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Determinants of Technical Efficiency of Wheat Farming in Southeastern Anatolia, Turkey: A Nonparametric Technical Efficiency Analysis

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Abstract: This study analyses technical efficiency of wheat growing farms in Southeastern Anatolia in Turkey. Data were collected from farms through a questionnaire study carried out following 2000-2001 growing season. Analysis was accomplished in two steps. In the first step, technical efficiency scores were calculated using an input oriented Data Envelopment Analysis (DEA). In the second step, Tobit regression analysis was used to identify determinants of technical efficiency. Results indicate that there is considerable scope for cost reduction in wheat farming in the Region. Main determinant of technical inefficiency was determined to be land fragmentation.

Key words: Efficiency, data envelopment analysis, wheat farming, Turkey

INTRODUCTION

Wheat is an important part of daily diet of millions of people in the world. Being easily transported and stored and used to produce a large variety of foods, wheat is a strategic food in terms of food security.

In Turkey, traditional cereals have an important role in total agricultural production. Turkey is among major wheat producers in the world and has a significant place among the world's biggest cereal producing countries. Per capita consumption is also one of the World's largest-averaging about 260 kg per annum.

As a part of its free market policy, Turkey is trying to phase out existing support policies and limit role of state and state purchasing agencies in domestic markets.

Since Turkey is leaving traditional supporting policies, farmers are expected to operate under more competitive conditions and increase their efficiencies. Government is also in search of new policy tools during this period. Before all, existing level of efficiency and its determinants should be clearly appreciated.

Southeastern Anatolia is one of the major wheat growing regions of Turkey. Although considerable amount of researches were conducted during recent years in this region, they are mostly focused on econometric analyses and deriving production functions. This study approaches to the subject matter from a management perspective. The objective is to analyze determinants of productive efficiency and give some idea to policy makers for their future decisions on improving efficiencies.

MATERIALS AND METHODS

The data used in this study is a part of a broader survey accomplished to make economic analysis of farms in Southeastern Anatolia Region. In this survey, Adiyaman province was selected as a representative of Southeastern Anatolia Region. The choice of this particular province was based on a preliminary survey of major crops grown in the region. The survey provides detailed cross sectional information on revenues and production costs for the surveyed farms during 2000-2001 production period. Original sample covers many farms producing the major crops of the region: wheat, barley, cotton and lentils. One hundred and ninety three wheat growing farms were selected from this data set in order to analyze technical efficiencies.

Wheat is an important crop for the region. Shares of wheat in cropping pattern, value of agricultural production and value of crop production in the province are 49, 15 and 23%, respectively. (Anonymous 1999, 2001a, b).

Efficiency measurements are typically implemented by either parametric (econometric) or nonparametric (mathematical programming) models. Both models are based on calculating efficiencies of production units with respect to a constructed production frontier. In parametric models, a functional form (such as Cobb-Douglas or Translog) is assumed and parameters of the production function are determined statistically. In nonparametric approach, no functional form is assumed for the underlying production technology and a piecewise linear function is constructed from the observed data.

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DEA is a well known non-parametric production frontier estimation technique based on linear programming. It is used to measure relative efficiencies of a collection of firms or entities (called decision making units) in transforming their inputs into outputs. Its mathematical development can be traced to Charnes and Cooper (1978) who introduced their CCR model based on the works of Farrell (1957) and others. Banker *et al*. (1984) modified this model to account for variable returns to scale conditions by adding a convexity constraint and introduced their BCC model.

Original DEA specification has been extended in several ways and multi stage models were developed in order to handling slacks and to meet more strict Koopmans (1951) criteria, to identify the nearest efficient points and to make the model invariant to units of measurements. Coelli (1997) developed such a multi stage methodology and a computer program which implements a robust multi-stage model among other options.

An input oriented BCC model is given below for N Decision Making Units (DMU), each producing M outputs by using K different inputs (Coelli *et al*., 1998):

$$
\begin{aligned}
&\text{Min}_{\theta,\lambda} \quad \theta \\
&\text{subject to} \\
&-y_i + y\lambda \geq 0 \\
&\theta x_i - X\lambda \geq 0 \\
&N1'\lambda = 1 \\
&\lambda \geq 0
\end{aligned}
$$

where, θ is a scalar, N1' is convexity constraint and λ is N x 1 vector of constants. Y represents output matrix and X represents input matrix. The value of θ will be the efficiency score for the i-th firm. This linear programming problem must be solved N times, once for each firm in the sample.

An input oriented DEA model was chosen in this study since farmers are thought to have more control on inputs than they have on outputs. One output and six inputs were used in the DEA model. The only output is the wheat yield per unit area (ha). The inputs included are (a) amount of seed used in unit area, (b) pure nitrogen applied to unit area, (c) pure phosphorus applied to unit area, (d) total labor used (hours/ha) in wheat farming from land preparation through harvest (both family and hired labor), (e) total machinery working hours and (f) total pesticide costs. All explanatory variables are expressed as technical units, except pesticide costs. Summary statistics related to variables used in the analysis are given in Table 1.

It is quite usual to incorporate some kind of functional analysis with the DEA model in order to identify inputs playing a significant role (Shafiq and Rehman, 2000). Thus, a Cobb-Douglas type of production function was fitted to the data and results of this econometric estimation were given in Table 2.

Table 1: Summary statistics for variables used in the efficiency analysis

Input/Output Variables	Min.	Max.	Mean	SD[a]
Output :				
Wheat yield (kg ha^{-1})	600.0	4200.0	1416.0	727.0
Inputs :				
Seed (kg ha^{-1})	86.0	297.0	209.45	68.74
Fertilizer-N (kg N ha^{-1})	0.00	328.44	77.04	59.68
Fertilizer-P (kg P_2O_5 ha^{-1})	0.00	257.07	41.86	40.49
Labor (h ha^{-1})	9.08	367.93	119.09	105.47
Machinery (h ha^{-1})	1.87	253.17	22.26	28.09
Pesticide (1000 TL ha^{-1})	350	87081.0	5246.0	7902.0

[a] Standard deviation

Table 2: Coefficients of Cobb-Douglas production function

Variables	Coefficients	S E	t
Intercept	3.1756*	0.5550	5.7209
Ln (Seed)	0.4075*	0.0869	4.6891
Ln (Fertilizer-N)	0.0015	0.0162	0.0912
Ln (Fertilizer-P)	0.0118	0.0114	1.5821
Ln (Labor)	0.1306*	0.0376	3.4711
Ln (Machinery)	0.0064	0.0407	0.1562
Ln (Pesticide)	0.1475*	0.0382	3.8556
Adjusted R^2	0.223		
F-value	10.164*		

SE: Standard Error; t: t-statistics, * Significant at 1 % level

Adjusted R square value given in Table 2 shows that the production function does not explain a great part of the relationship between inputs and output. All factors were found to have a positive impact on wheat yield. However, only effects of seed, labor and pesticide were found statistically significant. This is not contrary to the expectations for a traditional subsistence crop such as wheat.

DEA scores were estimated using the software DEAP version 2.1 developed by Coelli (1996). Efficiency scores of the farms were calculated under constant and variable return to scale assumptions (CRS and VRS).

After calculating DEA scores a Tobit regression model was employed in order to determine causes of inefficiencies. Several environmental factors were regressed upon DEA VRS scores in this model.

There are lots of factors affecting technical efficiency in agriculture. For example, a positive relationship between land ownership and technical efficiency is expected. However, since almost 90% of the farmers are owners of their lands in the study area, this parameter was not employed in this study. Environmental factors analyzed in this study are as follows: age and education of the farm head, number of plots, share of family labor, area allocated to wheat and specialization level represented by percentage of wheat lands in total area.

RESULTS AND DISCUSSION

Technical Efficiency of Farms: Results of Table 3 showed that 30 farms under CRS and 82 farms under VRS were found to be fully efficient. Thirty one farms under CRS and 3 farms under VRS showed a performance below 0.40. Predicted technical efficiencies differ substantially among sample farms, ranging between 0.38 and 1.00, with a mean technical efficiency of 0.83 (Table 3). These results indicate that efficiency of wheat growing farms in the area can be considerably improved. Sample farms may reduce their input costs by 17% on the average while remaining at the same production level.

For the inefficient farms, the causes of inefficiency may be either inappropriate scale or misallocation of resources. Inappropriate scale suggests that the farm is not taking advantage of economies of scale, while misallocation of resources refers to inefficient input combinations. Since mean scale efficiency of the sample wheat growing farms is relatively high (0.78), it can be concluded that inefficiencies are mainly due to improper input use.

Excess input use: Mean input slacks and excess input use percentages are given in Table 4. A slack indicates excess of an input. A farm can reduce its expenditure on an input by the amount of slack without reducing its output. The greatest slacks were in machinery and fertilizer use. When combined with the Tobit analysis results (Table 5), excesses in machinery working time may be attributed to small farm sizes and land fragmentation. Use of machinery and labor is difficult and time consuming in small and scattered plots.

Number of farms using excess fertilizer is also very high (Table 4). For phosphorus this is attributable to the fact that some farmers do not use phosphorus at all. Some of those farmers may be following a long term phosphorus strategy. In other words, they may be applying phosphorus once in a few years since phosphorus is combined with the soil by a process known as phosphorus fixation and is available for more than a year. However, according to the results of the questionnaire study, it is clearly understood that most of the farmers are in the habit of using mixed commercial fertilizers. Dissemination of extension knowledge on a fertilizing strategy based on soil analyses may help in improving efficiencies.

Causes of Inefficiencies: Several factors were regressed upon efficiency scores in order to determine causes of inefficiencies. Results of the Tobit regression analysis are given in Table 5.

Table 3: Frequency distributions of technical efficiency scores

	Data envelopment analysis		
Efficiency scores	CRS	VRS	SE
1.00	30	83	32
0.90-1.00	13	19	42
0.80-0.90	13	21	20
0.70-0.80	26	15	27
0.60-0.70	20	19	19
0.50-0.60	33	20	38
0.40-0.50	27	13	13
<0.40	31	3	2
Mean	0.65	0.83	0.78
Minimum	0.21	0.38	0.36
Maximum	1.00	1.00	1.00
Standard deviation	0.24	0.20	0.20

CRS : Constant Returns to Scale assumption, VRS : Variable Returns to Scale assumption, SE : Scale Efficiencies

Table 4: Input slacks and number of farms using excess inputs

Input	No. of farms	Mean slack	Mean input use	Excess input use (%)
Seed	41	11.17	209.45	5.33
Fertilizer-N	77	10.44	77.04	13.55
Fertilizer-P	80	9.94	41.86	23.75
Labor	57	23.11	119.09	19.41
Machinery	67	5.63	22.26	25.29
Pesticide costs	30	447.39	5246.0	8.53

Table 5: Results of Tobit Model for efficiency scores

Variables	Coefficients	SE
Constant	0.6205*	0.1520
Age of the farmer	0.0003	0.0011
Education of the farmer	-0.0019	0.0135
Share of family labor (%)	0.2240**	0.1348
Number of plots	-0.0387*	0.0108
Land size (ha)-for wheat	0.0014*	0.0005
Specialization (% of wheat area)	0.0006	0.0003
Number of observations		

SE: Standard Error, * Significant at 1 % level, ** Significant at 10 % level

Age of farmer parameter was found to have a positive sign. Older farmers are found to be more efficient. However, this result is not statistically significant.

Formal education of the farmer was found to have a negative effect on efficiency. This can be partially explained by the fact that more educated people do not commit themselves only to farming since they may have more off-farm opportunities. This parameter is also not statistically significant.

Percentage of family labor is expected to have a positive effect on efficiency due to stronger incentives for technical efficiency in small subsistence farming. The coefficient of share of family labor is positive, implying that the family laborers are more efficient than hired laborers. This parameter is statistically significant at 10%.

Most significant finding of this study reveals that the most important determinants of inefficiencies are the fragmented structure of farm lands (significant at 1%) and the greatest slacks are in machinery use. These two factors are closely related. Some of the excesses in machinery working hours can also be attributed to the fragmented farm lands. A comprehensive land consolidation plan may help in reducing machinery working hours and hence in improving efficiencies.

Suggestions for further studies: Technical efficiency is an important component of economic efficiency. However, allocation efficiency and economic efficiency should also be studied.

Finally, it is important to note that since efficiency analysis is based on a single season, extending its results to other production seasons should be made with care. Some other factors other than those analyzed in this study (timing of cultural operations etc.) can also have a significant impact on efficiency in agriculture. However, an appropriate model covering all components of whole farming system would require a more detailed and larger data set.

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