Iranian Journal of Veterinary Research, Shiraz University, Vol. 9, No. 4, Ser. No. 25, 2008

The effects of veterinary services on technical efficiency of dairy farms in Iran: a DEA approach

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(Received 10 Mar 2008; revised version 18 May 2008; accepted 26 May 2008)

Summary

The aim of this study is to investigate the context by which veterinary services may affect technical efficiency (TE) of Iranian dairy farms. A data envelopment analysis (DEA) was applied to a random sample of 840 dairy farms from six provinces across Iran to estimate regional frontier and metafrontier production functions and also to calculate corresponding TE of these farms. The relationship between the levels of veterinary services and TE scores were then examined using correlation analysis, t-test, and analysis of variance (ANOVA). The results indicated that mean technical efficiency estimated based on the regional frontier production function for selected provinces varies between 0.720 and 0.867 while ranges between 0.445 and 0.595 when evaluated based on the metafrontier production function. Also, our findings showed that veterinary services have a positive effect on TE scores. This implies that TE can be improved by utilizing higher levels of veterinary services. Furthermore, access to more suitable veterinary services was recognized to be a major determinant of technical operation as was the case in Tehran.

Key words: Veterinary services, Efficiency, Metafrontier, DEA

Introduction

Technical efficiency (TE) can be defined as the ability of a decision-maker (e.g. a dairy farm manager) to produce maximum output given a set of inputs and technology. It is a well established fact that economic performance can differ considerably among dairy farms even if they are operating under more or less similar conditions. Difference in economic performances is attributed to difference in the efficiency of the firms. Therefore, technical efficiency, its measurement and determining factors are of crucial importance in production economic. In this context, the effects of veterinary services upon dairy farm efficiency are of interest for several reasons. First, farm managers are interested in knowing the relationship between technical efficiency and veterinary services to evaluate the influence of such services on production and, thereby, economic performance to evaluate the effects of implemented disease control options.

Some studies (Fourichon *et al*., 1999, 2000) assessed the impact of veterinary services and diseases on the profitability of milk production. In general, a clear function is not defined in the models behind these studies and the performance of dairy farms is measured by comparing estimated averages in contrast to potential or maximum output estimates. Farmers may use veterinary services in a number of ways and therefore, the effects of veterinary services need to be evaluated using a whole farm measure such as technical efficiency (Lawson *et al*., 2004b). A great deal of time and effort have been spent on measuring technical efficiency in dairy farms (Kumbhakar *et al*., 1989; Bravo-Ureta, 1990; Zibaei, 1995; Fraster and Cordian, 1999; Tauer and Lordkipandize, 1999; Bakhshoodeh, 2000; Harsh *et al*., 2001; Dalton, 2004). However, most of such efforts are limited to assess the impact of veterinary services or diseases on technical efficiency (Lawson *et al*., 2003, 2004a, 2004b). This paper contributes to the literature on measuring the technical efficiency and investigating the effects of

veterinary services on technical efficiency of dairy farms in Iran.

Methodological Framework

The basic method for measuring farm efficiency level is to estimate a frontier production function that envelops all the input-output data with those firms lying on the frontier curve being described as technically efficient. Any farm that lies below the frontier curve is considered to be inefficient. This farm could either reduce its input use whilst maintaining output or it could use the same amount of input and increase output. Differences in available stocks of physical, human and financial capital, economic infrastructure, and resource endowments have led efficiency researchers to estimate separate production frontier for different regions and different groups of firms. After estimating a frontier production function for a region, it is common and straightforward to measure the technical efficiency of firms within the region (e.g., Fars dairy farms) based on the regional frontier production function. However, frontier must be identical for efficiency comparisons across different regions (e.g., comparing efficiency levels in Fars dairy farms with Isfahan dairy farms). Therefore in this study, we measured efficiency relative to a common metafrontier. Metafrontier can be estimated using data envelopment analysis (DEA) or stochastic frontier analysis (SFA) (Battese and Rao, 2002; Rao *et al*., 2005). DEA was used to estimate technical efficiency because it does not require a parametric specification of a function form to estimate the frontier production function and it can also accommodate multiple outputs into analysis (Sharma *et al*., 1999).

Data envelopment analysis

If province k consists of data on L_K firms, a convex metafrontier can be identified using the DEA to the inputs and outputs of all $L = \sum_{k=1} L_k$ dairy farms in all studied provinces. The structure of metafrontier linear programming is as follows:

$$\max_{\phi,\lambda} \phi,$$

$$\text{such that} \quad -\phi y_i + Y\lambda \geq 0,$$

$$x_i - X\lambda \geq 0,$$

$$\lambda \geq 0,$$

Where

y_i: milk quantity for i-th firm;
x_i: N × 1 vector of input quantities for i-th firm;
Y: 1 × L vector of milk quantities for all L firms;
X: N × L matrix of input quantities for all L firm;
λ: L × 1 vector of weight

$1 \leq \phi < \infty$ is a scalar and $\phi - 1$ is the proportional increase in output achieved by i-th farm, with input use held constant. Therefore, $\frac{1}{\phi}$ that takes values between 0 and 1 is an estimate of the technical efficiency measure. To derive a set of N technical efficiency scores, the problem should be solved N times, one for each farm.

In practice, the tedious work of solving a different linear programming (LP) for every farm is usually undertaken using purpose-built software packages such as DEAP (Coelli, 1996b).

Above model can be used to construct a convex province-k frontier by applying the DEA model to the observed inputs and output of firms in a province.

Finally, having estimated the technical efficiencies of dairy farms with respect to the metafrontier and province frontier, it is straightforward to estimate the effects of veterinary services on technical efficiency using t-test, analysis of variance (ANOVA), and correlation analysis. Also, technology gap ratio (TGR) for province-k firms is calculated as:

$$TGR^k = \frac{TE}{TE^k}$$

Where, TE and TE^k are the technical efficiency with respect to the metafrontier and province-k frontier, respectively. This ratio shows the maximum output produced by a firm from province k as a percent of the output that is feasible using the metatechnology.

This ratio indicates the technical operation, and the studied provinces can be ranked based on their technical operation.

Data

The data used in this study consist of a sample of 840 dairy farms that were taken from a dairy farm census conducted by agricultural ministry of Iran in 2005.

The study covered six provinces (East Azarbaijan, Isfahan, Tehran, Khorasan, Fars and Yazd) that are the major milk producers of the country. These provinces produce roughly 44% of the Iran's milk output. The provinces included in the data set are evenly distributed over all the regions of Iran (East, West, North, Center and South). Since the application of DEA requires farms that their number of input and output variables must be kept at reasonable level, we consider five important input variables as follows:

X_1 = total number of cows in the herd
X_2 = quantity of concentrate fed to cows in kg
X_3 = quantity of forage fed to cows in kg
X_4 = labor force in person-day
X_5 = fuel costs in Rials.

and output variable is the milk output of the ith farm in liters (y_t).

Veterinary services expressed as their costs in this study fall into five main categories:

1- Breeding services (artificial insemination and pregnancy diagnosis)
2- Diagnostic services (laboratory diagnosis, postmortem and radiography)
3- Prophylactic services (deworming and vaccination)
4- Curative services (medical treatments, minor and major surgical treatments, gynecological and obstetrical treatments)
5- Miscellaneous services (livestock advisory services, distribution of fodder seedlings, on-farm consultancy services, etc.)

Results

Technical efficiency

The DEA estimates were obtained using Deap 2.1 (Coelli, 1996b). Average technical efficiency from regional frontier and metafrontier and technology gap ratio estimates for selected provinces are shown in Table 1. According to Table 1, for Tehran province, the average technical efficiency score is 0.757, indicating milk output is increased by about 76% of the potential, given its regional frontier. In other words, the technical efficiency score shows that the mean gap between the best producer and other producers is about 24% in Tehran. But the mean technical efficiency of this province is 0.566 when assessed based on the metafrontier. Therefore, technology gap ratio is 0.748 (0.566/0.757). This means that, given the input vector, the potential milk output for Tehran province is about 75% of that represented by the metatechnology.

Mean technical efficiency estimates based on regional frontier production function for selected provinces varies between 0.720 and 0.867.

Average technical efficiency for the studied provinces ranges between 0.445 and 0.595 when evaluated based on the metafrontier production function.

The highest mean technical efficiency based on both the regional frontier and metafrontier production function is devoted to Yazd while Isfahan has the lowest mean technical efficiency. Mean technology gap ratio for East Azarbaijan, Isfahan, Khorasan, Fars and Yazd are 0.606, 0.618, 0.664, 0.620 and 0.686, respectively. Therefore, DEA scores from metafrontier production function and technology gap ratio show that Tehran and Yazd have higher technical operation amongst the selected provinces. Also, results from regional frontier show that mean gap between the best producer and other producers is minimum in Yazd while it is maximum in Isfahan. The distribution of farm efficiency from metafrontier

Table 1: Technical efficiency and technology gap ratio estimates for selected provinces

Province	TE based on regional frontier		TE based on metafrontier		Technology gap ratio	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
East Azarbaijan	0.830	0.268	0.503	0.272	0.606	0.134
Isfahan	0.720	0.261	0.445	0.227	0.618	0.092
Tehran	0.757	0.208	0.566	0.210	0.748	0.054
Khorasan	0.771	0.219	0.512	0.226	0.664	0.063
Fars	0.781	0.220	0.484	0.212	0.620	0.106
Yazd	0.867	0.195	0.595	0.215	0.686	0.094

production function for studied provinces is presented in Fig. 1.

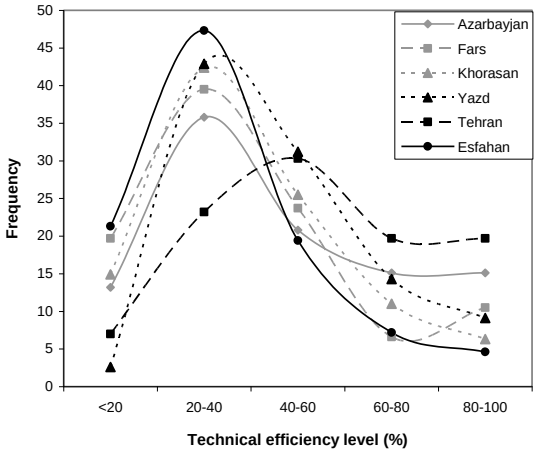

Fig. 1: Distribution pattern of technical efficiency estimates of dairy farms in selected provinces

The effects of veterinary services on technical efficiency

As presented in Table 2, the cost of veterinary services per dairy cow in the selected provinces varies between 113626 and 379672 Rials with a mean value of 172279.08 Rials. The results of ANOVA on the difference of the mean veterinary services cost among the studied provinces support the hypothesis that the provinces vary significantly in their mean veterinary services costs. The highest mean veterinary services cost comes from Tehran and the differences of the mean among other provinces are not statistically significant (Table 3).

The correlation analysis, t-test, and ANOVA were used in this study to investigate the relationship between technical efficiency and veterinary services. Pearson correlation coefficient between technical efficiency and veterinary services is positive (0.206) and significant at the 0.01 level (2-tailed). Most of the studied dairy farms (767 farms, 91.31%) used veterinary services and only 73 farms (8.69%) did not use such services in the studied year. The difference of the mean technical efficiency between these two groups is statistically significant $p<0.05$ (Table 4). Mean technical efficiency in group with veterinary services use is 0.434 that is more than group without veterinary services use (0.3745).

For the analysis of variance, sample farms were grouped into five categories based on their costs of veterinary services (Table 5). Then, ANOVA was used to test the hypothesis of the equality of mean technical efficiency. Results of ANOVA are presented in Table 6. As shown in this table, the means of groups are different enough not to have occurred by chance. Therefore, it is inferred that the independent variable (veterinary services) has a positive effect on the dependent variable (technical efficiency).

Table 2: Annual cost of veterinary services in the selected provinces

Province	Number	Annual cost of veterinary services per cow (Rials[1])	
		Mean[*]	Standard deviation
East Azarbaijan	53	157585.16[b]	222671.188
Fars	76	196658.81[b]	266346.655
Khorasan	255	123672.33[b]	161936.601
Yazd	77	117366.69[b]	206197.826
Tehran	142	379671.63[a]	376297.992
Isfahan	237	113625.71[b]	140250.819

[*]Grouping of statistically significant differences in means are indicated by different letters. [1]- 9220 Rials equal one US Dollar

Table 3: Analysis of variance on the difference of the mean veterinary services cost among the selected provinces

Source of variation	Sum of squares	Degrees of freedom	Mean square	F Ratio	Sig.
Between group	7.815 + 012	5	1.563 + 0.12	30.747	0.000
Within group	4.24 + 013	834	50838009590		
Total	5.02 + 013	839			

Discussion

How to satisfy the future demand for milk as a basic food is a vital question. This goal can be achieved by changing input use, accelerating appropriate technological change and improving efficiency. Since resources such as feedstuff are limited and considerable investment will be required to establish new dairy farms, improving the efficiency of existing dairy farms can be regarded as a more feasible way to meet the future demand for milk. Therefore, technical efficiency, its measurement and determining factors are of crucial importance in production economic. While technical efficiencies of firms obtained with respect to a given frontier are comparable, this is not normally valid case among firms that operate under different technologies. Such problem arises when comparisons of firms from different provinces, or regions of country are involved.

This study utilized concept of the metafrontier function to investigate regional differences in milk production technologies of Iran. Results of estimating regional frontier production function showed that mean technical efficiency for selected provinces varies between 0.720 and 0.867. This implies that, there are possibilities for either increasing total production of milk using the same inputs or decreasing input for the current level of milk production or a mixture of both by filling the gap between the best producer and other producers. This possibility is minimum in Yazd and maximum in Isfahan. It is worthwhile to compare these results with those found by Bakhshoodeh (2000). However, this comparison should be made cautiously because his TE scores for farms that operate under different technologies were obtained with respect to a given frontier using SFA while this study utilized concept of the metafrontier to investigate regional differences in milk production technologies, using DEA. Bakhshoodeh found the mean value of TE for Iranian dairy farms to be 0.83 that lies between the corresponding

Table 4: Results of t-test for equality of mean technical efficiency between groups with and without veterinary use

Groups	Number	Technical efficiency		T-test for equality of means			
		Mean	Standard deviation	t	Degrees of freedom	Sig. (2-tailed)	Mean Difference
Dairy farms used veterinary services	767	0.4336	0.235	2.049	838	0.041	0.0591
Dairy farms did not use veterinary services	73	0.3745	0.240				

Table 5: Association between the cost of veterinary services and technical efficiency

Groups	Number	Technical efficiency	
		Mean*	Standard deviation
0-150000	558	0.414[b]	0.226
150000-300000	159	0.412[b]	0.235
300000-450000	49	0.422[b]	0.215
450000-600000	25	0.490[ab]	0.252
>600000	49	0.623[a]	0.275
Total	840	0.428	0.236

*Grouping of statistically significant difference in means is indicated by different letters

Table 6: Analysis of variance on the difference of the mean technical efficiency among the veterinary services cost groups

Sources of variation	Sum of squares	Degrees of freedom	Mean square	F	Sig.
Between groups	2.117	4	0.529	9.911	0.000
Within groups	44.595	835	0.053		
Total	46.712	839			

indices calculated based on the regional frontier in this study. But, there are differences between Bakhshoodeh's finding and the TE scores obtained from metafrontier, because regional differences in milk production were excluded in his study. Also, Saboohy (1995) found the mean value of TE for dairy farms in Sepidan to be 0.71 that is close to the corresponding score computed based on Fars region in this study. Also, technology gap ratio (TGR) for the studied provinces ranges between 0.606 and 0.748. This ratio indicates the maximum output produced by a firm from province K as a percent of the output that is feasible using the metatechnology (we define the metatechnology as the totality of the regional technologies). Therefore, total production of milk can be increased considerably if firms use the metatechnology. The rank of studied provinces based on their technical operation is as follows: Tehran, Yazd, Khorasan, Fars, Isfahan and East Azarbaijan. There is difference between this finding and the result reported by Safavi (2002) because the rank of provinces in his study was based on regional frontier. While, frontier production function must be identical for efficiency comparisons across different regions. It has been shown that literacy, livestock training and education in technology adoption are significant determinants of farmer efficiency in milk production (Weir and Knight, 2005; Wubeneh and Ehui, 2006), therefore, the main reasons beyond the fact that Tehran province has the highest technical operation in comparison with other provinces are recognized to be educated farmers, access to more suitable veterinary services and a better dairy management.

The results of correlation analysis, t-test, and ANOVA support the hypothesis that veterinary services have a positive effect on technical efficiency in dairy farms. Therefore, it can be concluded that dairy farms which use high level of veterinary services are more technically efficient than the others. In other words, the level of efficiency of individual dairy farms in Iran can be improved by enhancing the use of veterinary services. This result is similar to those found by Lawson *et al*. 2004a.

Acknowledgement

This research was financially supported by grant No. 86-GR-AGR-4 from Research Council of the Shiraz University.

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