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Measurement of Efficiency Using Data Envelopment Analysis (DEA) and Social Factors Affecting the Technical Efficiency in Dairy Cattle Farms within the Province of Izmir, Turkey

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Abstract: Amongst the agricultural regions of Turkey, Aegean region takes the first place in milk production with 18%. As for Aegean itself, the province of Izmir comes second with 17%. In this study, technical efficiency levels of 94 dairy farms in the province of Izmir were measured using Data Envelopment Analysis (DEA) method. For assumptions of CRS (Constant Returns to Scale), 52% and for assumptions of VRS (Variable Returns to Scale), 62% of the dairy farms were found fully efficient. When, the farms were grouped according to their number of cows, it was noticeable that there were differences amongst the groups in terms of efficiency values. As the farm size expanded the efficiency scores increased. In farms with <50 cows, input and output losses are important. When farmer based social and intellectual factors affecting dairy cattle farming were investigated, it was observed that number of family members, experience and level of reading daily papers increased as the scores of efficiency in farms increased.

Key words: Dairy cattle farms, efficiency, data envelopment analysis, ordered logistic regression, Izmir, Turkey

INTRODUCTION

Within total value of agricultural production of Turkey, crops products account for 63% and animal products account for 23.95%. The proportion value of milk in animal products is 42.34% (Turkish Statistical Institute, 2007). Milk takes an important part in value of agricultural production. The ratio of milk processing plants in total food processing plants is 7.7% in 2004 (Artukoglu and Olgun, 2008). When, the distribution of milk production according to agricultural regions is examined, it is noticeable that first four places are occupied, respectively by Aegean region (1, 692, 626 ton); Black Sea region (1, 281, 039 ton); Central North (1, 167, 802 ton) and North-East (1, 112, 322 ton). Within total number of dairy farms, number of farms with 1-4 cows constitutes 59.71%; the ones with 1-9 cows take 85.3%. These farms accommodate 56.62% of the total number of dairy cattle in the country. Average number of cows per farm is 5.7 (Uzmay, 2004). As shown in the statistical inventory, the majority of dairy farms are small scale farms. Dairy farms in Turkey have structural differences depending on their regions. Therefore, research on technical efficiency undertaken regionally has great importance. The aim of this study, was to determine technical the efficiency of dairy farms in various sizes in the province of Izmir within Aegean region and to detect input and production losses caused by ineffectiveness. As the method, Data Envelopment Analysis (DEA) was used.

Important reason for this method to be used was the fact that there has been almost no study regarding the measurement of efficiency in dairy cattle farming in Izmir and Turkey and that studies on this issue have rather dealt with crops production. However, there are a great number of international studies on the matter; Cloutier and Rowley (1993) in Canada, Jaforullah and Whiteman (1999) in New Zeland, Fraser and Cordina (1999) in Australia, Reinhard *et al.* (2000) in Holland, Arzubi and Berbel (2001) in Argentin, Gerber and Franks (2001) in England and Wales'de, Saha and Hemme (2004) for 27 Countries, Fraser and Graham (2005) in Australia, Stokes *et al.* (2006) in Pennsylvania, Ortner *et al.* (2006), in Avusturya'da, Hansson (2007) in Sweden.

Also, identifying farmer-related social and intellectual factors that affect technical efficiency in dairy cattle farming was one of the objectives of the study.

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MATERIALS AND METHODS

The main material of the study consists of the data gathered from the farmers through questionnaires. In the study, effectiveness measurements of farms, which are registered members of the Union of Brood Stock Breeders, were taken into consideration. In districts of Izmir such as, Bergama, Tire, Odemis, Bayindir and Kiraz, there are totally 4784 farms, which are registered members of Cattle Breeders Union. These members cover 85% of Izmir's milk production. Number of farmers to be interviewed was determined through sampling method (95% confidence interval and 10% error ratio were taken into consideration) (Newbold, 1995).

$$n = \frac{Np(1-p)}{(N-1)\,\sigma_{px}^{2} + p\,(1-p)}$$

where:

n = Sample volume
N = Population
σ_{px}^2 = Variance

Maximum sample volume was aimed to be achieved in the study. In doing so, p: 0.50 and (1-p): 0.50 were taken. Ninty four farmers from the study area were interviewed. The data belongs to the year 2006. When, the data was being analyzed, the farms were grouped into 5 groups depending on their sizes (Table 1).

In this study, technical efficiency of dairy cattle farms in Izmir was measured through Data Enveloping Analysis (DEA). DEA is a non-parametric measurement method developed to measure the relative efficiency of economical decision units similar to one another in terms of goods and services they produce. DEA uses linear programming as an efficiency measurement technique based on combinations of inputs and outputs that are >1. Efficiency measures are then calculated relative to this surface (Coelli *et al*., 2002).

$$\begin{aligned} &\min_{\theta\lambda}\theta, \\ \text{st}\quad & -y_i+Y\lambda\geq 0, \\ & \theta x_i - X\lambda \geq 0, \qquad (1) \\ & \lambda\geq 0 \end{aligned}$$

where:

θ = A scalar
λ = A NX1 vector of constants

This envelopment form involves fewer constraints than the multiplier form (K+M<N+1) and hence, is generally, the preferred form to solve. The value of θ obtained will be the efficiency score for the ith firm. It is satisfied: θ<1, with a value of 1 indicating a point on the frontier and hence, a technically efficient firm, according to the Farrel (1957) definition.

Table 1: Farm groups depending on the number of cows and number of sampled farms

Farm groups	No. cows	No. sampled farms
1	05-14	28
2	15-29	27
3	30-49	19
4	50-99	14
5	100-499	6
Total	-	94

DEA is used under assumptions of both Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). Assumption of Constant Returns to Scale was developed by Charnes, Cooper and Rhades and therefore, is called CCR Model. Later a limitation was added to CRS Model by Banker *et al.* (1984) and was converted to a model that also gives variable returns to scale.

The CRS linear programming can be easily modified to account for VRS by adding the convexity constraint: to Eq. (1) to provide:

$$\begin{aligned} &\text{Min}_{\theta\lambda}\,\theta, \\ \text{st}\quad & -yi+Y\lambda\geq 0, \\ & \theta xi - X\lambda\geq 0, \\ & N1'\lambda = 1 \\ & \lambda\geq 0 \end{aligned}$$

Through DEA approaches of not only obtaining maximum output (output based/oriented) without any increase in the input but also obtaining data output with least input (input based/oriented) can be used. While, these 2 approaches might give same results in assumptions of Constant Returns to Scale, they might give different results in assumptions of Variable Returns to Scale. In efficiency measurements of this study, output based/oriented DEA method under assumptions of Variable Returns to Scale was used. As a result of interviews held with farmers in Izmir, they didn't seem to be able to increase their inputs. Therefore, output based/oriented approach was preferred. In the study, DEA software version 2.1 developed by Coelli (1996) was used.

In the study, gross production value of milk, animal sale values and value increase of animals were taken as output. As for the input, number of animals (standart animal unit), labor, feed field, concentrate feed cost, forage cost, depreciation and other costs were taken (Table 2).

In addition, considering some factors (social and intellectual characteristics of the farmers) that were likely

Table 2: Descriptive statistics for the sample of 94 dairy farms

Descriptions	Mean	SD	Minimum	Maximum
Outputs				
Production value of milk (YTL) (Y_1)	155882.20	116248.50	5346.60	1212375.00
Animal sale values (YTL) (Y_2)	49796.95	39544.90	0.00	250000.00
Value increase of animals (YTL) (Y_3)	71723.03	64415.38	6946.06	457251.56
Inputs				
Number of Animals (head) (X_1)*	66.80	64.45	5.60	330.00
Labor (hour/day) (X_2)**	2.81	1.53	0.75	9.98
Forage feed cost (YTL) (X_3)	41147.36	48140.35	2206.57	340178.11
Concentrate feed cost (YTL) (X_4)	51488.26	98011.14	141.40	896142.02
Other cost (YTL) (X_5)	28415.33	56311.88	768.00	328000.00
Feed field (ha) (X_6)	20.35	24.38	0.00	1210.00
Depreciation (YTL) (X_7)	12199.42	21763.08	0.00	180000.00

*Coefficients for each unit of animals (cow 1.00, female-pregnant heifer, 0.70, female, male heifer calf, 0.40, calf 0.20), **Labor in dairy farm (labor for feed is not included)

Table 3: Distributions of technical efficieny scores in farms*

Efficiency (E) score	CRS	VRS
0.60-0.69	9	7
0.70-0.79	13	9
0.80-0.89	16	14
0.90-0.99	7	6
1.00	49	58
Mean	0.9025	0.9267
SD	0.12270	0.11145
Min.	0.62	0.66
Max.	1.00	1.00

*Data pertains to 94 farms

to affect the technical efficiency, an ordered logistic regression model was formed. Efficiency levels of the farms was grouped into 5 groups (dependent variable) from low to high efficiency according to their efficiency scores given in Table 3.

In cases, in which the dependent variable is put in order or is a categorized variable, an ordered logistic regression can be used. The ordered multiple choice model assumes the below given relationship (Emec, 2002).

$$G\ (\text{Prob}(Y \leq j)) = \alpha\, j + \beta\text{'}x\ j = 1, \ldots, k \qquad (1)$$

Here, the variable Y is measured by one of K+1 from a different category, J, K are constant cut parameters. β'is a gradient vector that doesn't include a constant pause term.

Therefore,

$$\alpha\ 1 < \alpha 2 < \ldots < \alpha\ k\text{-}1 < \alpha k$$

Model no. 1 depends on cumulative probabilities of dependent variable categories and assumes a parallelism between regression functions of different Y categories and logit scale.

Descriptive statistics of independent variables for the 94 dairy cattle farms given in Table 4. Our estimations of this model were that as the farmer's experience, education and number of memberships in cooperatives increase, efficiency scores would increase.

RESULTS AND DISCUSSION

According to the results of the study, which was carried out with 3 outputs and 7 inputs, 52% of the farms (49 farms) were found effective under the assumptions of Constant Returns to Scale (CRS). On the other hand, under the assumptions of Variable Returns to Scale (VRS), 62% of the farms (58 farms) were observed to be effective Table 4. Technical efficiency values were 0.903 for CRS and 0.923 for VRS.

One of the most important problems of dairy cattle breeding in Turkey is that small-scale farms are the majority. In this regard, it is important that effectiveness values should be evaluated depending on the sizes of the farms. In Table 5, CRS and VRS are given according to the farm sizes. As shown in Table 5, the biggest farms are full efficient. In fact, there is difference between groups according to Kruskall-Wallis test ($p<0.05$).

When, the targeted and existing output values in dairy farms were compared, a noticeable loss of 1 401, 376 YTL (980 395 $) is calculated. In other words, there is a chance of increasing the output value by 6.7%. When, the chances of increasing the input were investigated among the groups (Table 6), losses were observed to be higher in the first three groups, especially in groups 2 and 3. Furthermore, in farms, which are found ineffective, some of the inputs were not used in calculations of targeted output value and remained stagnant, therefore, taken into consideration as input loss. In other words, the existing inputs (as the average of the whole farm) should be reduced by 7% for labor, 7% for forage cost, 3% for concentrate feed cost, 1% for feed field, 13% for depreciation and 4% for other costs. Resource waste, in particular, is observed in the first 3 groups.

Social and cultural factors, which are considered to be effective on technical efficiency of dairy farms, have been evaluated in Table 7 using ordered logistic regression model. As a result of the model, number of family members, dairy cattle breeding experience and

Table 4: Descriptive statistics for the sample of 94 dairy farms

Description	Mean	SD	Minimum	Maximum
Age of producer (year)	41.39	10.95	21.0	68
Education level of producer (year)	7.88	3.56	5.0	16
Family size (person)	5.21	2.09	2.0	11
Dairy cattle breeding experience of producer (year)	15.73	11.73	1.5	50
Membership in a cooperative	Yes: 49 (1)	No: 45 (0)	-	-
Reading newspaper	Yes: 44 (2)	Sometimes: 35 (1)	No:15 (0)	-
TV/radio programs (agriculture programs)	Yes: 75 (2)	Sometimes:11 (1)	No:8 (0)	-

Table 5: Efficiencies of dairy farms with different number of cows according to CRS and VRS

Farms	CRS	VRS
Group 1 N. 28	0.9001	0.9476
Min.	0.62	0.66
Group 2 N. 27	0.8770	0.8982
Min.	0.63	0.66
Group 3 N. 19	0.8608	0.8726
Min.	0.63	0.66
Group 4 N. 14	0.9714	0.9819
Min.	0.85	0.86
Group 5 N. 6	1.000	1.000
Min.	1.0	1.0
Group mean	0.9025	0.9267
Kruskall-wallis test	p(0.016) <0.05	p(0.008) <0.01

Table 6: Losses in outputs and inputs of farm groups (%)

	Losses in outputs (%)			Losses in inputs (%)						
Farm groups	Values of milk	Animal sale values	Val.increase of animals	No of animals	Labor	Forage cost	Concentre feed	Other cost	Feed field	Depre-ciation
1	7.77	14.33	7.82	0.00	3.43	3.00	2.69	2.07	7.02	15.98
2	18.04	16.04	12.41	0.34	17.40	14.29	8.11	6.98	2.68	14.76
3	15.36	17.08	15.90	2.02	7.61	8.40	2.97	16.53	0.28	8.60
4	1.44	1.31	3.53	0.03	0.00	0.92	0.95	4.07	0.00	0.29
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	6.34	7.70	6.98	0.50	6.95	6.56	2.51	4.41	1.18	13.45

Table 7: Results of ordered logistic regression model

		Independent variables					
Efficiency scores	Dependent variable	Social variables model	Coefficient	SE	z-statistic	Prob.	Odds ratio
1	0.60-0.69	Age of producer (year)	-0.0039533	0.226819	-0.17	0.862	0.996054
2	0.70-0.79	Education level of producer (year)	0.0176397	0.0708503	0.25	0.803	1.017796
3	0.80-0.89	Family size (person)	0.2494249	0.1130657	2.21	0.027*	1.283287
4	0.90-0.99	Dairy cattle breeding experience of producer (year)	0.0583162	0.0247851	2.35	0.019*	1.060050
5	1.00	Membership in a cooperative	-0.2818109	0.4573533	-0.62	0.538	0.754416
		Reading newspaper	0.6811503	0.3439499	1.98	0.048*	1.976150
		TV/radio programs (agriculture programs)	0.1165580	0.5562109	0.21	0.834	1.123623
		LR chi2(7)	13.28		Pseudo R2 = 0.0606		
		Log likelihood	-102.85053		Prob>chi2 = 0.0655		

*Significant at the ratio 0.05

reading newspaper were found to be significant at 0.05. These variables increase the efficiency scores from the lowest to the highest. The possibility of increasing efficiency scores (from the lowest to the highest) are 28% for family population; 6% for dairy cattle breeding experience and 97.6% for farmers who read newspaper. However, it is noticeable that age of the farmer, level of education, membership in a cooperative and watching TV (agriculture programs) and listening to the radio are not effective on efficiency of the farms. Our expectations were that those factors such as, their age, level of education and membership in a cooperative would be effective on efficiency of the farms.

It is noticeable that results of a previous study (Candemir and Koyubenbe, 2006) undertaken on 80 dairy farms in Izmir in 2003 reports that technical efficiency of the farms according to CRS model was found 49% and it was 58% for the model VRS. Technical efficiency values were 0.934 for CRS and 0.954 for VRS. As a result of both studies, overall efficiency values of the farms were quite close and the difference in overall efficiency for CRS was only 3.4%. This data enables a general evaluation of technical efficiency of dairy farms in the province of Izmir. When, compared to some study results obtained in other countries, technical efficiency values for the western part of Turkey can be considered relatively high. For example, in the study carried out by Jaforullah and Precmachandra (2003) in New Zealand, 264 farms were evaluated and total revenue was taken as the output. For inputs, labor, fixed assets, total dairy herd, animal health costs, feed supplements and grazing costs ($) and fertilizers ($) were taken into consideration. Technical efficiency was found 29% for CRS and 47% for VRS. Effectiveness values were 0.860 and 0.807, respectively. In a study conducted by Arzubi and Berbel (2001) in Argentin, 35 farms were handled and average efficiency (for output; milk production, for inputs area, number of cows and rest of cost were taken) of 78.2% with a larger number of farms operating at increasing return scale. In another study, by Gerber and Franks (2001), carried out in Wales England, farms with 70-160 dairy cows were evaluated and technical efficiency was found 87%.

In this study, when size based efficiency scores were compared, differences amongst the groups were observed. In other words, larger farms have higher scores. While, some foreign studies (Jaforullah and Whiteman, 1999; Gerber and Franks, 2001; Ortner *et al.*, 2006) report a positive effect of sizes of the farms on the effeciency, some other studies report no significant relationship between sizes of the farms and effectiveness (Jaforullah and Devlin, 1996).

In our study, positive effects on the efficiency scores of social and intellectual variables such as, population of the farm, experience of the farmer and reading newspaper were observed while age, education and watching TV and listening to radio had no effect. In some studies, carried out in the USA, on this issue, a positive relationship between age, level of education and technical efficiency was reported (Kumbhakar *et al.*, 1991; Tauer and Stefanides, 1998).

CONCLUSION

Ninety-four dairy farms were evaluated through DEA. For assumptions of CRS (Constant Returns to Scale), 52% and for assumptions of VRS (Variable Returns to Scale), 62% of the dairy farms were found full efficient. When the farms were classified depending on their milk production capacity, differences were observed and farms with >100 cows were found full efficient. Resource waste (value/amount) in terms of input/output was noticeable in the first 3 groups of farms (farms with <50 cows). These farmers need to be made aware.

When social and intellectual factors, which affect technical efficiency scores of dairy cattle farms, are examined, from the farms with the lowest efficiency score to the one with the highest (between the levels), family population, dairy farming experience and level of reading newspaper increases. Possibility of these variables to increase technical efficiency scores (from the lowest to the highest) are; 28% for family population, 6% for dairy farming experience and 97.6 for farmers who read newspaper. The age, level of education, membership in a cooperative and level of watching TV/radio programs (agriculture programs) were not found effective on technical efficiency of the farms.

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