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Determination of technical efficiency in wheat (*Triticum aestivum* L.) production of Turkey: A case study of Cukurova region

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Abstract

Wheat production in Turkey has always been costly due to the high input prices that reduce competitiveness between Turkish and foreign farmers. So far, few attempts have been done to resolve problems regarding the wheat production and marketing in Turkey. Therefore, as an initial effort we carried out present study to determine technical efficiency of wheat growing farms in Cukurova region of Turkey. Wheat growing farmers provided the data through a questionnaire study in the 2004-2005 growing season. Technical efficiency of wheat farming was estimated by using the data envelopment analysis (DEA). Technical efficiency scores were calculated by employing an input-oriented DEA and Tobit regression analysis was used to identify determinants of technical efficiency. The results showed that wheat farmers could save from the variable inputs by at least 20% remaining at the same production level. The efficiency level is mainly affected by farmer education level and number, size and location of wheat plots of 103 farms, of which 13 showed constant, 87 increasing and 3 decreasing returns to scale conditions. Determining variations in technical efficiencies of wheat growing farms and the causes of inefficiencies, our results are expected to be useful for policy makers as well as wheat growers.

Key words: Economic efficiency, data envelopment analysis, wheat production, Tobit analysis, Turkey.

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops utilized for food consumption in both Turkey and most of the world. Turkey's wheat production was 21 million tons on 9.3 million ha in 2005. The world wheat production is about 630 million tons on 217 million ha in 2005. China is the biggest wheat producing country followed by India, Russia, U.S.A. and France, respectively. These countries have about 52% of the world wheat production [1].

In terms of production and planting area, wheat production takes the first place within the cereals followed by barley and maize in Turkey. Changing agricultural policies after 1990s and specially 2000 pushed Turkish farmers into more competitive markets. Increasing competition in the world markets and new approach in Turkish agricultural policies such as liberalization and competitiveness encourage Turkish producers to increase their production effectiveness. Therefore, the results of the current research about effectiveness are very important for both the policy makers and producers.

There are two general approaches to measure technical efficiency. These are the parametric and the non-parametric methods. Data Envelopment Analysis (DEA) is a nonparametric method, and can easily handle multiple input and multiple output cases. Moreover, DEA application inputs and outputs can have very different units of measurement without requiring any priori tradeoffs or any input and output prices. Given these highly desirable features of the nonparametric methods, it is not surprising that they have recently become very popular among researches [2].

Some researchers estimated technical efficiency of wheat production. For example, Bakhshoodeh and Thomson estimated farm-level output-based technical efficiency measure (the Timmer index) and an input-based measure (the Kopp index) of wheat growing farms in Iran [3]. Using 1995 data from 164 farms in Kerman province of Iran, the average Timmer and Kopp indexes were estimated at 0.93 and 0.91, respectively. Wilson *et al.* estimated technical efficiency of wheat farms by a stochastic frontier production function by using panel data for the 1993-1997 crop years in eastern England [4]. Alemdar and Ören applied DEA to wheat growing farms in Southeastern Anatolia, Turkey [5, 6]. Results indicate that wheat producers could increase their output by 21-27% through better use of available resources.

In recent years DEA is also being used to analyze agricultural production in Turkey. DEA was applied to cotton and tobacco production and apple farms [7-12]. The objectives of the present study were to determine the measurement of technical and scale efficiency of wheat growing farms in Cukurova region in Turkey. To this end, a modified input-oriented DEA approach was applied in 103 farms located in Cukurova region of Adana and Hatay provinces and to give some idea to policy makers for their future decisions on improving wheat farming efficiencies.

Materials and Methods

The data used in this study were collected through a questionnaire study from wheat growing farmers in Adana and Hatay provinces of Turkey. These two provinces account for about 74% of the Cukurova region's wheat production and about 7.4% of Turkey's wheat production [13]. The survey provides detailed cross sectional information on revenues and production costs for the surveyed farms during 2006-2007 production period. Sample farms were selected with a stratified sampling procedure. A total of 103 wheat growing farms were interviewed for the analysis. Farm groups and interviewed farm numbers are given Table 1.

Table 1. Groups and number of interviewed farms.

Planting area (ha)	Farms sampled (number)	Distribution of sampled farmers (%)
0-4.9	31	30.1
5.0-9.9	30	29.1
10.0-19.9	15	14.6
20.0 -+	27	26.2
Total	103	100.0

Efficiency is generally measured using either parametric or nonparametric methods. Parametric methods include deterministic frontier production functions, stochastic frontier methods, and panel data models [14]. Non-parametric models involve mathematical programming. Data Envelopment Analysis is a nonparametric method widely used in efficiency measurement studies. One of the advantages of DEA is that one does not need to specify a distributional form for the production function and the inefficiency term. In this method, an efficiency score is given to each production unit, based on its distance to a production frontier constructed by means of linear programming model. No explicit functional form is assumed for the underlying production technology in DEA [15].

Mathematical development of DEA can be traced to Charnes and Cooper who introduced their basic CCR (Charnes-Cooper-Rhodes) model based on the works of Farrell and others. Banker *et al.* modified this model to account for variable returns to scale conditions by adding a convexity constraint and introduced their BCC (Banker-Charnes-Cooper) model [16-18].

An input-oriented BCC model is given below for N Decision Making Units (DMU), each producing M outputs by using K different inputs [19]:

$$\text{Min}_{\theta,\lambda} \quad \theta$$

$$\text{subject to}$$

$$-y_i + Y\lambda \geq 0$$
$$\theta x_i - X\lambda \geq 0$$
$$N1'\lambda = 1$$
$$\lambda \geq 0$$

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. A θ value of one indicates that the firm is technically efficient according to the Farrell definition [17]. However, slacks are not handled in Farrell definition of efficiency. According to a more strict efficiency definition known as Koopmans criteria, a firm is only technically efficient if it operates on the frontier and furthermore all associated slacks are zero [20].

Original DEA specification has been extended in several ways and multi stage models were developed in order to meet more strict Koopmans criteria, to identify the nearest efficient points and to make the model invariant to units of measurements. Coelli developed such a multi-stage methodology and a computer program which implements a robust multi-stage model among other options [21, 22].

A ratio of technical efficiency scores obtained from DEA under CRS (Constant Return to Scale) and VRS (Variable Return to Scale) assumptions measures scale efficiency (SE). This scale efficiency measure can be interpreted as the ratio of average product of a firm operating at a point to the average product of another firm operating at a point of technically optimal scale. A value of scale efficiency equal to one implies that the farm is scale efficient and a value less than one suggests the farm is scale inefficient. A farm operating under decreasing returns to scale conditions means that it is operating under super-optimal conditions. On the other hand a farm operating under increasing returns to scale is operating under sub-optimal conditions.

Second concern is related to making a choice between input- and output-oriented models. Although in many cases this choice does not affect the results, an input-oriented DEA model was chosen since farmers have more control on inputs than they have on outputs. So an input-oriented DEA model was chosen. One output and six inputs were used in the DEA model. The only output is the wheat yield per unit area (kg/ha). The inputs included were (1) pure nitrogen applied to unit area (kg/ha), (2) pure phosphorus applied to unit area (kg/ha), (3) amount of seed used in wheat unit area (kg/ha), (4) total labor used (hours/ha) in wheat farming from land preparation through harvest (both family and hired labor), (5) total machinery working hours (hours/ha) and (6) total pesticide costs (YTL/ha).

Summary statistics related to variables used in the analysis, socio-economic characteristics of wheat growing farmers and farms are given in Tables 2-3, respectively. When coefficients of variations are taken into consideration, it is clearly seen from Table 3 that the greatest variations are in fertilizer, seed and pesticide use. Those great variations may be an indicator of mismanagement problems.

DEA scores were estimated using the software DEAP version 2.1 developed by Coelli [21]. Efficiency scores of the farms were calculated under constant and variable return to scale assumptions (CRS and VRS).

Tobit regression model was employed in order to determine causes of inefficiencies after calculating DEA scores. Several environmental factors were regressed upon DEA VRS scores in this model. Farmer age, education level, wheat growing experience of the farm head, number of wheat plots (land fragmentation), and wheat land and location of land were used.

Cukurova region includes Adana, Hatay, Mersin, Kahraman Maras and Osmaniye provinces and takes the first place in agricultural production in Turkey. Although, it has only 5.3% of total agricultural land area (1.4 million ha) but produces 8.82% of total agricultural production value and 11.43% of total plant

Table 2. Socio-economic characteristics of wheat growing farmers.

Variable	Minimum
Average population in farm (person)	4.54
Male (%)	53
Female (%)	47
Head of farm education level (year)	6.01
Wheat growing experience of the farm head (year)	29.68
Farmer age (year)	49.36
Average planting area (ha)	19.83
Average wheat planting area (ha)	7.93
Agricultural income out of farm (YTL)	284.09
Farm out Income (YTL)	513.44

*YTL New Turkish Liras (currency).

Table 3. Summary statistics for variables used in the efficiency analysis.

Input/output variable	Minimum	Maximum	Mean	Standard deviation
Output:				
Wheat yield (kg ha^{-1})	1600.00	7760.00	3890.70	1615.46
Inputs:				
Fertilizer-N (kg ha^{-1})	40.00	530.00	194.87	73.21
Fertilizer-P (kg ha^{-1})	0.00	250.90	82.39	41.23
Seed (kg ha^{-1})	114.86	570.00	308.00	60.91
Labour (h ha^{-1})	2.98	87.27	15.76	13.91
Machinery operating time (h ha^{-1})	1.05	63.33	9.17	7.09
Pesticide (YTL ha^{-1})	0.15	310.08	24.60	43.87

production value [13]. This situation can be bound to a high intersection between the farm enterprisers in the region and the climate suitable for second crop production and an ecological variations [23].

Cukurova region has 4.06 million ha surface area of which 34.6% (1,405,510 ha) is agricultural land area. This rate for Turkey is 32.4%. The principle agricultural products of the region are wheat, cotton, citrus, maize and groundnut. The most important crops are wheat and cotton that occupy 47.9% and 34.9% of the total area, respectively. About 39% of agricultural land area is being irrigated.

Total Turkish agricultural land area is about 26.4 million ha and 69% of it is sown land area, 18.3% fallowed land area, 9.7% fruit and olive grove, vineyards and orchards and 3% is vegetable area. The average size of land holdings is 12.2 ha. Specialization in agricultural holdings is more common compared with the rest of Turkey. While 38.4% of total area is cultivated by their owners, 44.9% of area is cultivated by sharecropping and rest by tenancy basis [13].

Results and Discussion

Farms' technical efficiencies: Results of the input-oriented DEA analysis are given in Table 4. Thirteen farms under CRS and 26 farms under VRS were found to be fully efficient. Forty-four farms under CRS and 2 farms under VRS showed a performance below 0.40. Predicted technical efficiencies differ among sample farms, ranging between 0.38 and 1.00, with a mean technical efficiency of 0.80 (Table 5). These results indicate that there are some opportunities for improving resource use efficiency. Sample farms may reduce their input costs by 20% 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 farms is relatively high (0.72), it can be concluded that inefficiencies are mainly due to improper input use and also inappropriate scale.

Mean scale efficiency of the sample wheat farms is 0.80. Of 103 wheat farms, 13 showed constant returns to scale and 87 increasing returns to scale, and there were 3 farms practicing under decreasing returns to scale conditions. Characteristics of optimal, sub-optimal and super-optimal farms are given in Table 4. As it is seen, there are great differences between wheat yield per ha and mean gross return per unit.

Table 4. Characteristics of farms with respect to returns to scale.

	Number of farms	Yield (kg ha^{-1})	Mean gross return (YTL ha^{-1})
Sub-optimal	87	359.19	192.89
Optimal	13	591.13	209.61
Super-Optimal	3	542.39	202.25

Excess input use: Mean input slacks and excess input use percentages are given in Table 6. 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 pesticide, labour, machinery and phosphorus and nitrogen fertilizer use.

Table 5. Frequency distributions of technical efficiency scores obtained with DEA model.

Efficiency scores	DEA		
	CRS	VRS	SE
1.00	13	26	13
0.90-1.00	8	14	17
0.80-0.90	6	15	11
0.70-0.80	5	14	10
0.60-0.70	11	15	15
0.50-0.60	16	13	19
0.40-0.50	10	4	11
0.30-0.40	23	2	6
<0.30	11	0	1
Minimum	0.13	0.38	0.28
Maximum	1.00	1.00	1.00
Mean	0.59	0.80	0.72
Standard deviation	0.26	0.18	0.21

In the wheat production of the region, agricultural contamination against grass seed is quite high. This ineffectiveness can be due to ineffective components in the herbicides, application time and climate. In addition, some of the farmers are using conventional methods. For example, some farmers decide to fertilize (timing or quantity of fertilizer) by refinance of their own or fathers' experiences. They do not have their soil analyzed. Neighbors are also effective on their decisions. This is same for seed selection, planting and applying herbicides or insecticides. Therefore, to improve and apply agricultural extension strategies about basic farm applications such as fertilizer, seed and other input usage are very important to increase effectiveness in the farm.

Determinants of technical efficiency: VRS DEA technical efficiency scores were regressed on farm specific characteristics in order to identify sources of inefficiencies. Since efficiency scores range between 0 and 1, a two-tailed Tobit model was employed in place of OLS regression [24]. Results of the Tobit regression analysis are given in Table 7. Formal education of the farmer was found to have a positive effect on efficiency. This can be partially explained by the fact that more educated people are generally open to new technologies and expected to follow and apply innovations. This parameter is statistically significant at 1% level.

Number of plots is expected to have an adverse effect on efficiency, because fragmented farms create difficulties in machinery and labor use. Same as expected, this parameter has a negative sign and is significant at 5% level.

Table 6. Input slacks and number of farms using excess inputs.

Input	Number of farms	Mean slack	Mean input use	Excess input use (%)
Fertilizer-N (kg ha^{-1})	32	9.83	194.87	5.05
Fertilizer-P (kg ha^{-1})	38	9.04	82.39	10.98
Seed (kg ha^{-1})	9	2.56	308.00	0.83
Labour (h ha^{-1})	29	3.05	15.76	19.39
Machinery operating time (h ha^{-1})	49	1.06	9.17	11.57
Pesticide (YTL ha^{-1})	24	5.24	24.60	21.32

Table 7. Results of Tobit model for efficiency scores.

Variable	Coefficient	Std. error	z-score	Significance
C	0.781124	0.083960	9.303530	0.0000
Education level	0.022643	0.006797	3.331295	0.0009
Number of wheat plots (land fragmentation)	-0.013634	0.007197	-1.894265	0.0582
Location of land	-0.100123	0.033856	-2.957273	0.0031
experience of the farmer	0.001893	0.001826	1.036585	0.2999
Wheat harvested land	9.69E-05	0.000126	0.768780	0.4420
Farmer age	0.010196	0.044878	0.227191	0.8203
R^2				0.251138
Adjusted R^2				0.195959

In the investigated area, the wheat area structure is added to the model and the result is highly significant at the 0.001 probability level. As a result, when the slope of the land increases, efficiency score moves to opposite direction.

Farmer's age is included as a dummy variable equal to 1 if farmer is younger than 40 and 0 otherwise. The age variable serves to test the hypothesis that younger farmers are more receptive to innovations and therefore, they may be more efficient. This variable is not statistically significant even at 10% level.

Years of wheat farming experience is expected to have a positive effect on efficiency since efficiency increases with experience. The coefficient of wheat farming experience is positive, but this parameter is not statistically significant at the 0.1 probability level.

Total wheat area was found to have a positive effect on efficiency, but this parameter is not significant at the 0.1 probability level.

Conclusions and Recommendations

This study set out to provide estimates of technical efficiency in wheat production and to explain variations in technical efficiency among farms in Cukurova region. Farm specific technical efficiencies were computed using 2004/2005 wheat production data by the surveys in Cukurova region, Turkey. An input-oriented DEA approach was used to generate technical efficiency estimated using DEAP [21].

Results showed that mean technical efficiency was estimated at 80 percent. Therefore, there is a 20 percent scope for increasing wheat production by using the present technology. However, TE ranged between 38 to 100 percent among the wheat producers in the region.

The greatest excesses were observed in pesticide, machinery and labor use and also fertilizer use. All these excesses adversely affect technical efficiencies of wheat farming. Inefficiencies indicate a wrong input mix between these inputs.

Finally, it should be kept in mind that inefficiency is not just a result of the amount of inputs used. Environmental factors have also an effect on efficiency. In addition, technical efficiency can be improved trough well-organized education, extension program and research and development programs. Although technical efficiency is an important component of economic efficiency, allocation efficiency should also be examined in future studies.

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