Assessing pure technical efficiency of dairy farms in Turkey

Hodnocení čisté technické efektivnosti mléčných farem v Turecku

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Abstract: Compared with results from other studies of dairy farm production in developing countries, this study finds that the samples of 132 dairy farmers in Burdur province, Turkey, are producing at a low level of technical efficiency. Using Data Envelopment Analysis, technical efficiency ranges from 28.6 to 100.0%, with the average being 64.2%. Forage feed and labor inputs are used most inefficiently. A statistically significant, positive relationship between a herd size and efficiency underscore the importance of larger herd size to catch benefit of scale economics. This study also finds no statistically significant relationship between contact with extension and the degree of farm production efficiency. In contrast to expectation, negative and statistically significant relationship was found between forage feed land size and production efficiency.

Key words: pure technical efficiency, dairy farms, data envelopment analysis (DEA)

Abstrakt: Ve srovnání s výsledky jiných studií zaměřených na mléčné farmy v rozvojových zemích autoři dochází na základě výzkumu vzorku 132 mléčných farem v provincii Burdur v Turecku k závěru, že jejich technická efektivnost je nízká. Technická efektivnost zjištěná metodou Analýzy obalu dat se pohybuje v rozmezí od 28,6 do 100,0 % s průměrnou hodnotou 64,2 %. Inputy práce a objemných krmiv jsou využívány velmi neefektivně. Statisticky významná pozitivní závislost mezi velikostí stáda a efektivností podtrhuje význam většího stáda pro využití ekonomického efektu. Nebyl shledán žádný statisticky významný vztah mezi využitím poradenských služeb a produkční efektivností farmy. V protikladu k předpokladům byla prokázána negativní statisticky významná závislost mezi výměrou půdy pro pěstování objemných krmiv a produkční efektivností.

Klíčová slova: čistá technická efektivnost, mléčné farmy, Analýza obalu dat (DEA)

The Turkey dairy sector has historically been one of its most important farm sectors in the terms of value added and employment. However, a decline has characterized the Turkey dairy sector in the recent years. The number of dairy cows has decreased from 5.9 million in 1990 to 4.3 million in 2007, or by 27% (FAO 2007). This decline has been reflected on the dairy farms exit from the sector. To help its dairy sector to cope with this exit, Turkey has adopted various public policies. They include a milk premium, a livestock headage payment and a roughage feed support. Because Turkey is seeking the admission to the European Union, these policies have come under review as Turkey aligns its agricultural policy with the EU agricultural policy. In addition, the World Trade Organization rules require countries to reduce their

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trade barriers, including their custom level. These policy changes are likely to exacerbate the historical economic pressures that have been developed over the last quarter century for the Turkey's dairy industry. Improving the dairy sector economic efficiency, thus becoming more competitive and improving its chances to survive the competition not only from the EU but also the rest of the world, should be the main goal.

Numerous studies have examined the dairy production efficiency in both developed and developing countries. Recent studies include Bailey et al. (1989), Fraser and Coridna (1999), Mbaga et al. (2002), Sharma and Gulati (2003), Dalton (2004). The studies have examined the profitability and characteristics of dairy farms in Turkey (Erkus et al. 1987; İnan 1989; Bal and Yildirim1999; Erdogan et al. 2004; Yavuz et al. 2004). However, to the authors' best knowledge, no study has examined the production efficiency of dairy farms in Turkey. Given the lack of studies of production efficiency, the competitive pressures confronting the Turkey dairy sector, and the importance of the dairy sector in Turkey, this study examines the production efficiency of dairy farmers in the Burdur province, Turkey.

The rest of the paper is laid out as follows. The next section contains a discussion of the data collection and sampling process. The general methodology and the specific methodology, the Data Envelopment Analysis (DEA), used in this study, are discussed in the methodology section. It is followed by discussion of the empirical results. The paper ends with conclusions and implications for dairy farmers in Turkey and for the Turkey farm policy.

MATERIAL

The data used in this study were collected through personal interviews with dairy farmers in the Burdur Province, Turkey, during the spring of 2004. This area was selected because milk production and processing are important activities there and 46% of farm income comes from the dairy sector, which is much higher than the average (32%) of Turkey (SIS 2003).

A two stage sampling process was used. In the first stage, 18 villages in the Burdur, Bucak and Yeşilova Counties were identified through communication with the Directory of Agriculture in the Burdur Province. Given the farms record of the Directory of Agriculture, 80% of the dairy cows in the Burdur Province are located in these counties. The farmers in the 18 villages formed the population for this study. In the second stage, 138 farmers from 18 villages were chosen for interviews using a stratified random sampling procedure. The sample was stratified by the herd size. Useable interviews were obtained for 132 farms, which form the data set for this study. The sampling parameters are presented in Table 1.

A wide range of socio-economic and business characteristics were elicited in the interview. They include the number of cows, the amount of milk produced, the major dairy inputs (feed, labour, and capital), hectares of the cultivated land, hectares of fodder crops, the farm operator's education and experience, the contact with the extension, the membership in cooperative and producer organizations. These variables have been included in the previous studies of production efficiency (Bailey et al. 1989; Bravo-Ureta and Rieger 1991; Mbaga et al. 2002; Binam et al. 2004). The only variable included in these studies not included in the regression analysis was the age of the farmer. The reason is that the theoretical arguments and empirical findings are mixed. *A priori,* older farmers have acquired more human capital through their experiences, but they also may be less willing to adopt new ideas. Abdulai and Hufman (1998) found that older rice farmers in Northern Ghana were less efficient than younger farmers. Coelli et al. (2002) found that younger rice farmers in Bangladesh were more efficient than the older rice farmers. Binici et al. (2006) found that age has no statistically significant effect on the cotton farms technical efficiency in Turkey.

Descriptive statistics of the variables are presented in Table 2. The dairy herd varied in size from 1 to 48 cows, with an average of 10 cows. The input use varied substantially, with the maximum use being at least 11 times the minimum use for each of the four major input categories.

Table 1. Sampling parameters of the examined dairy producers

Herd size (cows)	Farmer population	Farmers sampled	Distribution of the sampled farmers (%)
1–5	1 022	54	41
6–10	640	43	33
11+	554	35	26
Total	2 216	132	100

Table 2. Characteristics of the surveyed dairy producers

Variable	Mean	Standard deviation	Minimum	Maximum
Herd size (number)	10	9	1	48
Annual milk production (kg/cow)	2 111	899	340	6 750
Concentrated feed (kg/herd)	1 570	574	225	4 500
Roughage feed (kg/herd)	1 796	1 130	2	6 525
Human labour (man-days/herd)	30	17	6	91
Farm capital (new Turkish lira/herd)	4 019	2 414	1 610	18 100
Fodder crop (ha)	26	24	0	141
Education attainment (years)	6	2	0	15
Experience (years)	17	9.23	1	40
Use of individual feeding system (%)	62			
Contact with extension (%)	66			
Cooperative member (%)	100			

METHODS

Farell (1957) developed the first theoretical treatment of production technical efficiency. The standard methodology for measuring farm level production efficiency is to estimate a production frontier that envelopes all the input/output data available for the analysis. Within this context, the technical efficiency of a farm is measured relative to the input/output performance of all other farms in the sample (Fraser and Cordina 1999). Farms located on the production frontier are considered efficient. Farms located inside the frontier are considered inefficient because they are generating less output that is feasible given the level of inputs. Production efficiency of inefficient farms is measured as the relationship between the observed output and the output that could be obtained if the farm produced on the frontier, given its observed level of inputs.

The two most commonly-used empirical procedures for examining production efficiency are (1) Stochastic Production Frontier (SPF) analysis (Aigner et al. 1977; Meeusen and van den Broeck, 1977) and (2) Data Envelopment Analysis (DEA) (Charnes et al. 1978). Both are based on the Farell's (1957) seminal paper and estimate a production frontier.

The DEA uses mathematical programming techniques to generate a maximum performance measure for each farm relative to a composite farm derived from the other farms in the data set (see, for example, Charnes et al. 1978; Yin 1998; Sharma et al. 1999). The DEA is popular because it allows multiple inputs and outputs and because it provides insights into the type and magnitude of adjustments an inefficient farm needs to make to become efficient (Fraser and Cordina 1999). The DEA is criticized because it is deterministic and thus does not allow for the impact that measurement error and other noise can have on the estimated frontier (Schmidt 1985; Coelli 1995; Sharma et al. 1999).

The SPF, on the other hand, allows for the stochastic noise when estimating a production frontier. Statistical tests also can be performed regarding the structure of production and the degree of inefficiency (Sharma et al. 1999). Conclusions can be drawn from the statistical tests concerning the changes the firm can make to improve its production efficiency and the causes of inefficiency that are beyond its control. A limitation with the SPF is that the researcher cannot specify a specific functional form for the frontier or a specific distributional form for the error term. If either is not known, the non-parametric DEA approach has an advantage because it avoids the statistical problems that can arise from assuming an incorrect functional form or an error term distribution. Given the lack of previous studies to assist in specifying the appropriate production function and the error term distribution for dairy production in Turkey, the DEA was chosen for this study.

Data envelopment analysis for dairy production

This discussion on the DEA models is relatively brief, with little technical detail. An extensive discussion and technical details are is available in Charnes et al. (1978), Seiford and Thrall (1990), Lovell (1993) and Ali and Seiford (1993). The DEA first estimates an envelopment surface using data from all farms in the data set. Two basic types of envelopment surfaces can be estimated. One is referred to as a Constant Return to Scale surface (CRS); the other is referred to as a Variable Return to Scale (VRS) surface (Charnes et al. 1978).

The performance of each farm then is evaluated relative to the envelopment surface. The measure of the relative farm performance is called the Global Technical Efficiency, if the CRS surface is estimated (Iraizoz et al. 2003) and the Pure Technical Efficiency (PTE), if the VRS surface is estimated (Llewelyen and Williams 1996; Iraizoz et al. 2003).

When estimating a CRS surface, farms are assumed to be operating at their optimal level of scale. However, it is widely recognized that several factors, including imperfect competition and financial constraints, can cause farms to operate at less than their optimal scale (Coelli 1995). A lack of scale efficiency will likely result in the Global Technical Efficiency being measured with an error (Coelli 1996). The possibility cannot be ruled out that the scale efficiency does not exist for the farmers who were surveyed for this analysis. Thus, a VRS surface is estimated and the Pure Technical Efficiency (PTE) is measured.

PTE of a decision-making unit, in our case a farm, is calculated by solving the following model:

$$Min_{\Theta,\lambda}\Theta_j \tag{1}$$

$$\sum_{j=1}^{132} Y_{c,j}\lambda_j \geq Y_j \tag{1a}$$

$$\sum_{i=1}^{4} X_{i,j}\lambda_j \leq X_j\Theta_j \tag{1b}$$

$$\sum_{j=1}^{J} \lambda_j = 1 \tag{1c}$$

$$\lambda_j \geq 0$$

$$X_I, Y_J \geq 0$$

where $Y_{c,j}$ is the amount of milk produced by farm *j*; $X_{i,j}$ is the amount of input *i* used by farm *j*. There are 132 dairy farms in the sample; information is available for 4 inputs. λ_j is farm *j*'s weight used to develop the composite dairy farm based on all dairy farms in the sample. Farm *j*'s performance is measured against the composite dairy farm. The constraint (1a) states that the milk production associated with the composite farm ($Y_{c,j}$) is at least as large as the cotton produced by the farm *j*. Constraint (1b) states that the weighted average of inputs associated with the composite farm ($X_j\theta_j$) is no larger than the amount of input *i* used by the farm *j*.

θ_j is farm *j*'s PTE score (Iraizoz et al. 2003). It is less than or equal to 1, with 1 indicating that the farm lies on the VRS envelopment surface. The farm thus is technically efficient and cannot reduce its observed combination of inputs without reducing its output of cotton. A PTE score of less than 1 indicates the farm is technically inefficient. This score can be interpreted as the amount by which the farm can reduce its combination of inputs while still producing the same level of output. For this study, the statistical package used to obtain the PTE scores is FRONTIER Analyst (Version 2.0.0).

RESULTS AND DISCUSSION

Pure technical efficiency

The distribution of PTE scores for the 132 sampled dairy farms is presented in Table 3. 18% of the farms had PTE scores of 90% or higher, including 13.6% of the farms with the PTE score of 100%. The lowest PTE score was 28.6%. The mean PTE score was 64.2%.

Compared with other studies of dairy technical efficiency, dairy farmers in the Burdur province exhibit a low degree of technical efficiency. The average technical efficiency was estimated to be 83% for a sample of U.S. (New England) dairy farms (Bravo-Ureta and Rieger 1991), 92% to 95% depending on the type of production function specified for a sample of Canadian (Quebec) dairy farmers (Mbaga et al. 2002), 77% for a sample of Ecuadorian dairy farms (Bailey et al. 1989), and 79% and 84% for a sample of dairy farmers in Northern and Western regions of India, respectively (Sharma and Gulati 2003). In contrast to the above studies, our results are in line with Finland livestock farmers, who have 64% of mean technical efficiency level (Lansik et al. 2002).

Results from the DEA analysis can be used to determine how much a farm's technical efficiency can be improved by reducing the given input while maintaining output.

For the surveyed dairy farmers as a group, all four major used inputs, concentrated feed, forage feed, labour, and capital, can be reduced by 15.36, 24.56, 26.50, and 13.58% respectively, while maintaining the same level of milk production. It implies that the inputs were used with a rather high degree of inefficiency (Table 4).

Table 3. Distribution of the farm level measures of pure technical efficiency

Degree of pure technical efficiency (%)	Number of dairy farms
Equal to 100	18
90.0–99.9	6
80.0–89.9	12
70.0–79.9	10
60.0–69.9	17
50.0–59.9	28
40.0–49.9	18
30.0–39.9	18
20.0–29.9	5
Less than 20	0

Table 4. Potential improvement of pure technical efficiency

Input	Potential improvement in pure technical efficiency (%)
Concentrated feed	15.36
Forage feed	24.56
Labour	26.50
Capital	13.58

Factors associated with technical efficiency

Two approaches have been used to analyze the relationship between the firm specific attributes and the degree of production efficiency. One approach is a two-step procedure. It involves first estimating the efficiency scores, then regressing these scores against the firm specific attributes (Sharma et.al. 1999). The second approach is to incorporate the firm specific attributes into the estimation of the production frontier (Sharma et.al. 1999). While Kalirajan (1991) and Ray (1988) advocate the two-step procedure, others (Kumbhaker et al. 1991; Battese and Coelli 1995) advocate the second approach.

The primary argument for incorporating the firm specific attributes into the estimation of the production frontier is that the firm specific attributes directly impact efficiency. On the other hand, this approach requires *a priori* knowledge of whether the attribute has a positive or negative relationship with technical efficiency (Sharma et al. 1999; Coelli et al. 2002). Given the lack of previous investigations of the technical efficiency of dairy production in Turkey, the two-step procedure is used.

The following regression equation is used to examine the relationship between the farm-specific attributes and the PTE:

$$PTE_j = \beta_0 + \beta_1 z_{j1} + \beta_2 z_{j2} + \beta_3 z_{j3} + \beta_4 z_{j4} + \beta_5 z_{j5} + \\ + \beta_6 z_{j6} + \varepsilon_j \quad (2)$$

PTE_j is the farm *j*'s Pure Technical Efficiency score. Z_{1i} is a binary variable equal to one if the farmer had a degree higher than elementary school, and to zero otherwise. This dummy variable specification for education reflects the recent works of Weier (1999) and Binam et al. (2004). They argue that a threshold effect exists. Specifically, at least four years of schooling are needed before education impacts the production efficiency. Their threshold argument is operationalised in this study by using a dummy based on whether or not the farmer has completed the elementary school. Z_{2i} is experience, the numbers of year involved in the dairy business. Z_{3i} is a binary variable equal to one if the farmer contacted an extension officer in the past year and to zero otherwise. Z_{4i} is the number of cows. Z_{5i} is the ratio of forage feed land to the total farm land. Z_{6i} is a binary variable equal to one if the farmer used an individual feeding system and to zero otherwise. Because all the sampled farmers were members of the Agricultural Sale Cooperatives, this variable has not been included in the regression equation.

The estimated results derived from equation 2 are reported in Table 5.

Education is measured through the use of dummy variable of those who have the elementary school and a higher degree versus those who have not. As expected, education is positively associated with efficiency, but it is statistically insignificant. Similar results were reported for farmers in Bangladesh (e.g. Wadud and White 2000; Rahman 2004), Ethiopia (Weier 1999), and Cameroon (Binam et al. 2004). Conceptually, education improves the skill and entrepreneurial ability of the farmer to organize inputs for the maximum efficiency. However, Joshi (2001) argues that the gains from education are higher in the modernized agriculture than in the traditional agriculture. The findings in this study are consistent with Joshi's argument.

Economists have long recognized the effect of learning and experience on the firm decisions. Hence, the number of years is hypothesized to have a positive impact on dairy farms. It has the expected sign but is not statistically significant. A similar conclusive relationship was found for the ratite industry in U.S. (Gilespie et al. 1997), swine production in Hawaii

Table 5. Maximum-likelihood estimates of variables associated with pure technical efficiency

Variable	Parameter	Coefficient	*t*-ratio
Constant	β_0	–0.245	–3.035
Education	β_1	0.1057	0.796
Experience	β_2	0.0025	0.798
Contact with extension	β_3	–0.0381	–0.606
Total herd size	β_4	0.0316	3.388*
Forage feed land	β_5	–0.0051	–3.017*
Feeding type	β_6	0.0645	1.100

*Significant at the 5% level

(Sharma et al. 1999), rice farmers for Aman (wet) season in Bangladesh (Coelli et al. 2002).

The contact with an extension officer during the past year was negatively related to the dairy farm efficiency but was statistically insignificant. This finding is consistent with the findings of Feeder et al. (2004), Binam et al. (2004) and Rahman (2004). Each of the studies involved farmers in developing countries. The inability to find the correct sign and statistical significance has been attributed to the bureaucratic inefficiency, the deficiency in program design, (Feeder et al. 2004; Binam et al. 2004) and the use of a "top-down" instead of participatory approach (Braun et al. 2002). The Turkey's extension program has been characterized by a top-down approach (Aktaş 2004). The lack of a participatory approach may explain the insignificance of the Turkey's extension program in this analysis of dairy farm efficiency.

Previous studies have found that the herd size is positively related to efficiency (for example, see Bailey et al. 1989; Bravo-Ureta and Rieger 1991; and Tauer 2001. This study finds the same relationship and it is significant at the 95% level of statistical confidence.

The number of hectares of fodder crops is statistically significant but it has not the expected sign. Farmers who harvest larger acreages of fodder crops may use too much roughage in their feed rations, because it is available. However, the proper nutritional balance between feed concentrates and roughage feed is widely recognized as a key to attaining production efficiency (Andersen et al. 1986; Bailey et al. 1989).

In the study area, two types of feeding systems are used. In one system, the cows are fed individually. In the other system, the cows are fed as a group. The use of an individual feeding system was associated with achieving a greater degree of efficiency, but it is statistically insignificant.

CONCLUSION AND POLICY IMPLICATIONS

The Data Envelopment Analysis was used to analyze the technical efficiency of a sample of 132 dairy farmers located in the Burdur Province, Turkey. Compared with other studies of dairy farm production in developing countries, these dairy farmers were producing at a low level of efficiency with the mean of 65.2%. Only 13.5% of the dairy farms were using efficient levels of inputs. Concentrated feed and capital were used more efficiently compared to both forage feed and labour inputs. In average, all four major used inputs, concentrated feed, forage feed, labour and capital, can be reduced by 15.36, 24.56, 26.5, and 13.58% respectively, while maintaining the same level milk production. This finding suggests that extension programs should target these four inputs. Improving dairy production efficiency would improve both the profits of dairy farmers and the Turkey's international competitiveness in the dairy sector. Consumers also would benefit by paying lower prices for dairy products.

Two statistically significant factors associated with the variation in production efficiency are identified. One is the size of the forage feed which has a negative impact on efficiency. It means that most farmers use forage feed instead of concentrated feed. The other one is a larger herd size, which has a positive impact on efficiency. It has been found that there is a positive relationship, as expected, between the individual feeding system and efficiency. However, it is not significant.

Increasing the herd size is potentially attainable, although it implements costs. Allowing larger dairy farms to emerge requires that the policy makers either to acquiesce to the market forces, which will cause dairy farms to get larger, or to develop a program to help small dairy producers to adjust by getting larger, by developing niche markets, or by quitting, including the potential use of public funds to pay an exit bonus.

Using the right ratio of forage and concentrated feed could become the centrepiece of a national education campaign to improve the dairy herd production efficiency. However, this study also finds no statistically significant relationship between the contact with extension and the degree of farm production efficiency. A potential explanation for this finding is that the Turkey's extension program uses a top-down approach as opposed to a participatory approach. The top-down approach may fail to capture the attention of Turkey's farmers, especially the most efficient producers. Thus, the success of a national education campaign to raise the awareness of the value of an individual feeding system may require a revamping of the Turkey's extension program. If this option is deemed infeasible by the policy makers, an alternative may be the creation of a dedicated program using other delivery mechanisms

The scope of this study is limited since it investigates only the efficiency of dairy farms in the Burdur Province of Turkey. These limitations underline the need to conduct further work in different regions in order to verify the robustness of the findings of this study.

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