

## ACCEPTED ARTICLE

# 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 bootstrapped 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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32 In Turkey, especially beef cattle breeding has made significant progress over time, but has  
33 not yet reached a level sufficient for the population. In 2022, the number of cattle in Turkey  
34 was 17 850 543 heads, the number of slaughtered cattle was 5 134 441 heads, and beef  
35 production was 1 460 719 tons (MAF, 2023a). However, there is a significant gap between the  
36 amount of red meat produced and the amount needed to provide adequate and balanced nutrition  
37 for the current population.

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

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

52 Efficiency measurement is a very useful tool used in evaluating businesses. It allows farmers  
53 to evaluate their performance and identify areas that can be improved. Data Envelopment  
54 Analysis (DEA) models are highly effective, non-parametric efficiency approaches. DEA  
55 allows evaluation of the relative efficiency of different businesses. It helps identify top-  
56 performing businesses and benchmarks the performance of others against them. However, due  
57 to the non-parametric structure of DEA, it is a significant disadvantage that it attributes all  
58 measurement errors to inefficiency. To overcome this disadvantage, bootstrapping techniques  
59 must be used (Simar and Wilson 2007). Bootstrap is a general computer-based statistical  
60 method used to calculate the accuracy of statistical predictions (Bogetoft and Otto 2011). The  
61 basic idea of Bootstrap is to replaceably sample observations from one's dataset, thus creating  
62 a new "random" dataset the same size as the original. Using this dataset, the necessary statistics,  
63 called replicates, can be calculated. This process is repeated to create an instance of the copies.  
64 Based on this example, we can draw conclusions about the distribution of the statistics we are  
65 interested in (Bogetoft and Otto, 2011). In practical problems only a given sample  $S=s$  is drawn

66 and the remaining N-n elements of the population are unknown. Therefore the only information  
67 available is the drawn sample. The distribution and variance of the population mean and sample  
68 mean are unknown and need to be estimated. One way is to use analytical prediction functions.  
69 An alternative way to estimate the variance of the sample mean is the bootstrapping method  
70 (Behr, 2015).

71 Various methods are used to perform efficiency analyzes in beef cattle breeding in different  
72 countries. While some researchers prefer the parametric method called Stochastic Frontier  
73 Analysis (SFA) (Ruiz et al., 2000; Trestini, 2006; Serin et al., 2008; Fleming et al., 2010; Otieno  
74 et al., 2012), others preferred the DEA method (Rakipova et al., 2003; Finneran and Crosson,  
75 2013; Umar et al., 2014; Gabdo et al., 2020; Musliu et al., 2023).

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

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

## 95 MATERIALS AND METHODS

96 The main material of this study was the data obtained from the fully specialized beef cattle  
97 farms through questionnaires. According to the 2013 year MFAL (Ministry of Food,  
98 Agriculture and Livestock) report in which the research was conducted, Izmir province has a  
99

100 total of 862 beef cattle farms in operation. The sample size for the study was determined as 62  
 101 farms, using the formula specified by Newbold (1995) and Miran (2021a).

$$102 \quad n = \frac{Np(1 - p)}{(N - 1)\sigma_{\hat{p}_x}^2 + p(1 - p)}$$

103 n: Sample size

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

105  $\sigma_{\hat{p}_x}^2$ : Variance (0,06079)

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

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

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

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

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

113  
 114 In this study, the efficiency in beef cattle farming was measured using bootstrap DEA.  
 115 Within this framework, the study aimed to determine whether the input efficiency adhered to  
 116 CRS or Variable VRS. This involved testing the null hypothesis, CRS, against the alternative  
 117 hypothesis, 'Variable Return to Scale (VRS). After determining the corrected efficiencies and  
 118 confidence intervals, the factors influencing efficiency were analyzed using truncated  
 119 regression method.

120 In truncated regression models, certain ranges of the dependent variable are excluded from  
 121 the sample. This means that observations of the dependent variable that fall below or above  
 122 certain threshold values are systematically removed from the sample. In truncated regression,  
 123 there are no observations for the dependent and independent variables corresponding to specific  
 124 threshold values. Therefore, truncation implies that only a portion of the dependent variable is  
 125 included in the sample. When it is excluded a subset of the population from the sample based  
 126 on the dependent variable, a truncated regression model emerges. Truncated regression differs  
 127 from censored regression models, where observations with censored dependent variable values  
 128 are still included in the regression. In truncated regression, observations that do not adhere to a  
 129 certain rule are not taken into account when estimating the regression equation. If truncated

130 samples are modeled using ordinary least squares (OLS), the coefficients will be biased and  
131 inconsistent. Truncated regression models are typically estimated using parametric maximum  
132 likelihood estimation methods (Miran, 2021b).

133  
134

### 135 **Data Envelopment Analysis**

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

$$\begin{aligned} 139 \quad & \min_{\theta, \lambda} \theta, \\ 140 \quad & \text{st. } -y_i + Y\lambda \geq 0, \quad (\text{Output restrictions}) \\ 141 \quad & \theta x_i - X\lambda \geq 0, \quad (\text{Input restrictions}) \\ 142 \quad & \lambda \geq 0 \end{aligned}$$

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

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

158 In this study, there is no control over the output, but it is possible to control the use of inputs.  
159 Therefore, input-oriented DEA has been used. Input-oriented DEA models are generally  
160 approached with either CRS or VRS. CRS means that if there is a proportional change in inputs,  
161 there will be an equal change in outputs. For example, if inputs double, outputs will also double.  
162 VRS refers to the situation where production exhibits decreasing, constant, or increasing returns

163 to scale depending on the scale of operations (Miran, 2021b). Actually, it was used bootstrap  
164 DEA to determine which returns to scale approach to prefer.

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

177

#### 178 **Bootstrap DEA model for beef cattle farming**

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

181 **Y<sub>1</sub>: Total live weight gain (kg/year)** = Total live weight of sold animal - Total live weight of  
182 purchased animal

183 **Y<sub>2</sub>: Total amount of manure (ton/year)**

184 **X<sub>1</sub>: Total labor (MLU<sup>2</sup>/year)** = Family labor + Permanent labor + Temporary labor

185 **X<sub>2</sub>: Total amount of purchased concentrate feed (ton/year)**

186 **X<sub>3</sub>: Total amount of barley (ton/year)** = Amount of purchased barley + Amount of barley  
187 produced on the farm

188 **X<sub>4</sub>: Total amount of silage (ton/year)** = Amount of purchased silage + Amount of silage  
189 produced on the farm

190 **X<sub>5</sub>: Total amount of straw (ton/year)** = Amount of purchased straw + Amount of straw  
191 produced on the farm

192 **X<sub>6</sub>: Farm size (head)** = Number of beef cattle in a fattening period x Number of fattening  
193 periods per year

194 **X<sub>7</sub>: Total fuel costs (TL/year)**

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<sup>2</sup> 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).

195 **X<sub>8</sub>:Total electricity and water costs (TL/year)**

196 **X<sub>9</sub>:Total veterinary costs (TL/year)**

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

198

199

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

<i>Variables</i>	<i>Unit</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Min.</i>	<i>Max.</i>
Y <sub>1</sub>	(kg/year)	69 557.83	72 668.78	4 620.00	349 258.00
Y <sub>2</sub>	(ton/year)	704.28	778.82	42.60	3 551.10
X <sub>1</sub>	(MLU/year)	2.37	1.46	0.18	9.04
X <sub>2</sub>	(ton/year)	95.62	155.52	0.01	765.50
X <sub>3</sub>	(ton/year)	718.23	5 072.67	0.01	40 000.00
X <sub>4</sub>	(ton/year)	416.73	611.36	0.01	2 600.00
X <sub>5</sub>	(ton/year)	74.25	82.24	0.01	386.00
X <sub>6</sub> *	(head)	230.19	250.07	14.20	1 183.70
X <sub>7</sub>	(TL/year)	20 558.06	44 350.48	500.00	350 000.00
X <sub>8</sub>	(TL/year)	6 768.71	10 581.88	150.00	80 000.00
X <sub>9</sub>	(TL/year)	12 596.77	20 532.03	500.00	150 000.00

201

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

206 **H<sub>0</sub>: Constant returns to scale (CRS)**

207 **H<sub>a</sub>: Variable returns to scale (VRS)**

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

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

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

215 In a situation with K observations, if at least one of the calculated scale efficiencies is less  
216 than 1, it is needed to reject the null hypothesis. Considering the uncertain or stochastic  
217 connection between the technology set and SE, if at least one of the calculated scale efficiencies  
218 is significantly lower than 1 or, in other words, if one of the scale efficiencies is lower than a

219 critical value, the null hypothesis is rejected. Instead of examining each scale efficiency  
220 individually, it can be calculated the test statistic (S) to accomplish this:

$$221 \quad S = \frac{\sum_{k=1}^K E_{CRS}^k}{\sum_{k=1}^K E_{VRS}^k} = \frac{59.83394}{60.68813} = 0.985925$$

222 If the null hypothesis is true, the value of S will be close to 1, while if the alternative  
223 hypothesis is true, the value of S will be less than 1. To determine statistically that S is less than  
224 1, it is needed a critical value. If S is smaller than this critical value, it is rejected the null  
225 hypothesis. The critical value, Ca, will allow to be perform this test. For a given  $\alpha$  level, if  $S <$   
226  $Ca$ , it is rejected the null hypothesis and concluded that it is VRS [ $\Pr(S < ca | H_0)$ ].

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

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

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

245 In estimating the technical efficiency scores using truncated regression, it was employed a  
246 double bootstrap technique to account for non-discretionary factors. This approach was applied  
247 after empirically obtaining the derived technical efficiency values. The quantification involves  
248 taking the inverse of the technical efficiency values. As a result, the variable dependent on the  
249 set of non-discretionary variables is transformed from the double boundary dimension to the  
250 single boundary dimension. In such a case, the efficiency score is confined to the interval  $[1,$   
251  $\infty)$  and the left-limit truncation regression is used to determine factors associated with the



252 reciprocal of the technical efficiency scores. The value of efficiency that equals one indicates  
 253 an efficient farm, while a larger efficiency value indicates an inefficient farm (Isgin et al. 2020).  
 254 DEA scores may be correlated with the efficiency factors when classic regression models  
 255 are applied (Kumbhakar and Lovell, 2000). In this paper, bootstrapped truncated regression  
 256 (100 replications) model was applied to find effects of the efficiency factors (Simar and Wilson,  
 257 2007). Factors thought to be effective on efficiency are given in Table 3:

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

	<i>Efficiency factors</i>	<i>Unit</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Min.</i>	<i>Max.</i>
	Reciprocal dcrs		1.133016	0.1740463	1.009	1.969
f <sub>1</sub>	Age	year	49.016130	10.925220	28	76
f <sub>2</sub>	Education level of breeding	year	8.145161	3.683578	1	16
	Education level <sup>2</sup>	year	79.693550	70.260310	1	256
f <sub>3</sub>	Union membership	0:no 1:yes	0.7903226	0.4104015	0	1
f <sub>4</sub>	Chamber membership	0:no 1:yes	0.9354839	0.2476756	0	1
f <sub>5</sub>	Cooperative membership	0:no 1:yes	0.2903226	0.4576167	0	1
f <sub>6</sub>	Credit usage	0:no 1:yes	0.5322581	0.5030315	0	1
f <sub>7</sub>	Farm size (Number of cattle)	head	230.189	250.0704	1183.7	14.2
f <sub>8</sub>	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 <sub>9</sub>	Beef cattle insurance	0:no 1:yes	0.1451613	0.3551390	0	1
f <sub>10</sub>	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 <sub>11</sub>	Number of fattening periods per year	RPY**	1.385484	0.3753323	1	3
f <sub>12</sub>	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

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

## 260 RESULTS

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

265 The results of the DEA analysis in this study, which considered 9 inputs and 2 outputs,  
 266 revealed that among the examined farms, 52% were fully efficient, 3% were high efficient, and  
 267 45% were very high efficient under the CRS assumption. Under the VRS assumption, 69% of  
 268 the farms were fully efficient, 3% were high efficient, and 28% were very high efficient.

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

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

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

<i>Efficiency scores</i>	<i>CRS</i>	<i>VRS</i>	<i>SE</i>	<i>Cor. CRS</i>
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%)
<b>Summary</b>				
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
<b>Maximum</b>	1.00	1.00	1.00	0.99
Confidence interval	Lower limit: 0.8174112			
(95%)	Upper limit: 0.9334603			

280  
 281 Truncated regression was employed to model the relationships between corrected  
 282 efficiencies and the influencing variables (Table 5). The Wald Chi-square test indicates that the  
 283 truncated regression model was statistically significant. Since the dependent variable in the  
 284 truncated regression equation is the reciprocal of the corrected input oriented CRS efficiency  
 285 score, the signs of the coefficients should be interpreted in reverse. In other words, a positive  
 286 sign indicates a negative effect, while a negative sign indicates a positive effect.

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

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

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

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

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

	<i>Coefficient</i>	<i>Std. error</i>	<i>Z</i>
f <sub>1</sub> :Age	0.0056107	0.0169831	0.33
f <sub>2</sub> :Education level of breeding	-0.3833495	0.3570153	-1.07
Education level <sup>2</sup>	0.0133802	0.0193656	0.69
f <sub>3</sub> :Union membership	0.9373200*	0.5253611	1.78
f <sub>4</sub> :Chamber membership	-0.4894960	0.8376676	-0.58
f <sub>5</sub> :Cooperative membership	0.8502074	0.5545404	1.53
f <sub>6</sub> :Credit usage	0.2681738	0.4138680	0.65
f <sub>7</sub> :Farm size (Number of cattle)	-0.00015460	0.00014640	-1.060
f <sub>8</sub> :Farm groups			
Group 2	-0.6275366	0.5343065	-1.17
Group 3	2.010874**	0.8972282	2.24
f <sub>9</sub> :Beef cattle insurance	-0.4849906	0.6823509	-0.71
f <sub>10</sub> :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 <sub>11</sub> :Number of fattening periods per year	-1.0807470**	0.5040591	-2.14
f <sub>12</sub> :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 <sup>2</sup> (20) = 603.23***	

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

298

## 299 DISCUSSION

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

307 examined and significant inadequacies in the services provided by the organizations to the  
308 breeders.

309 When compared with the results of other studies, the efficiency values in this study were  
310 relatively higher than those reported in some other studies. Rakipova et al. (2003) found an  
311 average efficiency score of 0.92 under VRS; Ceyhan and Hazneci (2010) reported 0.87 under  
312 CRS and 0.92 VRS, with a scale efficiency of 0.95; Gozener and Sayili (2012) calculated  
313 efficiency as 0.83 for Group 1 and 0.89 for Group 2 under VRS; Ozden and Armagan (2014)  
314 found 0.80 under VRS. Umar et al. (2014) determined the scale efficiency as 0.54; Gabdo et al  
315 (2020) reported as 0.92 under CRS and 0.92 VRS, with a scale efficiency of 0.99; Demirkol  
316 and Aydin (2021) found the scale efficiency as 0.97. The higher efficiency values obtained in  
317 this study may be due to the fact that the farms within the scope of this study specialize in beef  
318 cattle breeding.

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

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

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

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

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

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

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

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

## 357 358 **SUGGESTIONS**

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

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

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

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

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

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

387

## 388 CONCLUSIONS

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

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

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

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

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

416

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419

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