too large,

while $\sum_{j=1}^n \lambda_j \leq 1$ the scale of a firm is too small. Firms for which $\sum_{j=1}^n \lambda_j = 1$ are operating at the most productive scale (Cooper, Seiford, and Tone, 2000).

The Data

The 1997 data set of the Farm Agricultural Data Network (FADN) - from which the information for the empirical analysis comes from - contains 200 sheep farms located in mountainous and disadvantaged regions throughout Greece. The construction of a representative DEA best practice frontier, however, requires that the farms in the sample operate under common environmental and biological constraints. The sheep production systems in the mountainous areas of Epirus, Sterea, and Thessaly are semi-extensive (relying on communal and private grazing grounds and having high labor and low capital requirements). The climatic conditions in the three areas are very similar. Moreover, the basic sheep species in these areas is *Vlahiko* (a very well adapted one to the geographical configuration and to the environmental conditions). In the FADN data set 49 farms are located in Epirus, 29 in Sterea, and 23 in Thessaly. These 101 farms are used here for the empirical analysis.

The production technology is specified as a two-output and five-input one. Outputs are meat and milk, while inputs are labour, capital, purchased feedstuff, farm produced feedstuff, and animal stock (herd size). The capital input includes machinery and structures in 1997 prices. Table 1 presents descriptive statistics for the inputs and the outputs.

Table 1. Descriptive Statistics of the Data*

| | Outputs | | Inputs | | | | |
|---------|---------|------|--------|---------------------|-------------------------|-----------|---------|
| | Milk | Meat | Labour | Purchased Feedstuff | Farm Produced Feedstuff | Herd Size | Capital |
| Average | 18177 | 1664 | 4720 | 2098 | 860 | 165 | 9480 |
| SD | 10799 | 933 | 2254 | 1662 | 1044 | 95 | 8185 |

* Outputs are measured in kg. Labour is measured in Annual Average Units (AWA), while herd is the number of animals. The remaining inputs are measured in 1000 GRD; SD: Standard Deviation.

The Empirical Results

Table 2 presents information on the distribution of efficiency (overall, pure technical, scale) for the farms in the sample. The average level of overall efficiency is 0.823 suggesting that almost 18 percent cost savings would be possible, provided that the farms followed the best observed practice and -at the same time- they operated at the most productive scale. The average level of the pure technical efficiency is 0.893 implying that radial reductions in all inputs by 11 percent would be possible, holding the output levels constant. The efficiency estimates obtained under the CRS and VRS hypotheses are quite different. For example, from the 43 farms which are technically efficient, 21 (=43-22) are not scale efficient. On average, pure technical efficiency exceeds overall efficiency by 7 percentage points. These results suggests that the CRS hypothesis, under which the sheep farms operate at the most productive scale, is not compatible with real world data since part of the estimated inefficiency under CRS is actually scale inefficiency. The average level of scale efficiency is 0.922 implying

that 8 percent cost savings would be possible, provided that the farms operated at the most productive scale. The empirical results therefore indicate that pure technical and scale efficiency are almost of equal importance in the determination of the overall efficiency.

As explained in Section 2, scale inefficiency arises both from too small farms and from too large farms. From the sum of the intensity variables (λ_s) corresponding to each individual farm it appears that 60 percent of them are operating under increasing returns to scale. For these farms, increase in size is required to achieve cost savings. 21.8 percent operate under constant returns, while only 17.8 percent operate under decreasing returns to scale. The small farm size has been cited by many researchers as one of the most important structural problems of the agricultural sector in Greece as a whole (e.g. Papageorgiou and Spathis, 2000). The DEA approach indicates that sheep farming in the mountainous areas of Greece is not an exception to the general rule.

Table 2. Efficiency Distribution in the Sample

Overall Efficiency

Average: 0.823

Standard Deviation: 0.16

| | | | | | | |
|---------------------|------|----------|------------|------------|------------|-------|
| Overall Efficiency | 1 | [0.9, 1) | [0.8, 0.9) | [0.7, 0.8) | [0.6, 0.7) | < 0.6 |
| Percentage of Farms | 21.8 | 15.8 | 18.8 | 15.8 | 18.8 | 8.9 |

Pure Technical Efficiency

Average: 0.893

Standard Deviation: 0.13

| | | | | | | |
|---------------------------|------|----------|------------|------------|------------|-------|
| Pure Technical Efficiency | 1 | [0.9, 1) | [0.8, 0.9) | [0.7, 0.8) | [0.6, 0.7) | < 0.6 |
| Percentage of Farms | 42.6 | 17.8 | 12.9 | 14.9 | 7.9 | 4 |

Scale Efficiency

Average: 0.922

Standard Deviation: 0.101

| | | | | | |
|---------------------|------|----------|------------|------------|-------|
| Scale Efficiency | 1 | [0.9, 1) | [0.8, 0.9) | [0.7, 0.8) | < 0.7 |
| Percentage of Farms | 21.8 | 49.5 | 15.8 | 6.9 | 5.9 |

In the empirical works on technical efficiency, a standard exercise involves the identification of factors affecting its level. In the relevant literature, several such factors have been proposed. These include age, education and experience, input usage and/or other farm characteristics (e.g. Battese and Coelli, 1995; Huang and Liu, 1994; Sharma et al., 1997). The estimated efficiency levels are typically regressed on such factors. A positive coefficient implies that the factor in question works towards raising technical efficiency. Unfortunately, the FADN

data set does not provide information on personal characteristics of farmers. The lack of such relevant information in a regression model may result in biased and inconsistent estimates (specification error). Therefore, this paper, instead of estimating a potentially spurious regression presents a number of simple correlation coefficients between pure technical efficiency levels and farm characteristics. Since the correlation coefficients, however, are partial measures of association they must be interpreted with caution especially because the economic theory does not really provide any guide on the factors which may affect pure technical efficiency.

Table 3 presents correlation coefficients and the respective t-statistics (Kintis, 1994) with the typical gross margin, with the contribution (in percentage terms) of subsidies to the farm family income, with the contribution (in percentage terms) of milk to the total gross revenue from sales, and with the ratio of the farm produced to the purchased feedstuff.

Table 3. Correlation Coefficients of Technical Efficiency Levels with Certain Farm Characteristics

| Farm Characteristics | Empirical Value | t-statistic |
|--|-----------------|-------------|
| Typical Gross Margin | -0.19 | -2.01* |
| Subsidies to Total Farm Family Income (%) | -0.21 | -2.18* |
| Value of Milk to Gross Sales Revenue (%) | 0.027 | 0.29 |
| Value of Farm Produced Feedstuff to Value of Purchased Feedstuff (%) | -0.28 | -2.99* |

*, statistically significant at the 5 percent level

The typical gross margin here represents the farm size. Several authors (e.g. Sen, 1962; Berry and Cline, 1979; Binwanger et al., 1993) have reported evidence that smaller farms tend to attain higher efficiency levels than larger farms. Evidence, however, for the opposite is also available mainly for dairy farms (e.g. Hallam and Machado, 1996; Lund et al., 1993). The contribution of subsidies to farm family income has a negative correlation coefficient with technical efficiency suggesting that subsidies may work towards lower technical efficiency levels. A possible reason for this is that subsidies distort market signals. The "orientation" of farms to milk production does not seem to have any statistically significant association with the technical efficiency levels. Finally, the ratio of the farm produced to the purchased feedstuff has a negative association with technical efficiency. This may be an indication that farmers do not evaluate properly the former since they do not purchase them in the market.

Figure 2 presents the distribution of pure technical efficiency across the three study regions. In Epirus more than 70 percent of the farms have technical efficiency levels above 0.9, compared to 58 percent in Sterea, and only 34 percent in Thessaly. As a result, the average level of pure technical efficiency in Thessaly (0.82) is almost 10 percentage points below those in Epirus and Sterea. Figure 3 presents the distribution of scale efficiency across the three study regions. In

Thessaly, almost 80 percent of farms have scale efficiency levels above 0.9 compared to 68 percent in Sterea and 69 percent in Epirus. The average scale efficiency in Thessaly is 93.4 percent, in Epirus 92.2 percent, and in Sterea 91.3 percent.

These results may be explained in the light of the association between farm size and pure technical efficiency reported above. In the Thessaly, the average typical gross margin, measured in Economic Size Units (one Economic Size Unit equals 1200 EURO) is 12.8 compared to 9 in Epirus and 10 in Sterea. Also, the average herd size in Thessaly is 220, compared to 130 in Sterea, and 170 in Epirus. Given the negative correlation coefficient between farm size and pure technical efficiency one expects that Thessaly will have the lowest pure technical efficiency levels. At the same time, the higher farm sizes in Thessaly result into higher scale efficiencies relative to the other two regions.

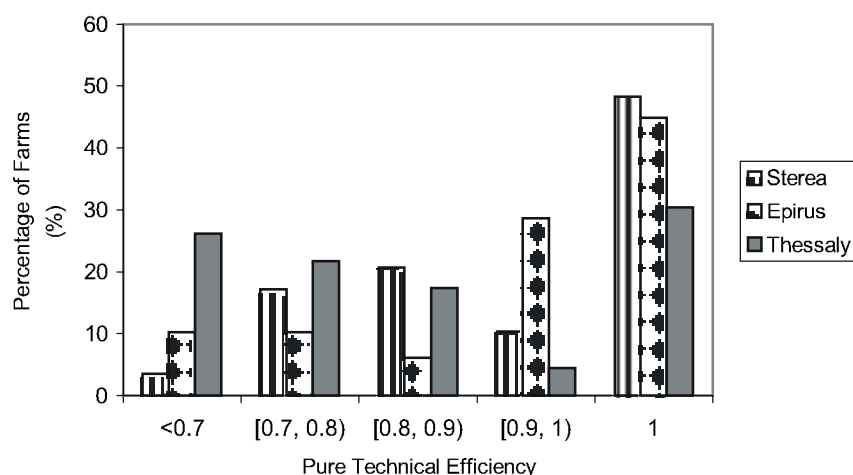


Figure 2. The Distribution of Pure Technical Efficiency Across Regions

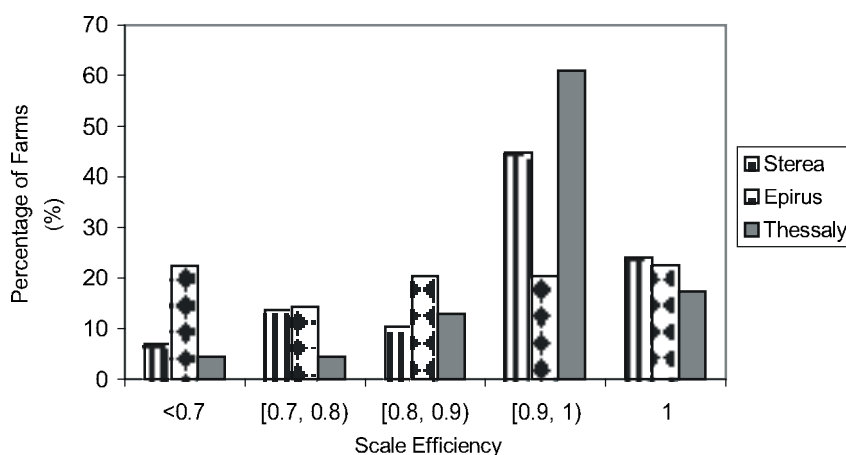


Figure 3. The Distribution of Scale Efficiency Across Regions

Figure 4 presents the distribution of overall efficiency across the study regions. Epirus has the highest overall efficiency (84.35 percent), followed closely by Sterea (83.54 percent). Thessaly, however, has an overall efficiency level of only 76.17 percent, due to the relative poor performance in terms of pure technical efficiency.

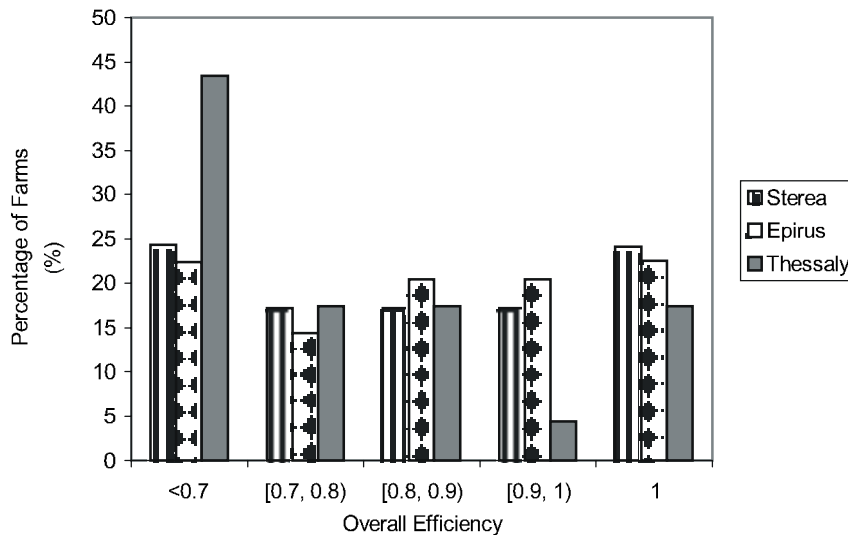


Figure 4. The Distribution of Overall Efficiency Across Regions

Conclusions

The objective of the present paper has been the assessment of overall efficiency of sheep farming in mountainous areas of Greece and its decomposition into pure technical and scale efficiency. This has been pursued by applying both the VRS and the CRS DEA models to a sample of 101 FADN farms located in Epirus, Thessaly, and Sterea. The empirical results suggest:

a) The pure technical and scale efficiency are almost of equal importance in the determination of the overall efficiency. Therefore, DEA models of the sector which rely on the assumption of a constant returns to scale technology are likely to underestimate the true level of pure technical efficiency.

b) The scale inefficiency stems mainly from too small farms (that is, farms operating under increasing returns to scale).

c) The average overall efficiency for farms in Epirus and Sterea are above 80 percent, while the overall efficiency for farms in Thessaly is below 80 percent. This must be attributed to the fact that pure technical efficiency in Thessaly is relatively low.

d) The farm size, the subsidies, and the high usage of on farm produced feed-stuff have negative and statistically significant associations with the level of pure technical efficiency.

Since the small scale of operations does have an influence on the overall efficiency, investment assistance (provided in the past on the basis of the EU Regulation 2328/91, superseded now by the EU Regulation 1257/99) is likely to work towards higher overall efficiency levels in sheep farming. Pure technical efficiency can be improved through well-organized education and extension programs along with public and private research and development programs. Finally, the drive to liberalization may play a role through imposing the market discipline to producers.

The present paper examined only technical efficiency. An extension to the measurement of allocative efficiency is certainly warranted. A major problem has been that the FADN data set does not contain reliable information on the prices of all inputs, something that is necessary for such type of analysis.

References

- Banker, R.D., Charnes, A. and W. Cooper (1984). Some Models for Estimating Technical and Scale Inefficiencies in DEA. *Management Science*, 30: 1078-92.
- Battese, E. and T. Coelli (1988). Prediction of Firm Level Technical Inefficiencies with a Generalized Frontier Production Function and Panel Data. *Journal of Econometrics*, 38: 387-99.
- Battese, E. and T. Coelli, (1995). A Model of Technical Efficiency Effects in a Stochastic Frontier Production Function with Panel Data. *Empirical Economics*, 20: 325-32.
- Bauer, P. (1990). Recent Developments in the Econometric Estimation of Frontiers. *Journal of Econometrics*, 46: 39-56.
- Bera, A. and S. Sharma (1999). Estimating Production Uncertainty in Stochastic Production Frontier Models. *Journal of Productivity Analysis*, 12: 187-206.
- Berry, R. and W. Cline (1979). *Agrarian Structure and Productivity in Developing Countries*. John Hopkins University Press, Baltimore, MD.
- Binswanger, H., Deininger, K., and G. Feder. (1993). *Power, Distortions, Revolt and Reform in Agricultural Land Relations*. Discussion Paper, World Bank, Washington DC.
- Charnes, A., and W. Cooper, (1985). Preface to Topics in DEA. *Annals of Operational Research*, 2: 59-94.
- Charnes, A., Cooper, W. and E. Rhodes (1978). Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research*, 2: 429-44.
- Coelli, T., Prasada Rao, D. and E. Battese, E. (1998). *An Introduction to Efficiency and Productivity Analysis*. Kluwer Academic Publishers, Boston, MA.
- Cooper, W., Seiford, L. and K. Tone (2000). *Data Envelopment Analysis. A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. Kluwer Academic Publishers, Boston, MA.

- Hallam, D. and J. Machado (1996). Efficiency Analysis with Panel Data: A Study of Portuguese Dairy Farms. *European Review of Agricultural Economics*, 23: 79-93
- Huang, J. and T.Liu, (1994). Estimation of non Neutral Frontier Shift Using Panel Data. *Journal of Productivity Analysis*, 5:171-80.
- Jondrow, J., Lovell, C., Materov, I. and P. Schmidt (1982). On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Model. *Journal of Econometrics*, 19: 223-38.
- Karagiannis, G. and K. Galanopoulos (2000). Quality Characteristics of Milk and Technical Efficiency of Sheep Raising in Epirus (in Greek). Paper Presented at the 6th Annual Meeting of the Association of Greek Agricultural Economists. Thessaloniki.
- Kintis, A. (1994). *Statistical and Econometric Methods*. Gutenberg, Athens (in Greek).
- Kopp, R. (1981). Measuring the Technical Efficiency of Production: A Comment. *Journal of Economic Theory*, 25: 450-52.
- Lund , M., B. Jacobsen, and L. Hansen (1993). Reducing Non Allocatable Costs on Danish Dairy Farms. *European Review of Agricultural Economics*, 20: 327-41.
- Neff, D., Garcia, P., and C. Nelson (1993). Technical Efficiency. A Comparison of Production Frontier Methods. *Journal of Agricultural Economics*, 43:479-89.
- Papageorgiou, K. and P. Spathis. (2000). *Agricultural Policy*. Stochastis, Athens (in Greek).
- Piot-Lepetit, I., Vermerch, D., and R. Weaver, R. (1997). Agriculture and Environmental Externalities. DEA Evidence from French Agriculture. *Applied Economics*, 29: 331-38.
- Psychoudakis, A. and E. Dimitriadou (1999). An Application of DEA in a Sample of Dairy Farms. *Medit*, 3: 46-50.
- Sen, A. (1962). An Aspect of Indian Agriculture. *Economic Weekly*, Feb. 243-46.
- Sharma, K., Leung, P. and M. Zaleski (1997). Productive Efficiency of the Swine Industry in Hawai: Stochastic Frontier vs DEA. *Journal of Productivity Analysis*, 8: 447-59
- Shafiq, M. and T. Rehman (2000). The Extent of Resource Inefficiencies in Cotton Production in Pakistan's Punjab: An Application of DEA. *Agricultural Economics*, 22: 321-330.
- Thanassoulis, E. (2000). DEA and its Use in the Regulation of Water Companies. *European Journal of Operational Research*, 127:1-13.
- Townsend, R., Kirsten, J. and V. Vink (1998). Farm Size, Productivity and Returns to Scale in Agriculture Revisited: A Case Study of Wine Producers in South Africa. *Agricultural Economics*, 19: 175-80.