Short communication

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Improving the technical efficiency and productivity of dairy farms in Greece

This paper aims to examine the current state of dairy cattle farming in Greece, to identify factors that affect its profitability, and to analyse the efficiency of farms, using the non-parametric Data Envelopment Analysis (DEA) method. It also assesses the economic viability of dairy cattle farms by quantifying the technical efficiency of their processes, with a view to suggesting measures that may serve to improve competitiveness. Results have shown that the mean technical efficiencies estimated for the CRS and VRS DEA approaches are 0.693 and 0.754 respectively, indicating that 30.7% and 21.6% equiproportional decreases in inputs are feasible, given the level of outputs and the production technology.

Keywords: data envelopment analysis, efficiency, dairy cattle farms, financial management

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Introduction

The livestock farming sector in Greece represents 30% of total agricultural production. One of the most important livestock activities is dairy cow farming, the main output of which is milk intended entirely for human consumption. The number of dairy cows kept in Greece is about 106,000, representing about 20% of the total bovine population (Eurostat, 2019). Their annual production of milk stands at about 650,000 tons, representing only 1% of the EU-28 cows' milk production and covering about 40% of the total consumption of Greece (Eurostat, 2019). The Greek dairy cow sector is mainly characterised by relatively small farms, in terms of the number of the cows that they breed, and low milk yields (Theodoridis and Ragkos, 2014).

The dairy cow sector has low competitiveness due to the high production costs compared with other EU countries (Vlontzos and Theodoridis, 2013; Aggelopoulos *et al.,* 2009). Greece has the highest feeding costs among the EU countries, which in the case of dairy account about 70% of the total production costs (Arsenos, 2018). However, in Greece, due to existing semi-arid climatic conditions that characterised by low height of rainfall throughout the year and dry summers, the annual pasture production is relatively low. Therefore, the dairy cows' nutrition relies exclusively on harvested feedstuffs, with all that this entails for feed costs (Siafakas *et al.,* 2019). Other components of production cost that plays an important role in dairy farming are the annual costs of purchased imported animals (replacement heifers), the annual costs of fixed assets and the compensation of labour (Kitsopanidis, 2006). Most farms in the country operate under increasing returns to scale, so in order to achieve lower production costs and improved profitability, an increase in size is required (Theocharopoulos *et al.,* 2007).

The high production cost of Greek dairy cow farms is one of the major problems of the sector, resulting in reduced efficiency and low competitiveness in relation to other EU countries. As a result, every business development initiative in the industry ought to be coupled with reducing production costs. Moreover, with the abolition of quotas (March 2015), a new framework came into being for milk producers all over the EU. Under this new regime, it has been estimated that an 11% increase in cows' milk production would be achieved by 2020, an increase expected to come mainly from the Northern European countries (Kempen *et al.,* 2011; Jansik *et al.,* 2014).

Nowadays, dairy markets worldwide are facing increasing competition, a fact which highlights the need to improve the competitiveness of milk production in the European Union. In this environment of growing liberalisation and competition, it is essential for the Greek dairy sector to improve its performance and to increase its productivity by identifying and adopting the best farm practices (Theodoridis and Ragkos, 2014).

Over the last ten years, milk yields have shown an increase, a fact which demonstrates that the animals have become far more productive than in previous years. This was achieved because, in order to take advantage of the favourable aspects of the new policy framework, farmers have made large investments in infrastructure. This change in the structure of the sector and the concomitant need for investments were readily appreciated by dairy farmers, who chose to shift from small-scale family farming to a form of entrepreneurial livestock farming activity, in the process bringing about a considerable improvement in the general conditions under which dairy cow farms operate. Dairy farmers replaced their traditional sheds, which were usually situated next to the family house, with modern buildings outside the villages, whose capacity was capable of sustaining larger herds. The adoption of such modern practices resulted in improved animal welfare, better hygiene conditions and higher milk yields (Abas *et al.,* 2013).

Nonetheless, the low competitiveness of the dairy sector in Greece clearly shows that the modernisation of building facilities and machinery were not designed rationally but were based on limited data and misleading projections of the future, which finally led to an overestimation of their efficiency (Tsiouni *et al.,* 2017).

Technical efficiency measurement is a very useful tool for evaluating agricultural sectors and economies under development status. Specifically, Data Envelopment Analysis (DEA) models that first established by Farell (1957) and then improved by Charnes *et al.* (1978) and Banker (1984) are extremely effective non-parametric approaches of technical efficiency, which do not require any specification of a functional form for the formation of the production frontier. However, due to its non-parametric nature, DEA attributes all measurement errors to inefficiency and requires the application of bootstrapping techniques to overcome this disadvantage (Simar and Wilson 2007).

So far, a small number of research papers have determined the competitiveness of the dairy cattle sector in Greece. Vlontzos and Theodoridis (2013) measured the efficiency and the productivity change of Greek dairy firms, using a non-parametric approach (DEA). This implementation provided helpful information regarding the efficiency ranking of the firms that operate in the Greek dairy industry. Their results showed that inefficient firms were over-invested and over-exposed to high-risk operation practices, findings which implied that remedial actions were possible with a view to improving efficiency in the future.

By contrast, Psychoudakis and Dimitriadou (1999) applied Data Envelopment Analysis in the data of 86 dairy farms and found that the majority of those farms were relatively efficient.

Theodoridis and Psychoudakis (2008), by studying the level of output-oriented technical efficiency (TE) in 165 cows' farms, indicated that their TE increased with their size. Valergakis (2000), by using data from 120 dairy cows' farms, concluded that the family farms, who owns between 70 and 150 cows, and have an average annual milk yield 7 tonnes/cow, were the most efficient, based on technical and economic parameters. Mitsopoulos (2012), based on a sample of 123 dairy cows' farms, found that management failures on farms negatively affected both the amount and quality of outputs (milk).

Overall, Data Envelopment Analysis (DEA) tends to show that focusing on animal production by increasing farm size in terms of the number of cows kept within the limits set by the available quantities of the production factors, increasing the amount of available time spent – especially the farmer's own work hours – on effectively monitoring and managing livestock, and investing more in animal farming while reducing investment in home-grown feedstuffs, would improve the farms' TE. This makes farms more efficient and clearly indicates that milk production in Greece could be increased significantly from its present levels at an unchanged level of investment.

Taking all of the above into consideration, this paper was considered appropriate due to the relative paucity of research undertaken in Greece. The surveys that have been conducted concerning the efficiency of the dairy cow sector have not taken into account numerical indicators describing the financial and operational situation of a holding. This paper aims to examine the current state of dairy cow farming in Greece, to identify factors that affect its profitability, and to analyse the efficiency of farms, making use of the non-parametric Data Envelopment Analysis (DEA) method.

It also assesses the economic viability of dairy cattle farms by quantifying the technical efficiency of their processes, with a view to suggesting measures that may serve to improve competitiveness.

Methodological framework

Technical efficiency is defined as the deviation of the observed product of a production unit from the maximum product that the unit could, in theory, produce and is related to the techniques of the manager's administrative capacity. The level of technical efficiency of a production unit, in the present analysis of a dairy farm, is estimated as the deviation of the farm under study from the potential ceiling of the possibilities afforded by the applied production technology.

The TE of a production unit is considered to be comprised of three elements (Fare *et al.,* 1994): 1. TE which refers to the ability of a production unit to operate (or not) within the limits of the potential of the manufacturing technology it uses; 2. Scale Efficiency (SE) which refers to the ability of a production unit to operate at the optimum size, that is to maximise the average product using the existing manufacturing technology and 3. Allocative Efficiency (AE) which refers to the ability of a production unit to use its inputs at optimum levels at a given market price for these inputs and a given manufacturing technology.

Based on Farrell's (1957) pioneering article, several approaches to efficiency measurement have been developed. Among these, Stochastic Frontier analysis (SFA) models and Data Envelopment Analysis (DEA) models have proved to be an extremely useful tool in the measurement of the technical efficiency of production units. The stochastic frontier approach was initiated by Aigner *et al.* (1977) and Meeusen and van der Broek (1977), while DEA approach was proposed by Charnes *et al.* (1978). Many authors in economic literature have dealt with the two approaches.

DEA is a linear programming method that calculates the frontier production function of a set of decision-making units (farms in our case) and evaluates the relative technical efficiency of each farm, allowing us to make a distinction between efficient and inefficient farms. Those identified as "efficient" are given a rating of one, whereas the degree of technical inefficiency of the rest is calculated on the basis of the Euclidian separation of their input–output ratio from the frontier (Coelli *et al.,* 1998).

The formulation of the present study is input oriented, solving the following model:

$$Max\theta = \sum_{r=1}^{s} y_{rj} u_r - \sum_{i=1}^{m} x_{ij} v_i , \quad (1)$$

s.t.:

$$\sum_{r=1}^{s} y_{rj} u_r - \sum_{i=1}^{m} x_{ij} v_i \leq 1, j = 1, \ldots, n ,$$

$$\sum_{r=1}^{s} u_r + \sum_{i=1}^{m} v_i = 1, \quad (2)$$

$u_r \geq$ for $r = 1, ..., s$

$v_i \geq$ for $i = 1, ..., m$

where yi is the (k×l) vector of outputs produced and xi is the (m×l) vector of inputs used for unit i. Y is the (k×n) vector of outputs and X is the (m×n) vector of outputs of all n units included in the sample Λ is a (n×l) vector of weights and Θ is a scalar with boundaries of one and zero that determines the efficiency score of each Decision Making Units (DMU) (where 1 DMU = 1 farm).

Data Description and Model Specification

The data for the empirical analysis was gathered from a sample of 118 dairy farms in Central Macedonia, Greece. The choice of this particular area for study was due to the fact that almost half of the cow milk production in Greece comes from this region. The sample size was determined through a random stratified sampling. The research data was collected by using questionnaires and personal interviews with the "heads" of the dairy cow farms during the years 2018-2019. The sampled farms accounted for all types typically operating in the region, from small family farms to larger modern ones. The questionnaire completion time was estimated at 60 minutes for each dairy cow farm. The data obtained from the questionnaires were first introduced in Microsoft Office 2010 and specifically in Excel program and then, for the statistical analysis, SPSS24 was used. The variety of breeding conditions in this area allows the generalisation of the research results with no significant deviation from reality (Aggelopoulos *et al.,* 2015).

In this study, the input-oriented model is used, because in Greece there is a lack of milk production, the country does not cover the national consumption and an increase in production is required to restore the balance of supply and demand. The model includes, as inputs, the number of cows, the area of cultivated land (in acres of equivalent irrigated land), human labour (in hours), total variable costs (in €) and the annual costs of fixed capital, while output used gross income (in €).

Results

According to Tables 1 and 2, the mean technical efficiencies estimated for the CRS (constants returns to scale) and VRS (variable returns to scale) DEA approaches are 0.693 and 0.754 respectively, indicating that 30.7% and 21.6% equiproportional decreases of inputs are possible, given the level of outputs and the production technology. The mean technical efficiencies of the DEA models indicate that there is substantial inefficiency among the dairy farms in the sample, a finding which confirms initial expectations. Thirty farms are fully technically efficient in terms of the VRS model and eighteen farms are fully technically efficient under the CRS model. The technical efficiency scores estimated under the CRS DEA frontier are equal to or less than those calculated under the VRS DEA model. This

Table 1: Frequency distribution of technical and scale efficiency from the DEA models.

Efficiency Score	Data Envelopment Analysis					
	CRS		VRS		SE	
	Number of farms	%	Number of farms	%	Number of farms	%
< 0.4	10	8.5	4	3.5	1	0.8
0.4-0.5	8	6.8	11	9.3	0	0.0
0.5-0.6	24	20.3	15	12.7	4	3.5
0.6-0.7	22	18.6	20	16.9	1	0.8
0.7-0.8	17	14.4	20	16.9	8	6.8
0.8-0.9	10	8.5	8	6.8	15	12.7
0.9-1.0	9	7.6	10	8.5	71	60.2
1.0	18	15.3	30	25.4	18	15.3
Total	**118**	**100.0**	**118**	**100.0**	**118**	**100.0**

Source: Own calculations

Table 2: Descriptive statistics of TE and SE of DEA models.

Efficiency	CRS	VRS	SE
Mean	0.693	0.754	0.920
Minimum	0.179	0.193	0.359
Maximum	1.000	1.000	1.000
Standard Deviation	0.207	0.204	0.113

Source: Own calculations

relationship, as stated above, is used to obtain the measure of scale efficiency SE. The scale efficiency index for the sample ranges from 0.359 to 1.000 with a sample mean and standard deviation of 0.920 and 0.113, respectively. It is used as an interpretative tool to show the optimum amount by which productivity can be increased, within a given manufacturing technology, if the decision-making unit, in this case the dairy cows' farm, moves to the technical optimal productive scale (TOPS). On the other hand, the analysis reveals weaknesses and problems in the sector, which pertain to the management and structure of the dairy cows' farms.

Moreover, nine farms according to the CRS and ten farms according to the VRS model achieve a TE greater than 0.9, and that shows that 7.6 and 8.5% of the farms respectively exhibit satisfactory efficiency without necessarily being regarded as fully efficient. The scale efficiency is 0.92 with a standard deviation of 0.113. This indicates that farms have the potential to reduce inputs by 8% without changing the output level if they make the appropriate size adjustments with the standard technology and output level.

According to Table 3, the average technically efficient farm raises 150 cows, and each cow produces 7,445 kg milk year. The average farm cultivates 0.67 acres of irrigated soil equivalent for feed production and uses 49 hours of human labour.

An analysis of the statistics reveals that the mean score of gross margin in efficient farms is about 3,661 €/cow. The gross revenue in efficient farms is 1,678 €/cow and there is profit that is 1,118 €/cow. The land expenses are 18 €/cow, the labour expenses are 176 €/cow, the costs for purchased feed in efficient farms amount to 1,641 €/cow, accounting for about 83% of total variable costs and 64.5% of total production costs. The annual production costs of fixed capital for the average efficient operation are 366 €, indicating 14.4% of the total production costs. The share of fixed costs in total production costs for efficient farms can be characterised as low, as the dairy sector belongs to the production sectors with a high percentage of fixed costs, mainly due to the high investment in buildings.

Discussion

According to other studies using the DEA model to measure the efficiency of Greek dairy sector, Theodoridis and Psychoudakis (2008) reported similar results to ours, while Siafakas *et al.* (2019) reported less mean technical efficiency obtained of both VRS and CRS DEA model (0.549 and 0.676, respectively) and a lower scale efficiency (0.823).

The data in Table 3 show that the increased farming size (cows per farm) of the high scale-efficient farms has led to 1) increased productivity; 2) higher efficiency of labour and invested capital; 3) reduced production costs and 4) relatively high profitability per livestock unit. Similar conclusions have been reached by Siafakas *et al.* (2019), indicating a corresponding height of average milk production/cow 7,896.3 kg of milk (7,445.3 in our study) on efficient farms.

In an extensive study (200 dairy farms) of Kelly *et al.* (2012) in Ireland where the farming system is mainly pasture-based, the number of cows raised had no effect on the efficiency of the holdings, but only the available hectares of pastureland. The reduced efficiency of such systems is due to the greater need for purchased concentrate feedstuffs per cow. In contrast to the research of Demircan *et al.* (2010) in Turkey, small inefficient farms made almost exclusive use of grazing rather than concentrated feed.

In terms of feeding costs, which is the largest component of variable costs, this is higher in efficient farms than in inefficient ones. This is explained by the greater availability of cultivated land for feed available to inefficient farms.

Table 3: Technical and economic data of the efficient and the inefficient farms.

Decision making units – DMU Output	Average farm (118)	Standard Deviation	Average of efficient farms (30)	Standard Deviation	Average of inefficient farms (88)	Standard Deviation	p
Technical data							
Number of dairy cows	123	310	150	450	108	160	0.223
Milk yield (cow/year)	7,936	6,024.1	7,445.3	1,425.8	6,007.3	1,327.9	0.081
Cultivated land (in acres of equivalent irrigated land)	2	8.6	0.67	3.4	1.38	1.7	0.031
Labour in hours (per cow)	53.2	1,348.9	49	103.2	89.3	114.2	0.432
Economic data							
Land expenses (€/cow)	39.42	40.1	18.1	29.3	43.21	31.08	0.561
Labour expenses (€/cow)	196.4	126.7	176.2	132.4	224.1	149.7	0.482
Variable capital expenses (€/cow)	2,018.9	4,897.7	1,983.4	2,488.6	3,568.2	2,341.8	0.645
- Value of Purchased Feed (€/cow)	1,798.7	2,014.6	1,641.9	1,463.2	1,456.8	1,974.5	0.018
- Other Variable capital expenses (€/cow)*	372.4	296.3	342.2	301.9	418.4	287.9	0.214
Fixed capital expenses (€/cow)	416.3	333.7	366.5	297.8	329.9	203.4	0.128
Production expenses (€/cow)	3,087.4	2,109.2	2,543.2	1,987.3	3,457.3	2,014.9	0,358
Gross margin (€/cow)	3,657.1	2,807.1	3,661.0	2,423.,7	2,982.4	2,098.7	0.421
Gross revenue (€/cow)	1,638.2	3,417.6	1,678.0	2,596.1	1,432.3	2,110.8	0.396
Profit or Loss (€/cow)	569.7	3,413.5	1,118.0	3,104.3	231.9	2,986.6	0.512

Source: Own calculations

Siafakas *et al.* (2019) in their own study also showed that the farmers with the most cultivated areas failed to ensure the efficient operation of their farms. Corresponding results in terms of the effect of food costs associated with the quality of feed used were shown by Hansson and Öhlmér (2008) who reported technical output efficiency in a sample of Swedish farms of between 86% and 89%.

From the above, we conclude that inefficient dairy cow breeders have attached great importance to their own production of the necessary feed for their farms and less to the effective management of their farms. In essence, the multifunctionality they display makes them stand out as land and cow farmers. Superior business as well as farming management skills are likely to be the cause of efficient farms, because they make efficient use of debt capital. These farmers exploit their invested capital better on livestock farming equipment rather than land cultivation machinery.

Conclusions

This paper has applied the DEA methodology as an analytical tool to explore, at the microeconomic level, the potential shortcomings in the efficiency of Greek dairy cow farms that may be holding the sector back and hindering its future growth. Taking into consideration the importance of the dairy cow sector, it is possible to understand that the performance of the sector can have a marked effect on the agricultural development in Greece.

The analysis of farm efficiency showed that there could be significant improvements in the sector through the reorganisation of farm inputs. The economic development of every inefficient farm is feasible because for each inefficient farm, there is at least another efficient one. Given the existing technology, most farms exhibit serious technical inefficiency and can, in theory, reduce inputs by more than 30% in the short run and by 25% in the long run, maintaining in both cases the same level of output.

In conclusion, the inefficient holdings should reduce – to a lower or higher extent depending on the class of performance – the expenses of variable and fixed capital, the hours of labour and acres of cultivated land. The reduction of labour hours can be achieved by using mechanised production (e.g. installation of milking systems), and a modernisation of the facilities for ergonomic purposes should lead to a reduction of this cost component. Moreover, to reduce the feed cost, a well-balanced and inexpensive feeding is recommended. The knowledge of animal feed contents in nutritious ingredients and their suitability as well as efficient feeding and storage facilities of animal feed should lead to the improvement of the used animal feed. Furthermore, the cultivation of the land for feed production should lead to the reduction of the inefficient farms.

The conclusion that can be drawn is that if the production system is operated rationally and efficiently, it will improve the competitiveness and consequently the economic sustainability of the cow milk producing sector in Greece.

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