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Efficiency Analysis of Beef Cattle Farms Using Bootstrap Data Envelopment Analysis in Izmir/Turkey

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ABSTRACT

This study aimed to determine the efficiency levels of beef cattle farms in the province of Izmir and identify the factors that affect their efficiency by means of boorstapped data envelopment analysis. The study covers 62 farms engaged in beef cattle farming in five different districts of Izmir. The Bootstrap Data Envelopment Analysis for beef cattle farming provided the result that the analysis should be conducted with the Constant Return to Scale assumption. The average corrected input oriented Constant Return to Scale efficiency after bootstrapping was found to be 0.90. According to the results of truncated regression analysis, a positive relationship was found between adjusted input-oriented efficiency scores and the number of fattening periods per year. On the other hand, it has been determined that union membership has a statistically significant negative effect on efficiency. In addition, big farms have lower efficiency than smaller farms, farms in Buca district have lower efficiency than those in Odemis district, and those who fatten old cattle have lower efficiency than those who fatten young cattle. As a result, farms that fatten cattle for shorter periods of time, farms that do not increase the number of animals much, and farms that fatten young cattle achieve higher output per unit of input used, indicating higher technical efficiency.

Keywords: Beef Cattle, Efficiency, Bootstrap DEA, Truncated Regression, Turkey.

INTRODUCTION

It is accepted that consumption of animal products plays a vital role in ensuring a healthy and balanced diet of societies. Therefore, in today's world, the issue of nutrition is becoming increasingly important and finding a solution is becoming more difficult due to the rapidly increasing population. The livestock sector in Turkey has an important potential not only in terms of nutrition, but also in terms of ensuring the profitability of farms, providing raw materials to the industry, increasing exports and foreign exchange income, expanding employment opportunities, and utilizing pasture and grazing areas.

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In Turkey, especially beef cattle breeding has made significant progress over time, but has not yet reached a level sufficient for the population. In 2022, the number of cattle in Turkey was 17 850 543 heads, the number of slaughtered cattle was 5 134 441 heads, and beef production was 1 460 719 tons (MAF, 2023a). However, there is a significant gap between the amount of red meat produced and the amount needed to provide adequate and balanced nutrition for the current population.

One of the provinces with high potential for beef cattle breeding in Turkey is Izmir. According to 2022 data, Izmir province has approximately 5% of the country's total cattle population (778 468 heads) and approximately 3% of the total beef production (42 000 tons) (MAF, 2023b). For this reason, the research focused on Buca, Kemalpasa, Odemis, Menemen and Menderes districts of Izmir province. Since these districts constitute approximately 35% of the total number of cattle in Izmir province (MAF, 2023b), they are considered representative of the beef cattle farms in the region.

The lack of adequate support for animal production in Turkey, the increase in input prices above world prices, and the import of both live animals and meat have led to a decrease in competitiveness in the livestock sector and significant production and income losses. While the costs of beef cattle farming are rising, low prices in the free market put serious pressure on producers. To solve these problems, it is essential to ensure efficiency in production. Ensuring efficiency in production requires carrying out efficiency studies at the enterprise level and creating and implementing sustainable policies regarding efficiency.

Efficiency measurement is a very useful tool used in evaluating businesses. It allows farmers to evaluate their performance and identify areas that can be improved. Data Envelopment Analysis (DEA) models are highly effective, non-parametric efficiency approaches. DEA allows evaluation of the relative efficiency of different businesses. It helps identify top-performing businesses and benchmarks the performance of others against them. However, due to the non-parametric structure of DEA, it is a significant disadvantage that it attributes all measurement errors to inefficiency. To overcome this disadvantage, bootstrapping techniques must be used (Simar and Wilson 2007). Bootstrap is a general computer-based statistical method used to calculate the accuracy of statistical predictions (Bogetoft and Otto 2011). The basic idea of Bootstrap is to replaceably sample observations from one's dataset, thus creating a new "random" dataset the same size as the original. Using this dataset, the necessary statistics, called replicates, can be calculated. This process is repeated to create an instance of the copies. Based on this example, we can draw conclusions about the distribution of the statistics we are interested in (Bogetoft and Otto, 2011). In practical problems only a given sample S=s is drawn and the remaining N-n elements of the population are unknown. Therefore the only information available is the drawn sample. The distribution and variance of the population mean and sample mean are unknown and need to be estimated. One way is to use analytical prediction functions. An alternative way to estimate the variance of the sample mean is the bootstrapping method (Behr, 2015).

Various methods are used to perform efficiency analyzes in beef cattle breeding in different countries. While some researchers prefer the parametric method called Stochastic Frontier Analysis (SFA) (Ruiz et al., 2000; Trestini, 2006; Serin et al., 2008; Fleming et al., 2010; Otieno et al., 2012), others preferred the DEA method (Rakipova et al., 2003; Finneran and Crosson, 2013; Umar et al., 2014; Gabdo et al., 2020; Musliu et al., 2023).

Very few studies have been conducted on efficiency measurement in beef cattle farms in Turkey. In these studies, Ceyhan and Hazneci (2010) used the DEA method, while Özden and Armağan (2014) and Gözener and Sayılı (2015) used both DEA and SFA methods together. However, no study on this subject has been found in Izmir. For this reason, this study is important as it is the first efficiency analysis conducted in the beef cattle industry in Izmir province.

Additionally, there are very few studies in the international literature that use Bootstrapping DEA in beef cattle efficiency analysis. Of these, Musliu et al. (2023) and Gabdo et al. (2020)'s studies applied bootstrapping, but neither of them made the choice between Constant Return to Scale (CRS) and Varable Return to Scale (VRS). Also, Gabdo et al. (2020) used bootstrapping in the free disposal hull approach. Ceyhan and Hazneci (2010) did not choose between CRS and VRS and also analyzed the efficiency results with tobit regression, although the literature recommends truncated regression. In this study, bootstrapping was used to choose between CRS and VRS, and truncated regression was used as recommended by the literature. In this context, the main purpose of this study is to evaluate the input-oriented efficiency of beef cattle farms in the Izmir region using the return to scale approach and thus to demonstrate that beef cattle breeders will gain a competitive cost advantage. Another aim of the study is to analyze the factors affecting effectiveness with the correct regression technique suggested by the literature.

MATERIALS AND METHODS

The main material of this study was the data obtained from the fully specialized beef cattle farms through questionnaires. According to the 2013 year MFAL (Ministry of Food, Agriculture and Livestock) report in which the research was conducted, Izmir province has a total of 862 beef cattle farms in operation. The sample size for the study was determined as 62 farms, using the formula specified by Newbold (1995) and Miran (2021a).

$$n = \frac{Np(1-p)}{(N-1)\sigma^2_{\hat{p}_x} + p(1-p)}$$

n: Sample size

N: Total number of farms engaged in beef cattle in Izmir province (862)

σ^2_{px} : Variance (0,06079)

P: Proportion of breeders engaged in beef cattle (0,50)

In determining the sample volume, 90% reliability and 10% margin of error were used. In order to reach the maximum sample volume, the breeding ratio was taken as 0.50.

While analyzing the collected data, the farms were divided into 3 groups according to the number of cattles fed in a fattening period (Table 1).

Table 1: Farm groups according to the number of cattles, number of farms included in the sample, and the ratio of farms in total.

Farm groups	*Number of cattles*	*Number of farms in the groups*	*Ratio of groups in total (%)*
Group 1	1-100	34	54.8
Group 2	101-400	23	37.1
Group 3	401+	5	8.1
Total		62	100.0

In this study, the efficiency in beef cattle farming was measured using bootstrap DEA. Within this framework, the study aimed to determine whether the input efficiency adhered to CRS or Variable VRS. This involved testing the null hypothesis, CRS, against the alternative hypothesis, 'Variable Return to Scale (VRS). After determining the corrected efficiencies and confidence intervals, the factors influencing efficiency were analyzed using truncated regression method.

In truncated regression models, certain ranges of the dependent variable are excluded from the sample. This means that observations of the dependent variable that fall below or above certain threshold values are systematically removed from the sample. In truncated regression, there are no observations for the dependent and independent variables corresponding to specific threshold values. Therefore, truncation implies that only a portion of the dependent variable is included in the sample. When it is excluded a subset of the population from the sample based on the dependent variable, a truncated regression model emerges. Truncated regression differs from censored regression models, where observations with censored dependent variable values are still included in the regression. In truncated regression, observations that do not adhere to a certain rule are not taken into account when estimating the regression equation. If truncated samples are modeled using ordinary least squares (OLS), the coefficients will be biased and inconsistent. Truncated regression models are typically estimated using parametric maximum likelihood estimation methods (Miran, 2021b).

Data Envelopment Analysis

Let there be N production units with K inputs and M outputs. In this case, the linear programming model for DEA. can be represented as follows, where X is the K×N dimensional input matrix, and Y is the M×N dimensional output matrix:

$\min_{\theta,\lambda}\theta,$

st. $-y_i + Y\lambda \geq 0,$ (Output restrictions)

$\theta x_i - X\lambda \geq 0,$ (Input restrictions)

$\lambda \geq 0$

Here, θ represents the efficiency as a scalar, λ is a N×1 dimensional vector of constants (decision units), y is the output vector, and x is the input vector. In other words, λ (lambda) typically represents the vector of weights assigned to various inputs and outputs when evaluating the efficiency of decision-making units (DMUs). These weights determine the contribution of each input and output in the efficiency calculation.). This model is preferred more among different linear programming models as it is less restrictive. By solving the above linear programming model for each decision unit taken into consideration, N values of θ between 0 and 1 will be obtained. Each θ value obtained provides the efficiency for the respective production unit. When the θ value is equal to 1, it indicates that the decision unit is on the boundary or, according to Farrell's (1957) definition, has technical efficiency. In inefficient units, the θ value will be less than 1. In the production process, outputs are obtained by using inputs. Therefore, there are two different directions of efficiency, with respect to inputs and outputs. Accordingly, efficiency calculations are done using two different approaches:

- Input-oriented (IO) approach, which focuses on inputs
- Output-oriented (OO) approach, which focuses on outputs

In this study, there is no control over the output, but it is possible to control the use of inputs. Therefore, input-oriented DEA has been used. Input-oriented DEA models are generally approached with either CRS or VRS. CRS means that if there is a proportional change in inputs, there will be an equal change in outputs. For example, if inputs double, outputs will also double. VRS refers to the situation where production exhibits decreasing, constant, or increasing returns to scale depending on the scale of operations (Miran, 2021b). Actually, it was used bootstrap DEA to determine which returns to scale approach to prefer.

DEA relies on a specific set of input and output data to measure efficiency. However, in practice, these data may contain errors, or variations due to sampling. By employing bootstrapping, Bootstrap DEA generates multiple resamples from the original dataset, allowing researchers to estimate the uncertainty associated with efficiency scores and rankings. Traditional DEA methods often assume that the input and output data are fixed and known with certainty. Bootstrap DEA relaxes this assumption by generating resamples, which can be used to estimate confidence intervals for efficiency scores. This provides a more comprehensive understanding of the reliability and robustness of efficiency estimates. In DEA, different models can be used to assess efficiency, such as input-oriented, output-oriented, or CRS versus VRS models. Bootstrap DEA can be employed to compare the performance of different models by resampling and calculating efficiency scores for each model. This helps researchers select the most appropriate model for their specific analysis.

Bootstrap DEA model for beef cattle farming

The bootstrap DEA model for beef cattle considered two outputs and nine inputs. Descriptions and units of the variables in bootsrap DEA model are as follows:

Y_1:Total live weight gain (kg/year) = Total live weight of sold animal - Total live weight of purchased animal

Y_2:Total amount of manure (ton/year)

X_1:Total labor (MLU[2]/year) = Family labor + Permanent labor + Temporary labor

X_2:Total amount of purchased consantrate feed (ton/year)

X_3:Total amount of barley (ton/year) = Amount of purchased barley + Amount of barley produced on the farm

X_4:Total amount of silage (ton/year) = Amount of purchased silage + Amount of silage produced on the farm

X_5:Total amount of straw (ton/year) = Amount of purchased straw + Amount of straw produced on the farm

X_6:Farm size (head) = Number of beef cattle in a fattening period x Number of fattening periods per year

X_7:Total fuel costs (TL/year)

[2] MLU: (Male Labor Unit): 0.50 for those aged 7-14; 0.75 for women and 1.0 for men between the ages of 15-49; 0.50 for women over 50 ages and 0.75 for men (Erkus et al., 1995).

X_8:Total electricity and water costs (TL/year)

X_9:Total veterinary costs (TL/year)

The basic descriptive statistics variables used in Bootstrap DEA were presented in Table 2.

Table 2: Descriptive statistics of outputs and inputs for all farms (n=62).

Variables	*Unit*	*Mean*	*Std. Dev.*	*Min.*	*Max.*
Y_1	(kg/year)	69 557.83	72 668.78	4 620.00	349 258.00
Y_2	(ton/year)	704.28	778.82	42.60	3 551.10
X_1	(MLU/year)	2.37	1.46	0.18	9.04
X_2	(ton/year)	95.62	155.52	0.01	765.50
X_3	(ton/year)	718.23	5 072.67	0.01	40 000.00
X_4	(ton/year)	416.73	611.36	0.01	2 600.00
X_5	(ton/year)	74.25	82.24	0.01	386.00
X_6*	(head)	230.19	250.07	14.20	1 183.70
X_7	(TL/year)	20 558.06	44 350.48	500.00	350 000.00
X_8	(TL/year)	6 768.71	10 581.88	150.00	80 000.00
X_9	(TL/year)	12 596.77	20 532.03	500.00	150 000.00

In line with the aim of this study, which is to answer the question of whether constant or variable returns to scale technology is prevalent, certain tests were conducted to compare the hypothesis of technology exhibiting constant returns to scale against the alternative hypothesis of variable returns to scale (Bogetoft and Otto, 2011).

H_0: Constant returns to scale (CRS)

Ha: Variable returns to scale (VRS)

If the efficiencies calculated using VRS technology are the same as those calculated using CRS technology, the null hypothesis is accepted. If at least one of the CRS or VRS efficiencies is different, it is expected that the CRS efficiency is lower than the VRS efficiency. To determine this, it is tested whether the SE:

$$SE^k = \frac{E^k_{CRS}}{E^k_{VRS}} \quad (k = 1, \dots, K)$$

is equal to 1 for all farms. If the null hypothesis is true, it is concluded that the technology should be CRS; if the null hypothesis is false, it is concluded that it should be VRS.

In a situation with K observations, if at least one of the calculated scale efficiencies is less than 1, it is needed to reject the null hypothesis. Considering the uncertain or stochastic connection between the technology set and SE, if at least one of the calculated scale efficiencies is significantly lower than 1 or, in other words, if one of the scale efficiencies is lower than a critical value, the null hypothesis is rejected. Instead of examining each scale efficiency individually, it can be calculated the test statistic (S) to accomplish this:

$$S = \frac{\sum_{k=1}^{K} E_{CRS}^{k}}{\sum_{k=1}^{K} E_{VRS}^{k}} = \frac{59.83394}{60.68813} = 0.985925$$

If the null hypothesis is true, the value of S will be close to 1, while if the alternative hypothesis is true, the value of S will be less than 1. To determine statistically that S is less than 1, it is needed a critical value. If S is smaller than this critical value, it is rejected the null hypothesis. The critical value, Ca, will allow to be perform this test. For a given α level, if S < Ca, it is rejected the null hypothesis and concluded that it is VRS [Pr(S<ca | H0)].

Since the distribution of S under H_0 is unknown, Ca cannot be directly calculated. One way to address this lack of distributional information is to utilize the bootstrap method. In this study, DEA and 10 000 iterations of Bootstrap DEA were implemented using the R software.

For radial DEA, S was calculated as 0.985925. The p-value for S and S_b, calculated using the DEA Bootstrap approach with 10 000 iterations, was found to be 0.1211429. Therefore, since $p > \alpha$ for $\alpha = 0.05$, the null hypothesis is not rejected. Thus, CRS is present in beef production. To identify the necessary actions to improve efficiency, it is needed to utilize the corrected efficiency values with respect to input-oriented CRS.

The relationship between the corrected efficiency and the variables that influence it is modeled using truncated regression. Since the corrected efficiency values obtained from this study are ratio data ranging from 0 to 1, truncated regression model was used to assess the effects of some variables. To account for the censoring of the corrected efficiency values at 0 and 1, the truncated regression model was employed. The corrected efficiency value was treated as the censored dependent variable, and the farmer, farm, and resource utilization variables were considered independent variables. Covariates were included to control for potential confounding factors. The model parameters were estimated using maximum likelihood estimation, and the interpretation of the coefficients was based on their effects on the expected value of the corrected efficiency values.

In estimating the technical efficiency scores using truncated regression, it was employed a double bootstrap technique to account for non-discretionary factors. This approach was applied after empirically obtaining the derived technical efficiency values. The quantification involves taking the inverse of the technical efficiency values. As a result, the variable dependent on the set of non-discretionary variables is transformed from the double boundary dimension to the single boundary dimension. In such a case, the efficiency score is confined to the interval [1, ∞) and the left-limit truncation regression is used to determine factors associated with the reciprocal of the technical efficiency scores. The value of efficiency that equals one indicates an efficient farm, while a larger efficiency value indicates an inefficient farm (Isgin et al. 2020).

DEA scores may be correlated with the efficiency factors when classic regression models are applied (Kumbhakar and Lovell, 2000). In this paper, bootstrapped truncated regression (100 replications) model was applied to find effects of the efficiency factors (Simar and Wilson, 2007). Factors thought to be effective on efficiency are given in Table 3:

Table 3: Descriptive statistics of the variables used in regression analysis (n=62).

	Efficiency factors	***Unit***	***Mean***	***Std. Dev.***	***Min.***	***Max.***
	Reciprocal dcrs		1.133016	0.1740463	1.009	1.969
f_1	Age	year	49.016130	10.925220	28	76
f_2	Education level of breeding	year	8.145161	3.683578	1	16
	Education level^2	year	79.693550	70.260310	1	256
f_3	Union membership	0:no 1:yes	0.7903226	0.4104015	0	1
f_4	Chamber membership	0:no 1:yes	0.9354839	0.2476756	0	1
f_5	Cooperative membership	0:no 1:yes	0.2903226	0.4576167	0	1
f_6	Credit usage	0:no 1:yes	0.5322581	0.5030315	0	1
f_7	Farm size (Number of cattle)	head	230.189	250.0704	1183.7	14.2
f_8	Farm groups	DEC*				
	Group 1 (Reference group)		0.5322581	0.5030315	0	1
	Group 2		0.4032258	0.4945499	0	1
	Group 3		0.0645161	0.2476756	0	1
f_9	Beef cattle insurance	0:no 1:yes	0.1451613	0.3551390	0	1
f_{10}	Age of beef cattle at the beginning of fattening	DEC				
	0-6 month old (Reference)		0.0967742	0.2980636	0	1
	7-12 month old		0.4193548	0.4974818	0	1
	7-12 month old female		0.0322581	0.1781270	0	1
	Mixed age beef		0.0806452	0.2745122	0	1
	15-24 month old cattle		0.3548387	0.4823703	0	1
	Cow - ox fattening		0.0161290	0.1270001	0	1
f_{11}	Number of fattening periods per year	RPY**	1.385484	0.3753323	1	3
f_{12}	Districts	DEC				
	Odemis district (Reference)		0.2741935	0.4497487	0	1
	Buca district		0.0483871	0.2163345	0	1
	Kemalpasa district		0.1935484	0.3983042	0	1
	Menderes district		0.1451613	0.3551390	0	1
	Menemen district		0.3387097	0.4771345	0	1

*DEC: Dumi for each category, **RPY: Repetation per year

RESULTS

In the farms examined, 29.0% of the breeders were cooperative members, 93.5% were members of the Chamber of Agriculture, and 79.0% were members of the Red Meat Producers Union. In addition, 50% of the farms examined kept records on beef cattle breeding, 14.5% had animal insurance and 53.2% used credit.

The results of the DEA analysis in this study, which considered 9 inputs and 2 outputs, revealed that among the examined farms, 52% were fully efficient, 3% were high efficient, and 45% were very high efficient under the CRS assumption. Under the VRS assumption, 69% of the farms were fully efficient, 3% were high efficient, and 28% were very high efficient.

According to scale efficiency, 52% of the farms were fully efficient and 48% were very highly efficient (Table 4). The average efficiency values were found to be 0.94 for CRS and 0.96 for VRS, with a scale efficiency of 0.98. The minimum efficiency values were 0.52 for CRS, 0.53 for VRS, and 0.86 for SE.

Also, the bootstrap efficiency results are presented in Table 4. These results indicate that only 5% of the farms had high efficiency, and 95% had very high efficiency in their production. After correcting for any bias via the Bootstrap DEA, the minimum and maximum efficiencies were 0.51 to 0.99, respectively, and the average efficiency score was 0.90. The 95% confidence interval for the adjusted arithmetic mean computed for input-oriented CRS ranged from 0.8174 to 0.9335.

Table 4: CRS, VRS and SE scores for all the farms (n=62).

Efficiency scores	***CRS***	***VRS***	***SE***	**Cor. CRS**
Very low (0.00-0.24)	0	0	0	0
Low (0.25-0.49)	0	0	0	0
High (0.50-0.74)	2 (3%)	2 (3%)	0	3 (5%)
Very high (0.75-0.99)	28 (45%)	17 (28%)	30 (48%)	59 (95%)
Fully efficient	32 (52%)	43 (69%)	32 (52%)	0
Total	62 (100%)	62 (100%)	62 (100%)	62 (100%)
Summary				
Mean efficiency	0.94	0.96	0.98	0.90
Standard .deviation	0.10	0.10	0.37	0.09
Minimum	0.52	0.53	0.86	0.51
Maximum	1.00	1.00	1.00	0.99
Confidence interval (95%)	Lower limit: 0.8174112			
	Upper limit: 0.9334603			

Truncated regression was employed to model the relationships between corrected efficiencies and the influencing variables (Table 5). The Wald Chi-square test indicates that the truncated regression model was statistically significant. Since the dependent variable in the truncated regression equation is the reciprocal of the corrected input oriented CRS efficiency score, the signs of the coefficients should be interpreted in reverse. In other words, a positive sign indicates a negative effect, while a negative sign indicates a positive effect.

The efficiency of beef cattle farming was negatively influenced by union membership (Table 5). On the contrary, number of fattening periods per year exhibited a positive relationship with efficiency.

Among the districts analyzed, the efficiency values were generally similar, except for Buca district, which demonstrated less efficiency compared to the reference district (Odemis).

While the efficiency of the largest farms group was lower than the smallest farms group, it has been revealed that the efficiency of the smallest and medium-sized farms was the same.

Also, Farms that fatten 15-24 month old cattle and cows - oxen were less efficient than farms that fatten 0-6 month old calves.

Table 5: Estimation results of truncated regression model for corrected efficiencies.

	Coefficient	***Std. error***	***Z***
f_1:Age	0.0056107	0.0169831	0.33
f_2:Education level of breeding	-0.3833495	0.3570153	-1.07
Education level^2	0.0133802	0.0193656	0.69
f_3:Union membership	0.9373200*	0.5253611	1.78
f_4:Chamber membership	-0.4894960	0.8376676	-0.58
f_5:Cooperative membership	0.8502074	0.5545404	1.53
f_6:Credit usage	0.2681738	0.4138680	0.65
f_7:Farm size (Number of cattle)	-0.00015460	0.00014640	-1.060
f_8:Farm groups			
Group 2	-0.6275366	0.5343065	-1.17
Group 3	2.010874**	0.8972282	2.24
f_9:Beef cattle insurance	-0.4849906	0.6823509	-0.71
f_{10}:Age of beef cattle at the beginning of fattening			
7-12 month old calf	0.3214660	0.5347944	0.60
7-12 month old female calf	0.6473057	0.7171665	0.90
Mixed age beef	-0.8679528	0.5898748	-1.47
15-24 month old cattle	1.4209860**	0.5942299	2.39
Cow-ox fattening	2.971303***	1.0078600	2.95
f_{11}:Number of fattening periods per year	-1.0807470**	0.5040591	-2.14
f_{12}:Districts			
Buca district	1.0507130**	0.4892321	2.15
Kemalpasa district	-0.4976566	0.4923087	-1.01
Menderes district	-0.1806254	0.4997344	-0.36
Menemen district	-0.4001058	0.4792055	-0.83
Log likelihood=	76.214341	Wald $chi^2(20)$ = 603.23***	

*,**, and *** represent significance at 0.1, 0.05, and 0.01 levels, respectively.

DISCUSSION

Looking at the socio-economic characteristics of the farms examined, it can be said that the education level (8 years) and the membership rate in the cooperative (29%) are low. Membership rates in the Chamber of Agriculture and the Red Meat Producers Union appear to be quite high (93.5% and 79.0% respectively). However, the reason for these high membership rates is not that breeders benefit from the activities of chambers and unions, but rather that breeders have to become members of chambers and unions in order to receive direct income support and other livestock supports. Therefore, there is a lack of organization in the farms examined and significant inadequacies in the services provided by the organizations to the breeders.

When compared with the results of other studies, the efficiency values in this study were relatively higher than those reported in some other studies. Rakipova et al. (2003) found an average efficiency score of 0.92 under VRS; Ceyhan and Hazneci (2010) reported 0.87 under CRS and 0.92 VRS, with a scale efficiency of 0.95; Gozener and Sayili (2012) calculated efficiency as 0.83 for Group 1 and 0.89 for Group 2 under VRS; Ozden and Armagan (2014) found 0.80 under VRS. Umar et al. (2014) determined the scale efficiency as 0.54: Gabdo et al (2020) reported as 0.92 under CRS and 0.92 VRS, with a scale efficiency of 0.99; Demirkol and Aydin (2021) found the scale efficiency as 0.97. The higher efficiency values obtained in this study may be due to the fact that the farms within the scope of this study specialize in beef cattle breeding.

The efficiency score of 0.90 obtained through the bootstrap efficiency model implies that even with 10% less inputs, the same level of production could have been achieved. In other words, inefficient farms should reduce the use of total labor, concentrate feed, barley, silage, straw, farm size, fuel costs, electricity-water costs and veterinary costs. Because farms that utilized these inputs less have obtained higher efficiency scores.

According to the truncated regression model estimation, while it was expected that the breeder's age would negatively affect the efficiency of the examined farms and the education level would positively affect the efficiency, no statistical relationship emerged between variables and efficiency. The negative effect of union membership on efficiency shows that farms that benefit from the union's services tend to exhibit lower efficiency. This shows that union activities do not contribute to the efficiency of the farms.

In fact, while Chamber of Agriculture membership, Cooperative partnership and credit use were expected to have a positive effect on efficiency. The coefficients of these variables turned out to be statistically insignificant. Based on this, it is necessary to question the quality of the services provided by the Chamber of Agriculture, Cooperatives and credit institutions.

No statistical relationship was found between farm size and efficiency. On the other hand, the efficiency of large farms was lower than that of the small farms group, while the efficiency of small and medium-sized farms was the same. This was an unexpected result. Because it is generally thought that as farms grow, their efficiencies should increase. Such a result indicates that the farms in the region where the research was conducted should remain small or medium scale.

It can be considered that cattle insurance will positively affect the efficiency of the farms, as it covers the financial losses suffered by the insured due to the death or compulsory slaughter of beef cattle. In contrast, in this study, insurance was not statistically significant. Insufficient insurance services may have caused the breeder's insecurity.

It was observed that those who kept 15-24 month old cattle and cows and oxen were less efficient than those who kept 0-6 month old calves. This is because older cattle achieve lower live weight gain than young cattle. For this reason, farms in the region preferring young cattle for fattening will increase their efficiency scores.

İt has been determined that increasing the number of annual fattening periods has a positive effect on efficiency. Increasing the number of annual fattening periods means shortening the average fattening period. In other words, the extension of fattening time indicates that farms may face difficulties in achieving optimum resource use and performance.

The less efficiency observed in the Buca district compared to Odemis indicates regional variations in beef cattle farming performance. Factors such as geographical conditions, access to resources, or differences in management practices may contribute to the disparity in efficiency between the two districts. Further analysis is needed to understand the specific reasons behind this discrepancy and explore potential areas for improvement.

SUGGESTIONS

Given the high proportion of farms exhibiting very high efficiency, policy initiatives should focus on supporting and disseminating best practices on these farms to increase overall efficiency in the beef cattle sector. Government and agricultural authorities can develop education and extension programs to disseminate information on efficient farm management practices. Workshops, seminars and training programs can be organized to equip breeders with the latest developments in livestock management and husbandry practices. Further research on beef cattle efficiency could be encouraged, including consideration of other variables that may affect efficiency, such as climate, farm size, and breed characteristics.

Creating platforms where beef cattle producers can share their experiences, challenges, and solutions can foster collaboration and facilitate the exchange of information. Farmer cooperatives and unions can be established and networking events can be organized to encourage information sharing. Implementing incentive programs to adopt efficient and sustainable practices can motivate farmers to achieve higher levels of efficiency.

In order to increase efficiency in beef cattle breeding, in addition to solving the problems of education, publication, research and organization, some other precautions that should be taken in general can be listed as follows;

-Since DEA is sensitive to data quality, improving data collection processes can lead to more accurate efficiency measurements. Ensuring reliable data collection methods and addressing potential errors can increase the validity and credibility of efficiency analysis.

-Conducting regular benchmarking between farms can provide valuable insight into best practices and areas for improvement. Farms can learn from each other's success stories and identify potential areas where they can increase their efficiencies. Financial rewards, tax incentives or grants may be provided to farms that meet certain efficiency criteria. Comparative studies with other regions or other countries can also provide valuable information about regional differences and best practices.

-While increasing efficiency is important, it is equally important to promote sustainable practices in beef cattle farming. Promoting environmentally friendly approaches such as better waste management and responsible use of resources can help maintain ecological balance.

CONCLUSIONS

Efficiency analysis in beef cattle farming plays a crucial role in understanding the performance and potential improvements of the farms. The use of DEA provides a valuable tool to evaluate efficiency, but it comes with certain assumptions and limitations, such as fixed and known input and output data. In practice, data may contain errors or variations, which can affect the accuracy of efficiency scores.

To address these issues, Bootstrap DEA offers a powerful solution by generating multiple resamples from the original dataset. This method allows researchers to estimate the uncertainty associated with efficiency scores and rankings, providing a more comprehensive understanding of the reliability and robustness of efficiency estimates. Moreover, Bootstrap DEA allows for the comparison of different efficiency models, enabling researchers to select the most appropriate approach for their specific analysis.

In this study that focused on beef cattle farming in Izmir province, the Bootstrap DEA results revealed the efficiency levels of examined farms under CRS assumption. The majority of farms demonstrated high to very high efficiency, with some differences between the two assumptions. These findings indicate that the beef cattle farms in Izmir have the potential for improvement, especially in terms of reducing input usage.

The study also employed truncated regression to model the relationship between corrected efficiencies and influencing variables. The results highlighted the negative impact of union membership on efficiency. Conversely, the number of fattening period per year positively influenced efficiency. Also, big farms are less efficient than small farms, farms in Buca district are less efficient than farms in Odemis district, and farms that fatten old cattle are less efficient than farms that fatten young cattle. By identifying these factors, the study provides valuable insights for improving efficiency in beef cattle farming.

This study has illuminated the efficiency of beef cattle farming in the Izmir province through the utilization of Bootstrap DEA and truncated regression. The findings can contribute to the literature on agricultural efficiency and can serve as a basis for developing more targeted and effective policies to enhance the performance of beef cattle farms.

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