

Measuring technical efficiency of Greek red suckler cow breed's farms in Central Macedonia region using a data envelopment analysis model

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Abstract: This study aims to estimate the technical efficiency (TE) of a randomly selected sample of red Greek suckler cow breed farms in the area of Central Macedonia and identify the most technically efficient characteristics of cow-calf operations. Moreover, this work wants to verify the impact of local and European policies in support of the sector on the estimated efficiency. The

research investigates the technical efficiency of 64 suckler cow farms by using the data envelopment analysis (DEA) method. Findings reveal that the most efficient farms were larger, with higher gross revenue, and higher cost of fixed capital than non-efficient farms. In addition, the cost of variable capital, which directly affects profitability, was lower on efficient farms. Efficient farms demonstrate better techno-economic results and managerial practices. This is the first research that studies the red suckler cow breed, based on original data obtained from a direct survey in a field interview.

Keywords: data envelopment analysis; DEA; technical efficiency; financial indicators; suckler cow farming; red Greek breed.

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1 Introduction

1.1 The research background

In Greece, the suckler cow farming and the relative fattening of the Greek red breed have been developed primarily in Northern Greece and especially in the Area of Central Macedonia. The latter area is characterised by the presence of semi-mountainous and mountainous pastures that are utilised with extensive seasonal grazing, but also includes cultivated areas that provide the required feed for the intensive fattening of beef cattle. The use of these pastures to meet the nutritional needs of suckler cows is heavily influenced by the Common Agricultural Policy (CAP), which also determines the availability of their use by each type of farm animal (Yiakoulaki and Papanastasis, 2014; Delattre et al., 2020). According to EU Regulation No. 1306/2013 of the European Parliament and Council, it was established a comprehensive management and monitoring system for the Common Agricultural Policy in Greece by a government decision on the eligibility criteria and the allocation process to the country's livestock breeders, eligible pastures, and pasture land.

In contrast to broilers farming and pig fattening, the breeding of beef cattle is a pasture-based livestock activity (Rakipova et al., 2003). The technical and economic efficiency of these cow farms is affected by various factors. Firstly, competition for pastures, which in many cases are linked to subsidies, determines the viability and profitability of suckler cows as it directly affects the economic efficiency of animal nutrition (Kitsopanidis, 2005; Milan et al., 2006; Finneran and Crosson, 2013; Michalickova et al., 2016). Programs that provide subsidies for the conservation of rare breeds of farm animals are linked to the immediate priority of distributing pastures to

these animals. Thus, for pasture-based farming activities, such as suckler cow farming, the availability of high carrying capacity pastures is limited, increasing feed costs. Another parameter that significantly affects the efficiency of pasture-based farming systems is the lack of winter grazing (Casasús et al., 2002; Kitsopanidis, 2005; Gourdouvelis et al., 2019a). To achieve the highest reproductive yields during the winter period, it is essential to provide complementary to grazing feedstuffs and to restrict the cows as long as necessary (Villalba et al., 2006), before their maintenance in pastures. The suckler cow's fertility and ability to wean calves, affect the farm profitability (Syrucsek et al., 2017). Furthermore, like in other Mediterranean countries, the sector of suckler cows is faced with a shortage of workers especially during the summer period in the mountains (Kitsopanidis, 2004; Bernues et al., 2011), the high feed cost and the low feed self-production (Gourdouvelis and Dots, 2020).

On a local level, the red Greek suckler cow breed is financed by the Greek Ministry of Rural Development and Food through the program 'Genetic Resources in Animal Husbandry' action 10.2.1. The main goals of this program are:

- 1 collection and keeping of genealogical data of animals and establishment of genealogical books and registers
- 2 individual control of the qualitative and quantitative performance of animals
- 3 information of the breeders about the insemination and use of animal genetic material suitable for each region.

To support this sector, the European Union under the Common Agricultural Policy established with the Council Regulation (EC) No. 73/2009 specific support schemes as that provided by Article 68, which aimed to improve the production yields of the existing cattle population and consequently increase livestock income. Due to these favourable aids that have been given for the beef calves, suckler cow breeders, despite the different farming systems followed, have been chosen to breed a specific type of cow-calf, that came up after continuous crossbreeding of mixed breed cows with purebred Limousin bulls, which nowadays is called the Greek red breed. Breeders' associations of this breed were formed in Northern Greece as a result of all the above-mentioned processes to register genealogical information and yields, taking advantage of EU subsidies. In light of this, it is extremely important to evaluate the impact that the measures implemented in the past 10 years have had on the technical and economic efficiency of the farms due to the impact that they can have on the economic and social level of the affected territories.

Following is an outline of the paper. Literature about efficiency is reviewed, then a description of the material and methods is provided. In the results, the most significant findings are presented and discussed, related to the determinants of technical efficiency of suckler cow farming in Greece. The conclusions provide a summary of the purpose and results of the study.

1.2 Research gap and aim of the study

Previous studies demonstrate through the estimation of the gross profit of cow-calf farming in Greece (Kitsopanidis, 2004; Gourdouvelis et al., 2019b) general losses when farmers do not receive the EU subsidies. However, as emphasised by Farrell (1957), Charnes et al. (1978) and Banker et al. (1984) measurement of technical efficiency (TE)

of the sector is useful information that can enhance decision-making on the optimal resource utilisation and efficient use of inputs.

Studies have been conducted to determine the parameters of inefficient farming management for livestock farms in Greece but none have been conducted on suckler cows (Galanopoulos et al., 2011; Siafakas et al., 2019; Hatzizisis et al., 2019). Most of these studies use data envelopment analysis (DEA) to measure the efficiency and productivity of dairy farms (Alem, 2021). Mitsopoulos et al. (2021), used the DEA method to explore the potential weakness in the Greek dairy farms' efficiency that might be hampering the future growth of the sector. Inputs to the model include cow numbers, cultivated land areas, human labour, total variable costs, and annual capital costs, while outputs are based on gross income. Lozano and Adenso-Diaz (2021) proposed a model that can be used to determine in a set of dairy farms, the most beneficial merger. To estimate the total technical efficiency benefit that the merger would generate, the data envelopment analysis was used and the benefit was decomposed into a learning effect and a pure merger effect. Various factors have been considered in terms of the experiment design such as farm size, the proportion of farms with increasing returns to scale, and standard deviation of current farm efficiency. Siafakas et al. (2019), in their research, used DEA to measure efficiency in dairy cow farms in Greece. This empirical analysis was carried out using two basic models based on the assumption of constant return to scale (CRS) and variable return to scale (VRS). The models were output-oriented (milk yield) over a range of technology and production factors like the nutritional value of purchased or home-grown animal feed, hours of human labour, livestock value, average capital investment, and land.

DEA methodology has been widely used in the suckler cow livestock sector, where there is only one output (cattle). The determinants of technical efficiency have been studied in Louisiana's beef cattle sector (USA) by Rakipova et al. (2003), in extensive farming systems in Extremadura, Spain by Gaspar et al. (2009), in Kenua's beef cattle production systems by Otieno et al. (2011), and in Alberta (Canada) by Samarajeewa et al. (2012). Also, in an extended study of Irish beef farms the income and scale efficiency have been studied by Finneran and Crosson (2013). In the recent literature, several studies combine technical and economic indicators to calculate the technical efficiency, but they do not take into account that the productivity of a business's factors of production can determine the efficiency of the business efficiency (Ceyhan and Hazneci, 2010; Veyssset et al., 2015; Michalickova et al., 2015; Syrucek et al., 2017; Martinez Cillero et al., 2017). However, to date, no studies have been carried out to evaluate the technical efficiency of the red Greek suckler cow breed and verify the effect of policy measures adopted both within the CAP sphere and at the national level.

To fill this gap, this study aims to estimate the technical efficiency (TE) of a randomly selected sample of red Greek suckler cow breed farms in the area of Central Macedonia and identify the characteristics of cow-calf operations that are the most technically efficient. Furthermore, the technical efficiency analysis will make it possible to verify whether the measures to support the sector, both at the local and European levels, have had the desired effects. It is the first research that studies this particular cow breed and aims to evaluate the technical efficiency and productivity change of suckler cow farms in Greece, to define which holdings have shown the most beneficial results in performance adaptability since the genetic material was changed and to analyse the technical situation for cattle farmers at the beginning process of this emerging breed.

This article contributes to the economic literature in several ways. First, since farms in the same sector often face differences in their productivity, the detection of parameters that affect the observed heterogeneity is crucial for improving the economic efficiency of such farms. Secondly, in this study, the dynamics of the economic development perspective of the sector through the utilisation of such special genetic material will emerge from the scale efficiency results. Finally, this study efforts to assess the importance of the economic impacts of each production factor to draw conclusions that will ensure a satisfactory income for cattle breeders, maintain the social fabric in the countryside and the development of the sector, as well as assist policymakers with the design of efficient farm policies.

2 Materials and methods

2.1 Study area and data collection

The study was conducted in Central Macedonia, a region in Northern Greece. Considering the distribution of Greek red breed suckler farms, the percentage of large cattle-fattening farms in Central Macedonia is greater than Northern Greece's average. In the study area, there were activated two breeders' associations of the Greek red breed (Thessaloniki's and Panserraikos) out of the six in total that all existed in Northern Greece. In 2019, these two associations had as members 103 breeders who maintained a total number of approximately 5,900 cows. All farms receive financial support from the Greek Ministry of Rural Development and Food through the program 'Genetic Resources in Animal Husbandry'. A representative sample of 64 suckler cow farms from Thessaloniki and Panserraikos was selected by using Neyman's allocation method of stratified sampling. The total number of suckler cow farms was divided into two strata. The first stratum was related to farm size (h1: 20–50 cows; h2: 51–100 cows; h3: >100 cows), while the second one was represented by the breeders' associations where the farmer is a member (n1: Thessaloniki's; n2: Panserraikos).

The formula of Neyman's allocation is the following:

$$n_h = n \cdot \frac{N_h S_h}{\sum_{h=1}^H N_h S_h}$$

where

$$S_h = \sqrt{\frac{1}{N_h - 1} \sum_{i=1}^{N_h} (y_i - \bar{y}_i)^2}$$

n_h sample size in the stratum h

n total sample size

N_h population size in the stratum h

y_i variable of interest in the stratum h .

According to Alvarez and Arias (2008), the relationship between technical efficiency and size might be affected by farm heterogeneity. To achieve sample homogeneity, 13 of the 64 farms were excluded as they did not follow the cow-calf farming system but sold the calves after weaning.

Data were collected by using a questionnaire structured into 6 thematic sections:

- a the farm size determined by the number of suckler cows (LU) and the number of total livestock units (TLU) estimated by the assumption of 1 LU for each adult bovine, 0.6 LU for calves and heifers from 6–24 months and 0.2 LU for calves up to 6 months
- b productivity of cows studied according to the of number of weaned calves/number of cows' ratio
- c the exploitation of labour estimated for the TLU, using total annual work units (AWU) which resulted from the initial variables of family and hired labour
- d land use and management which, in addition to the initial variables pastures area and cultivated land (in ha), includes the constructed indicator of stocking rate (LU/ha indicates pastures availability)
- e the farmer's personal profiles comprise two variables, the age and the educational level (in years)
- f financial data includes all the variables that make up the variable cost, the cost of fixed capital and gross revenue.

To ensure readability, a pre-test survey was conducted, and questions were adjusted as needed. This pre-sampling was conducted among ten dairy farmers who raise suckler cows.

The survey was carried out with personal interviews of the owners at the location of the farms between January and March 2019.

The collected data from 51 suckler cowherds of the total of 64 were analysed, recorded in a database to further analyse data with SPSS version 25 and R.

2.2 Model specification

With DEA, one can construct a non-parametric piecewise model or frontier over data and evaluate how efficient each unit is. This allows for the differentiation of efficient and inefficient decision-making units (DMUs). From earlier research by Farrell (1957), Charnes et al. (1978) developed the DEA method. Methods of estimating the efficiency of organisational units have been used in several fields (Cooper, 1999). DMUs whose objective functions equal 1 in DEA are efficient and those whose objective functions are not equal to 1 are inefficient, which are then compared to other appropriate DMUs and simulated (Avkıran, 2011). The use of DEA has many advantages such as the coincident analysis of outputs and inputs, the relative efficiency can be compared to the best observation, there is no need to have information on prices and finally, there is no need to define the frontier form (Galati et al., 2018; Jordá et al., 2012). Additionally, DEA can be used to estimate technical efficiency when there is no objective way to use one efficiency index formula to identify an organisation's efficiency (Rakipova et al., 2003). According to Charnes et al. (1978), it is possible to be estimated two types of envelopment models.

The first referred to a constant return to scale model (CRS) and the second to a Variable Return to Scale (VRS) model. Total technical efficiency can be estimated when CRS is assumed. In addition to total technical efficiency, pure technical efficiency (PTE) and scale efficiency can be considered. We assume production technology displays the VRS as part of calculating PTE. The residual between the total and PTE is referred to as scale efficiency. Even if outputs are higher than revenues, the production unit will still be efficient if VRS holds.

The technical efficiency (TE) of a DMU refers to the amount of output that can be produced given a given set of inputs and technology (output-oriented) or the number of input quantities that can be minimised given input prices and output (input-oriented) (Farrell, 1957). It may be challenging to decide between input-oriented and output-oriented measures, and the choice is dependent on the unique characteristics of the set of DMUs under study. In this study, the input-oriented model is used, as the farmers' control over inputs in the agricultural sector is greater than their control over output since the output can be exogenously determined. Moreover, because the agricultural products have inelastic demand, the cost reduction is more understandable to the farmers to promote the agricultural economic development concerning output increase.

This study is input-oriented, and addresses the following model:

$$\text{Max } \theta = \sum_{r=1}^s y_{rj} u_r = \sum_{i=1}^m x_{ij} v_i$$

s.t.

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

$$\sum_{r=1}^s u_r + \sum_{i=1}^m v_i = 1$$

$$u_r \geq 1, \quad \text{for } r = 1, \dots, s$$

$$v_i \geq 1, \quad \text{for } i = 1, \dots, m$$

where y_i is the $(k * l)$ vector of outputs produced and x_i is the $(m * l)$ vector of inputs used for unit i . The Y variable contains the $(k * n)$ vector of outputs and the X variable contains the $(m * n)$ vector of outputs for all the n units in the sample Λ is the $(n * l)$ vector of weights and Θ is a scalar with boundaries of one and zero which determines the efficiency of the units.

The measurement of the size of SE – scale efficiency – is calculated by the math type:

$$SE_i = \frac{TE_{i,CRS}}{TE_{i,VRS}}$$

The DEA model applied in the current study consists of one output (gross revenue) and four inputs (fixed capital expenses, variable capital expenses without the feed expenses, feed expenses, labour expenses). According to the certificate management protocol principles described by Farrell (1957), Charnes et al. (1978) and Cooper (1999) the expression of economic parameters on a per livestock unit, labour unit, or hectare basis is

not appropriate because the measure of economic efficiency concerns the whole holding which is considered as one DMU.

2.3 Selection of input and output variables

To select the input and output variables to measure technical efficiency, two assumptions were made: each holding follows a similar production process with similar technologies and all inputs are homogeneous (Rakipova et al., 2003). Since there were no cattle breed, breeding method, and feeding methods differences, only the differences in the level of inputs were involved in the analysis of the technical efficiency (Otieno et al., 2011).

Literature provides some suggestions for the selection of input and output variables. Indeed, the breeders cannot control the price of their products, so it is essential to manage their production expenses. A competitive market determines the results of their economic activities, depending on the management of production costs and economies of scale (Rossi et al., 2014; Reis et al., 2001). From an economic perspective, the cost components can be divided into several categories, such as variable costs, fixed costs, labour, and land expenses. The main factors that determine the production costs at animal breeding holdings are labour, annual livestock expenses, fixed costs, and feed costs (Aggelopoulos et al., 2009; Kitsopanidis, 2006; Tsiouni et al., 2017, 2019; Gourdouvelis et al., 2019b). These variables have been included in the previous studies of technical efficiency and are suitable for testing differences in efficiency among farms (Nágllová and Pechrová, 2021; Mitsopoulos et al., 2021; Siafakas et al., 2019; Špička and Smutka, 2014).

Thus, the following variables were selected to investigate the level of technical efficiency of the 51 suckler cow farms (Table 1):

- Y gross revenue (€/year)
- X1 cost of fixed capital (€/year)
- X2 cost of variable capital without feed (€/year)
- X3 cost of feed (€/year)
- X4 labour cost (€/year).

As output variable (Y) was chosen the 'gross revenue' because this index expresses the economic profitability of suckler cow farm. According to the literature review, Mu et al. (2018) used DEA analysis in dairy cows, and outputs include only the total gross revenue. In the Gross revenue, it was calculated the total sold kilos of calves live weight multiplied with the selling price. The importance of the above-mentioned parameter depends on the demand price elasticity and indirectly as a sub-product of the quality of the carcass (Kitsopanidis, 2006). To incorporate price and yield variance in the estimation of efficiency, gross revenue was used as the output measure and to highlight the impotence of pasture-based systems in the improvement of carcass quality and the increase in selling price. It is advantageous to use gross revenue as an output because it accounts for quality differences (Abdulai and Tietje, 2007). The price that farmers normally receive from their sales depends mainly on animals' final body weight and their availability.

The inclusion of fixed cost (X1) in the full economic production cost is a good measure of long-term as well as short-term profitability estimation (Finneran and Crosson, 2013). The cost of fixed capital includes the fixed assets interest, depreciation of property and animals, insurance premiums, and maintenance. This reduces the likelihood of failing to explain higher profits as a result of increasing variable costs alone. The gross fixed capital formation of a farm refers to investing in assets that are continuously used over several years to produce goods (Gerdessen and Pascucci, 2013).

Total expenditure for livestock, which represents the cost of variable capital without a feed is the (X2) variable, which includes purchased livestock, veterinary services land improvements costs, overheads (water, electricity), and other annual expenses (i.e., the interest of working capital, fuels, lubricants) related to livestock production.

The annual feed cost (X3) is the dominant component of variable cost in this type of farming (Kitsopanidis, 2005; Gourdouvelis et al., 2019b) and since it has such a significant impact on output, it is considered separately from other variables. Total expenditure of feed includes the cost of purchased feedstuffs as well as the cost of seeds, fertilisers, and pesticides for the self-produced fodder crops.

Table 1 Descriptive statistics of important farm and farmer's characteristics

<i>Characteristics</i>	<i>Unit</i>	<i>Mean</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
Pastures area	ha	378.09	701.90	0	400
Stocking rate	LU/ha	12.34	34.07	0	42.68
Cultivated land	ha	93.96	137.34	0	825
Suckler cows (LU)	No	63.40	54.90	4	344
Weaned calves	No/year	58.64	54.97	0	340
Selling live weight	kg/calf	310	130	197	458
Selling price	€	2.80	0.65	2.20	3.60
Purchased feed	€/year	39,892	37,104.15	1,260	171,160
Farmer's age	Years	44.32	35.68	18	88.3
Education level	Years	8.4	4.9	0	18

Note: LU – livestock unit, the equivalent of an adult suckler cow

The (X4) labour cost variable, which includes both the family and the hired labour, was obtained by multiplying the work hours with the hourly wages. This cost is largely responsible for the output, as in pasture-dependent breeding systems the role of labour is more important than in highly mechanised farming conditions of the suckler cow sector (Abdulai and Tietje, 2007).

Detailed information on farm characteristics, such as production parameters, is stored in the database (e.g., herd size, weaned calves per year, selling weight and price, grazing and cultivated land) and production inputs such as cost of purchased feedstuffs, as well as farmer's characteristics. Table 1 provides the descriptive variables of the farm and farmer's characteristics.

3 Results

Table 2 shows the descriptive statistics of the output and inputs variables of 51 red Greek suckler cow farms.

Table 2 Descriptive statistics of selected variables used in the DEA model

<i>Variables</i>	<i>Type of insert in DEA</i>	<i>Unit</i>	<i>Mean</i>	<i>SD</i>
UNIT's = 51				
Y Gross revenue	Output	€	63,136.07	78,140.82
X1 Cost of fixed capital	Input	€	57,305.77	106,081.25
X2 Cost of variable capital without feed	Input	€	11,505.14	7,550.91
X3 Cost of feed	Input	€	39,892.15	37,104.15
X4 Labour cost	Input	€	12,066.63	6,582.80

Table 3 shows the Pearson's correlations between the selected variables. There are two statistically significant correlations among the cost of variable capital without the cost of feed and feed cost with the output variable (0.638, $P < 0.01$ and 0.554, $P < 0.01$, respectively). The cost of labour and fixed capital invested does not seem to affect the gross revenue. No statistically significant correlation was observed between the independent variables.

Table 3 Pearson's correlation matrix

	<i>Y: Gross revenue</i>	<i>X1: Cost of fixed capital</i>	<i>X2: Cost of variable capital without feed</i>	<i>X3: Cost of feed</i>	<i>X4: Labour cost</i>
Y Gross revenue	1				
X1 Cost of fixed capital	-0.089	1			
X2 Cost of variable capital without feed	0.638 ^a	-0.177	1		
X3 Cost of feed	0.554 ^a	-0.140	0.144	1	
X4 Labour cost	0.157	-0.070	0.216	0.229	1

Note: ^aCorrelation is significant at the 0.01 level (2-tailed).

According to Table 4, the mean technical efficiencies estimated for the CRS and VRS DEA approaches are 0.55 and 0.78, respectively. Based on the maximum and minimum values in the above table, it can be seen that cow farms exhibit wide variations in their efficiency because according to researches, developed and less developed farming sectors are usually inefficient (Finneran and Grosson, 2013; Michalickova et al., 2015; Ceyhan and Hazneci, 2010). Thirteen farms are fully technically efficient in terms of the CRS model and 21 farms are fully technically efficient under the VRS model. The scale efficiency index for the sample ranges from 0.30 to 1.000 with a sample mean of 0.68. Moreover, three farms according to CRS and six farms according to the VRS model achieve a TE greater than 0.8. On the other hand, 68.1% of the farms according to the CRS model are technical inefficiency (0.1–0.79) and 51% of the farms according to the

VRS model are technical inefficiency (0.1–0.79). Generally, when the VRS model is considered, the technical efficiency indicators are greater than, or equal to, the estimated efficiencies under the CRS model (Banker et al., 1984).

Considering scale efficiency, the technical efficiency on a farm can be expressed as the additional reduction in input consumption that could occur if the farm relocated to a productive scale that is technically optimal (Hatzizisis et al., 2019).

Table 4 Frequencies of technical and scale efficiency of studied farms

<i>The volume of T.E.</i>	<i>CRS num.</i>	<i>%</i>	<i>VRS num.</i>	<i>%</i>	<i>S.E. num.</i>	<i>%</i>
0.1–0.49	28	54.9	10	19.6	18	35.3
0.5–0.79	7	13.7	14	27.4	8	15.7
0.8–0.99	3	5.9	6	11.8	12	23.5
1	13	25.5	21	41.2	13	25.5
Total	51	100	51	100	51	100
Average	0.55		0.78		0.68	
St. deviation	0.33		0.23		0.30	
Max	1		1		1	
Min	0.105		0.286		0.121	

Table 5 shows that correlation coefficients between CRS-VRS and CRS-SE are positive and statistically significant ($p \leq 0.01$). These results suggest that the suckler cow farms, given the level of inputs used in model development, could increase the output, according to the CRS model, since this model was developed to increase the output by optimising the combination of inputs (Farhan et al., 2015; Parichatnon et al., 2018).

Table 5 Spearman's correlation matrix of studied DMUs

	<i>CRS model</i>	<i>VRS model</i>	<i>SE model</i>
CRS model	1		
VRS model	0.656 ^a	1	
SE model	0.856 ^a	0.217	1

Note: ^aCorrelations are statistically significant at level $p \leq 0.01$.

Table 6 shows the means and standard deviations of the main variables that are used in the DEA approach of the study area. To determine the reasons for any inefficiency found in the DEA analysis, Table 6 additionally includes the variables of Table 1 and their descriptive statistics separately for both efficient and inefficient farms. According to VRS scores twenty- one farms are efficient and thirty inefficient. Efficient farms represented 41.17% of the sample and inefficient 58.83%. Statistically significant differences ($p \leq 0.01$) were detected between efficient and inefficient DMUs concerning the following variables.

Efficient farms had an average of 96 suckler cows and the inefficient 75, respectively. The average yield/farm/year differed significantly between efficient and inefficient farms ($P = 0.000$), where the efficient farms have higher gross revenue. The cost of fixed capital is higher in efficient farms due to the modernisation of the buildings and machineries of the large-sized farms. Additionally, efficient farms have lower fixed capital costs and

lower variable costs, because they use capital more intensively and because they achieve economies of scale.

Table 6 Means and standard deviations of the main variables used

	<i>Unit</i>	<i>Efficient</i>	<i>Inefficient</i>	<i>p</i>
DMUs	No	21	30	
Y: gross revenue	€	77,732.38±108,646.05	52,918.66±43,172.57	0.000
gross revenue/livestock unit	€/LU	809.71±410.73	705.58±321.43	0.000
X1: cost of fixed capital	€	62,171.58±107,352.27	53,899.70±105,048.39	0.164
X2: cost of variable capital without feed	€	10,220.93±8,031.68	12,404.10±7,057.60	0.054
X3: cost of feed	€	41,301.90±46,717.02	38,905.33±28,466.10	0.210
X4: labour cost	€	11,573.73±4,173.50	12,411.66±7,822.07	0.881
Pastures area	ha	510.71±952.88	285.26±425.45	0.126
Stocking rate	LU/ha	14.21±32.03	10.28±12.94	0.231
Number of weaned calves	No/year	71.95±72.05	59.73±38.75	0.104
Education level	years	9.03±3.04	5.71±4.32	0.159
Age	years	37.02±30.06	45.07±40.81	0.227
Cultivated land	ha	89.28±175.11	97.23±102.84	0.231
Suckler cows (LU)		95.81±144.00	74.50±44.65	0.003
Selling live weight	kg/calf	340±110	280±70	0.167
Selling price	€	2.90±0.30	2.20±0.28	0.131
CRS	No	1	0.38±0.28	
VRS	No	1	0.62±0.18	
SE	No	1	0.56±0.27	

It is evident that efficient farms can meet their needs with lower variable expenses since they manage their resources properly and based on efficiency metrics.

Total feeding costs per farm and year were on average bigger for efficient farms but this result was not statistically significant. The labour cost is lower in efficient farms about inefficient farms. Furthermore, the efficient farms use more extended pastureland, achieve a higher number of weaned calves, the selling live weight in kilos is higher and consequently, the price of calves sold is higher in relation to the inefficient farms. The cultivated land in inefficient farms is larger than the efficient because the inefficient farms can be considered of 'mixed' production orientations, actives in crop production as well.

Finally, the education level of the 'efficient' farmers is almost nine years and in the inefficient is almost six years. In addition, in efficient farms, farmers are younger than farmers in inefficient farms, and this suggests that professional experience is not being used as well as training in this livestock sector.

4 Discussion

What does this study reveal about the technical efficiency of red suckler cow Breed farms in Greece and the main determinants of this performance? According to the DEA model, the most efficient companies are those with the largest number of animals and those which have invested in modernisation processes of tangible assets, have managed resources efficiently, and are managed by young entrepreneurs with a high level of training.

According to Veysset et al. (2015), a farm's efficiency is its ability to achieve good performances with a certain amount of inputs, which can be related directly to the farm's monetary productivity. Thus, the technical efficiency calculated from the total outputs and inputs also expresses the productivity of the farming system (Latruffe, 2010). Therefore, the costs involved in producing output are closely related to the variables and factors affecting the productivity of the production system. In light of this, it is of interest to exploit the measuring of technical efficiency to identify opportunities for improvement or reduction of inefficiencies (Gaspar et al., 2009). Our model reveals that the mean value of the estimated with VRS model technical efficiency (0.78) implies that on average the farms technically could produce the same amount of output with 22% fewer inputs. As it concerns the mean value of SE (0.68) suggests that the productivity could be increased (32%) by adjusting the holdings to their optimal scale.

According to our study, increasing herd size has led to economies of scale. These results are consistent with previous empirical findings that larger farms are more profitable and have lower production expenses (Basu et al., 2021; Rapikova et al., 2003; Samarajeewa et al., 2012).

Therefore, the improved productivity that shows the technically efficient farms in the current study has to do with the combination of increased size and economy of scale. These farms are more likely to gain competitiveness by increasing their yield performance when they will gain the ability to sell heavier calves than the mean value of 340 kg. In addition, the relatively low weight of calves sold by inefficient farms does not allow them to achieve better prices per kilos of product compared to the current market prices of heavier calves. According to Samarajeewa et al. (2012), optimal size may differ from farm to farm based on the available resources. As a result of the high cost of feed, farmers avoid selling heavier calves. Thus, the government should subsidise the purchase of animal feed or the cultivation of it.

Our findings demonstrate that in order to improve the economic solvency, it is essential to improve the production levels of the suckler cows and at the same time to utilise the inputs in a more efficiency way. So, to influence the profitability, it is recommended the sales weight of calves be higher, the selling cost per calves be lower and the production costs for replacement heifers to be lower (Michalickova et al., 2015).

Another factor affecting the efficiency of the farms is linked to the feeding of the livestock. In particular, two parameters determine the feed self-sufficiency:

- 1 self-produced feedstuffs
- 2 forage from available pastures, about their level of purchased concentrates and forages.

Indeed, an essential element contributing to the success of suckler cow farming is the efficient use of feed. In most cases, the higher cost of feed in the Red Greek breed suckler

cow farms is one of the major problems of the sector, resulting in reduced efficiency and low competitiveness (Theodoridis and Ragkos, 2014). The more intensive a farm is, the more vulnerable it is to feed price increases (Gelasakis et al., 2017). To reduce the cost of feeding and support production, it is important to increase crop production for feed.

According to our results the efficient farms present a higher cost of feed, they make more use of the pastures, but they cultivate fewer hectares for concentrated feed. Suckler cow herds receive a higher proportion of feed produced on the farm, compared to purchased feed, as reported by Michalickova et al. (2015). Feed costs will go down as more cows are used per hectare of grassland, allowing for more intensive use of pastures (Jan et al., 2017). Moreover, the use of forage programs, in which suckle cows graze for more days per year and the harvested forages fed for a shorter duration will decrease the feed expenses (Michalickova et al., 2015). By enhancing suckler cow farmers with direct or indirect subsidies from the national rural development programs, it will be possible for them to adopt alternative practices such as growing legumes for fodder crops in autumn to reduce their feed costs (Gourdouvelis et al., 2019b).

The dummy variables capturing the effect of available pastures on feed cost were the pasture area (ha) and stocking rate (LU/ha). In general, the mean stocking rate in our study was considered too high compared to other studies (e.g., 1.30 LU/ha in Veyssset et al., 2015; 1.24 in Finneran and Crosson, 2013).

The increased labour costs of inefficient farms can easily be explained by the lower level of fixed capital investment. Normally the lack of pastures and the high stocking rate observed in the above holdings should have led to an intensification of farming and not to an intensification of work. Moreover, the strong increase in labour cost per LU of inefficient farms didn't drive to an increase in output. Rakipova et al. (2003) contend that reducing labour input would only improve output-to-input ratios if it was accompanied by larger farm sizes, increased mechanisation levels, and better pasture utilisation. The entire mentioned above are the dominant structural characteristics of the mean efficient farm in our study (Table 6). Additionally, creating contractors to reduce mainly the cost of foreign engineering labour is recommended as well as using seasonal labour during the most labour-intensive times of the year.

Recruiting specialised employees in the fields of feeding, or rearing is expected to improve labour productivity (Tsiouni et al., 2021b)

As we can see from the result the efficient farmers are younger and have a higher education level. This can be explained because educated farmers have a greater capacity to understand and realise the association between gross revenue and production cost. Several media sources enable them to access information more easily as well (Fiore et al., 2020; Genius et al., 2006). Younger farmers have more access to technology and are more open to innovations than older farmers suggesting the importance of educating farmers and employees about the opportunities offered by the market (Galati et al., 2020; Tselempis et al., 2019). Moreover, older farmers are usually less educated and are uncertain about changing their management practices, and usually have less time to invest for the long-term and expect future higher returns (Liu et al., 2019). Farmers must be motivated to attend seminars regarding farm management. Furthermore, the adoption of technology advantages will bring improvement to the economy as a result of the adoption of innovations. By creating and enabling mobile advisory assist, farmers will be able to develop their management skills (Tsiouni et al., 2021b).

The European Union under the Common Agricultural Policy established specific support schemes, which aimed to improve the production yields of the existing cattle population and consequently increase livestock income. Although such measures have not been effective in improving productivity or competitiveness (Tsiouni et al., 2021a, 2021b), because the farmers used the economic support to cover some of the costs not covered by the market sales (Kvapilík and Zahrádková, 2007).

5 Conclusions

The results of our study of the Red Greek breed farms indicate a higher number of inefficient breeding operations, but at the same time provide us with insight into their most successful characteristics. As revealed by the DEA analysis, companies with a greater number of suckler cows, who have started modernisation processes about land and fixed capital, can allocate resources more efficiently, reducing variable costs. Furthermore, the most efficient companies are those run by young entrepreneurs with a high level of education.

Our study provides simultaneously managerial and political implications. From a managerial point of view, feed self-sufficiency is an important topic for Red Greek breed cow farms especially with the added pressure from rising prices on cereal and legumes forage crops and the multiplier effect on concentrate feed prices. Feed self-sufficiency will lead to the problem of high feed cost contributions to total production costs. The use of new technological advances on self-produced feedstuffs and the improvement of feed strategies and herd management practices will change the way that farm inputs are utilised. Continuous efforts to increase productivity led to an increase in the use of costly but value-adding inputs, such as genetically improved livestock and high protein feedstuff resources, without the goal of increasing productivity to be achieved.

The competitiveness of suckler cow breeding in Greece can be improved either through a further increase in productivity or by a reduction of the factors that affect the economic results. In order, to reduce the labour cost parameter, it is mentioned that, innovating should begin with rationalising the value of labour, mechanising production, and upgrading facilities to meet ergonomic needs.

Moreover, advanced productive use and rational utilisation of the fixed capital will lead to the reduction of this particular cost component. The cost of variable capital mainly consists of the cost of drugs and antibiotics and from the cost of fuels and electricity. Animal health programs can help prevent the occurrence of multifactorial diseases. The operating costs can be reduced if the breeders focus on renewable energy sources. It is recommended to use an inexpensive and well-balanced feeding program to reduce feed cost, with parallel rational use of available pastures for grazing.

From a political perspective, the study provides policymakers with insight and hints to identify effective measures to support strategic sectors such as Red Greek breed farms. Taking measures to support the enhancement of the cow productivity, but also training and education of the breeders is among the measures that could contribute to the growth of the sector and the development of the geographical region. An objective that requires the involvement of all supply chain stakeholders, according to an approach validated also in similar sectors such as that of stakeholder engagement and management (Fiore et al., 2020).

The current study has several limitations related both to the limited number of farms involved in the analysis and to the restriction of the geographical area, which does not allow us to generalise our results, and extend them throughout the country. However, the analysis remains valid. In light of these considerations, future research could be expanded in all regions that red Greek breed farms exist and over the years technical efficiency can be analysed between time series. In addition, future research should determine which countries shape the best-practice frontier and how to increase gross returns as well as stimulate innovation and technology diffusion, technology transfer, knowledge spillover, and fostering an innovative mindset.

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