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Measuring technical, allocative and economic efficiencies of dairy farms in western Turkey

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ABSTRACT

A study was conducted to determine the input efficiencies of 43 dairy cattle farms under the aegis of Agricultural Development Cooperative in Erikler Village of Center Town of Kirklareli Province in Western Turkey. Data envelopment analysis was used. The technical, allocative and economical efficiencies were found to be as 0.66, 0.43 and 0.23 respectively. The analysis results showed that only 23.26% of the farms were efficient (they had constant return to scale) regarding the usage of major inputs while the remaining 76.74% had increasing return to scale, indicating that these farms could maintain the current output with decreasing current inputs. The current output (gross production value) per cow could be maintained by saving 46.56, 46.72, 42.96, and 45.20% dry weed (kg), straw (kg), concentrated feed (kg), and labour (hour), respectively along with 39.82% veterinary and 46.73% the other expenses.

Key words: Dairy farms, Data envelopment analysis, Efficiency, Survey.

INTRODUCTION

Agriculture sector has benefited from the economic growth experienced recently in Turkey and its production value increased significantly reaching 62 billion $ by the end of 2013 year and ranking the seventh biggest in the World agricultural production value (Anonymous, 2014). Crop production consisted of nearly two-third (69.6%) of total agricultural production value, which means the animal production value is relatively low with remaining nearly one-third of total value (30.4%). The cow milking production value consisted of more than one-third (38.9%) of animal production value, thus becoming one of the most important contributing factor in reaching a high level of agricultural production value (Turk Stat, 2014a).

Western Marmara region of Turkey consisted of 10.69% of cow milk production quantities by 2013 year. Nearly all of the dairy cattle (96.4%) in the region are culture and cross-breed with high milk yield in the region, which has the highest yield value per cow (3653 kg) in Turkey (Turk Stat, 2014b).

The smallest province in the West Marmara region is Kirklareli, where the survey was conducted, in terms of population size. Although its economy is predominantly based on manufacture and service sectors, the agricultural sector is at an agreeable level. The total agricultural production value in 2012 year was 1.7 billion dollars in the province consisting of living animal, plant production and animal product values with 48.0, 35.4 and 15.6%, respectively (Turk Stat, 2013).

The dairy cattle farms in Kirklareli are predominantly in the form of family enterprises. Milk productivity increased from 2693 kg in 2011, to 3734 kg in 2013. Nearly all of the dairy cattle in province (97.7%) consisted of culture and cross-breed (Turk Stat, 2014b).

Dairy cattle activities have a great role at farm management as regards using the labour and feed sources more efficiently and providing a balanced cash flow (Oktay, 1988; Schaik *et al.*, 1996; Shamsuddin *et al.*, 2006). Moreover, dairy cattle have a special place in alleviating the migration from rural to urban areas (Yildirim and Sahin, 2003), constructing a balanced development among the regions (Tandogan, 2006) and promoting the establishment and improvement of dairy factories in the region, thus contributing to employment (Yildirim and Sahin, 2006).

This study primarily aimed at determining how to organize the inputs to be cost efficient to maintain the given level of output (gross production value per cow) for surveyed dairy farms. For this purpose, the technical, allocative and economic efficiencies of farms were calculated using Data Envelopment Analysis.

MATERIALS AND METHODS

The data were collected from 43 dairy cattle farms among 96 farms, which were associated to Agricultural Development Cooperative in Erikler Village of Center Town of Kirklareli Province in Western Turkey through the questionnaires. The physical input and output data of 2006 were converted to dollar values using price indexes.

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Data Envelopment Analysis (DEA), was used in determining the efficiency scores of surveyed dairy cattle farms. DEA is considered as a technique based on linear programming aiming at measuring the relative performances of decision units when the comparison is difficult due to the inputs and outputs with different measurement units or more than one inputs and outputs are measured with different scales. The relative efficiency of a decision unit is described as the ratio of total weighted outputs to total weighted inputs and called as technical efficiency (Külekci, 2014).

DEA is one of the most popular methods for estimating the best-practice production frontier and provides an analytical tool for determining effective and ineffective performances. It is preferred because it demands less data and works with relatively small simple sizes compared to stochastic models such as SFA (Johansson, 2005; Gunduz *et al*., 2011).

DEA approach has been extensively applied in agriculture to measure the productive efficiency of production entities (Mugera, 2013). Some studies investigating the cost efficiency of dairy cattle farms are (Bailey *et al.*, 1989; Fraser and Cordina, 1999; Jaforullah and Whiteman, 1999; Hambrusch *et al.*, 2006; Balcombe *et al.*, 2006; Hansson, 2007; Uzmay *et al.*, 2009; Günden *et al.*, 2010; Ayale and Beatrice, 2010; Aldeseit, 2013; Mugera, 2013).

Data envelopment analysis (DEA) are applied as constant return to scale, which was put forward by Charnes *et al.* (1978) and variable return to scale developed by Banker *et al*. (1984). Data envelopment models can be classified into two groups as input-oriented and output oriented. In this study input-oriented model was used. This model calculates the optimal input combinations to obtain a given output combinations (Charnes *et al*., 1981). The formulation of model is as follows: (Cooper *et al*., 2004), where,

$$E_k = \min \alpha - (\varepsilon \sum_{i=1}^{m} S_i^-) - (\varepsilon \sum_{r=1}^{t} S_r^+) \quad (1)$$

$$\sum_{j=1}^{n} (I_{ij}\,\mu_j) + S_i^- - (\alpha I_{ik}) = 0 \quad (2)$$

$$\sum_{j=1}^{n} (O_{rj}\,\mu_j) - S_r^+ - (O_{rk}) = 0 \quad (3)$$

$$\mu_j, S_i^-, S_r^+ \geq 0$$

$$r = 1, \ldots\ldots t;\ i = 1, \ldots\ldots, m;\ \sum \mu_j > 0$$

E_k The efficiency of kth decision unit
O_{rk}: r th output produced by k decision unit
I_{ik}: i th input used by k th decision unit
O_{rj}: r th output produced by j th decision unit
I_{ij}: i th input used by j th decision unit
ε : a sufficiently small positive number
n: number of decision units
t: number of output
m: number of input
α : contraction coefficient of input
s_i^- : The idle value of i th inputs of k decision unit
s_r^+ : The idle value of r th output of k decision unit
μ_j : Concentration value of j th of decision unit

At goal function of this model, the investigation is directed to how much the inputs of kth decision unit, whose efficiency is measured, could be organized to obtain a given output. If the related decision unit is efficient, the result would be as follows:

$$\alpha = 1,\ S_i^- = 0,\ S_r^+ = 0,\ \mu_j = 1,\ E_k = 1$$

If the measured decision unit is not efficient, á concentration coefficient would be smaller than 1 and the µ of reference units that form the institutional decision unit would be bigger than 0. In case the related decision units are not efficient, the input and output values of institutional decision unit could be made efficient by calculating them as follows:

$$I^{KB} = \sum_{j=1}^{n} (I_{ij}.\mu_j) \quad \text{Or} \quad I^{KB} = (\alpha.I^K) - S_i^- \quad (4)$$

$$O^{KB} = \sum_{j=1}^{n} (O_{rj}.\mu_j) \quad \text{Or} \quad O^{KB} = O^K + S_r^+ \quad (5)$$

In our study, the output was gross production value per cow ($). The inputs (six inputs) used were dry weed (kg), straw (kg), concentrated feed (kg), family and hired labour (hour), veterinary costs ($) (included all costs related to animal health) and the other variable costs ($), (included the electricity, water and matting sill etc.).

RESULTS AND DISCUSSION

The average input quantities used and the obtained production values per cow are presented at Table 1.

Nearly the third of dairy cattle farms (32.56 %) falls under 0.81-1.00 technical efficiency (TE) followed by 25.58, 23.25 and 18.60 % of farms which are categorized under 0.41-0.60, 0.20-0.4 and 0.61-0.80 technical efficiencies, respectively (Figure 1).

The average efficiency score calculated for the farms and the efficient farms percentages are presented at Table 2. The overall technical efficiency calculated under the assumption of constant return to scale was 0.66 and these farms consisted of 23.26% of total farms. The pure, technical and scale efficiency values calculated under the variable return to scale assumption was 0.87 and 0.76, respectively. The farms with these efficiency values consisted of 39.53 and 23.26% of total farms, respectively. If the scale efficiencies were reached at maximum in surveyed farms, it would have been possible to increase the technical

Table 1: Gross production value and the major inputs used per cow

Characteristics	Minimum	Maximum	Mean	Standard deviation
Gross production value ($)	777.97	7853.50	2289.36	1104.16
Dry weed (kg)	196.80	2219.40	715.80	445.65
Straw (kg)	1388.83	15001.50	4052.07	2395.48
Concentrated feed (kg)	500.05	6000.60	2901.53	1488.32
Labour (hour)	124.20	2342.08	477.21	359.02
Veterinary costs ($)	58.27	699.30	198.50	118.85
Other variable costs ($)	56.82	440.56	144.87	90.10

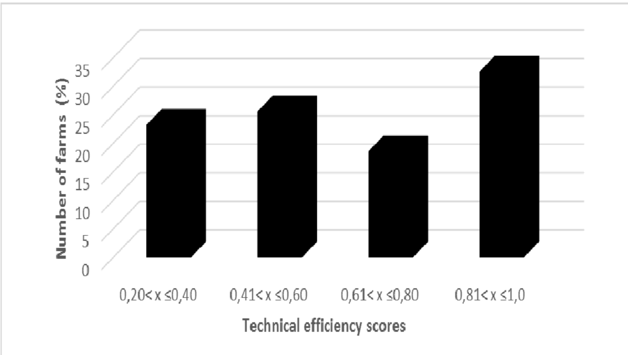

Fig 1: The relationship of number dairy cattle farms as percentages and technical efficiency scores

efficiencies from the current level of 0.66 to 0.87, which means 0.21 improvements.

The overall technical efficiency (0.66) was lower than that of 0.89 and 0.79 calculated for dairy cattle farms in Swedish and USA respectively (Tauer, 1993; Hansson, 2007), but similar to the values (0.65) calculated for dairy cattle farms in Australia (Balcombe *et al.*, 2006). On the other hand, as the overall technical efficiency calculated for dairy cattle farms in Turkey was similar to (0.62) (Günden *et al.*, 2010) our findings, the reported same figure of 0.488 and 0.217 for East African Countries and Jordan, respectively, were fairly lower (Ayele and Beatrice, 2010; Aldeseit, 2013) than that of our calculations.

Under the constant return to scale assumption, the average allocative and economic efficiency was calculated as 0.43 and 0.26, respectively (Table 2). Only 2.33% of total farms reached both the full allocative and economic efficiencies simultaneously. The input levels used, management skills and milk prices are considered the major factors affecting the low ratio. The economic efficiency (0.263) was lower than that of 0.692, 0.645 and 0.488 calculated for dairy cattle farms in Australia, Swedish and Turkey (Balcombe *et al.*, 2006; Hansson, 2007; Günden *et al.*, 2010) respectively. Nearly three quarter of farms (77.76%) had the increasing return to scale while the remaining 23.26% of farms had constant return to scale. The reported same ratios for dairy farms were 9.0 and 18.0% in Australia, (Hambrusch *et al.*, 2006), 28.7 and 9.2% in Turkey (Günden *et al.*, 2010), and 19.0 and 17.0% in New Zealand (Wei, 2014), respectively. The farms with constant return to scale had nearly two times higher gross production value per cow than the farms with increasing return to scale (US $ 2590 against US $ (Table 3).

The efficient dairy cattle farms obtained 85.48% higher gross production value per cow compared to inefficient farms by expending more by 17.6, 16.7, and 1.8 and 1.6% on dry weed, concentrated feed, straw and other expenses (included electricity, water and matting sill etc.), respectively, while saving veterinary and labour costs by 2.0 and 15.0%, respectively (Table 4).

Table 2: Technical, scale, allocative and economic efficiency measures

Efficiency measures	Mean	Standard deviation	Efficient farms (%)
Overall technical efficiency	0.661	0.254	23.26
Pure technical efficiency	0.867	0.157	39.53
Scale efficiency	0.759	0.229	23.26
Allocative efficiency	0.432	0.128	2.33
Economic efficiency	0.263	0.159	2.33

Table 3: Gross production values for different scales

	Number of farms (%)	Gross production values ($ per Cow)
Constant return to scale	23.26	2590.12[a]
Decreasing return to scale	0.00	0.00[b]
Increasing return to scale	76.74	1457.94[b]

[a, b] Significant by Mann-Whitney U test for *P<0.05.

Table 4: Comparison of efficient and inefficient dairy cattle farms

	Efficient farms	Inefficient farms
Gross production value ($)	2590.12	1457.94
Number of cows (Number)	8.30	4.85
Dry weed($)	323.26	392.43
Straw($)	2099.99	2139.65
Concentrated feed ($)	1321.93	1587.20
Labour($)	278.93	242.40
Veterinary cost ($)	228.02	189.55
Other variables costs ($)	143.12	145.41

Table 5: The comparison between current and optimum input levels per cow and possible changes

Inputs	Input use		
	Current	Optimum	Change (%)
Dry weed (kg)[a]	715.80	382.51	46.56
Straw (kg)[a]	4052.06	2158.72	46.72
Concentrated feed(kg)[a]	2901.53	1655.16	42.96
Labour (hour)[a]	477.21	261.53	45.20
Veterinary costs ($)[a]	198.50	119.45	39.82
Other variables costs ($)[a]	144.87	77.17	46.73

[a] Significant by Mann-Whitney U test for P<0.05

The current and optimum input quantities used to obtain the gross production value are presented at Table 5. The current gross production value per cow could be maintained by using 46.56, 46.72, 42.96, and 45.20% less inputs of dry weed (kg), straw (kg), concentrated feed (kg), and labour (hour), respectively along with 39.82 and 46.73% less veterinary and the other expenses, respectively (Table 5).

CONCLUSION AND SUGGESTIONS

The calculated overall technical (0.66), pure (0.87) and scale (0.76) efficiencies suggest that in case the scale efficiencies is ensured at full, technical efficiencies could be increased by 0.21 point. Taking into consideration the allocative (0.43) and economical (0.26) efficiencies, It could be concluded that the production costs could be decreased by 74% provided that the inefficient farms turn into efficient ones.

The big gap between the current and optimum input uses showed that the farms have the possibility to decrease their costs by nearly half of their current costs. The lack of correct knowledge about the input uses among some producers could possibly be one of the main obstacles against the efficient input uses. The knowledge regarding the production techniques are also required along with efficient input uses.

The study concludes that the managers of the inefficient farms should be trained on optimum input use per unit (per cow) and the efficient production techniques suitable to their working conditions. This could lead to not only income increase of farms but also the saving inputs which could otherwise have alternatively been used to increase the production levels that contribute to the prosperity of consumers.

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