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Full Length Research Paper

Determination of technical efficiency in cotton growing farms in Turkey: A case study of Cukurova region

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This paper analyses technical efficiency of cotton farms in Çukurova region in Turkey. Data was collected from cotton farms through a questionnaire study. Data collection was carried out following 2004-2005 growing seasons. Technical efficiency of cotton farms was estimated by using the Data Envelopment Analysis (DEA) and technical efficiency scores were calculated employing an input oriented DEA. Tobit regression analysis was used to identify determinants of technical efficiency. Results indicate that cotton farmers can save inputs by at least 20% while remaining at the same production level. Factors strongly affecting efficiency level of the farmers were found to be farmers' age, education level and groups of cotton growing areas.

Key words: Efficiency, data envelopment analysis, cotton, Turkey.

INTRODUCTION

Cotton has a significant role in the national economy in Turkey. Its fibre is used in industries (such as textiles). These industries have an important share in country's export revenues. Turkey has about 0.5% share in both world's cotton production and plantations, respectively. Also, cotton seed serves as a raw material in oil industry, and its cake used by stock breeders as a feed. Cotton farming and processing also constitute a large channel for employment.

In Turkey, cotton farming is practiced mainly in four regions: The Aegean region, Cukurova, Southeastern Anatolia and Antalya. Presently, the Aegean region has the greatest share in cotton output. It also raises the highest quality cotton used in textiles. In Cukurova region, output is subject to considerable fluctuations and in general it displays a declining trend.

The objective of the present paper is to measure the technical and scale efficiency of cotton growing farm in Çukurova region in Turkey. For this reason, a Data Envelopment Analysis (DEA) method was used. There are two general approaches to measuring technical efficien-cy. These are the parametric and the non parametric methods. Data Envelopment Analysis (DEA) is the non parametric method, and can handle easily multiple input and multiple output cases. Moreover, in DEA application, inputs and outputs can have very different units of measurement without requiring any a priori tradeoffs or any input and output prices. Given these highly desirable features of the non parametric methods, it is not sur-prising that they have recently become very popular among researchers (Fousekis et al., 2001).

During the 1980s, the province was in an important position in Turkey's cotton production for both planting areas and productivity. After the 1990s, however, the production was in decrease because of both the increase of costs due to the raid against increasing number of vermins and disease and the decrease of planting areas due to the pricing policy in practice. It could also be said that the loss of farm workers and forcing the GAP Project (Güneydo u Anadolu Projesi) are the other factors that led to the decrease in production

The technical efficiency of cotton growing has been estimated by so many researchers. For example, Shafiq.

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Table 1. Farm groups and interviewed farm numbers.

Planting Area (decare)	Farm sampled (numbers)	Distribution of sampled farmers (%)
0 - 49	40	50.6
50- 99	12	15.2
100- 199	12	15.2
200 and more	15	19.0
Total	79	100.0

1 hectare = 10 decares (da).

and Rehman (2000) used a DEA to identify sources of resource use inefficiency for cotton production in Pakistan's Punjab. There were a considerable number of farms that are both technically and allocatively inefficient. The use of DEA shows that the technique provides a clear identification of both the extent and the sources of technical and allocative inefficiencies in cotton production. However, both the interpretation of the farm level results generated and the projection of these results to a higher level require care, given the technical nature of the agricultural production processes.

Wossink and Denaux (2006) used DEA to identify the quantification of pesticide use efficiency for producers of transgenic cotton versus conventional cotton in order to test for the improvement promised by the genetically engineered crop. The data were from a survey of cotton growers in North Carolina, USA. Differences in environmental efficiency were found to be significant between herbicide tolerant and stacked gene (herbicide tolerant and insect resistant) cotton and between stacked gene and conventional cotton. In contrast, no statistically significant differences were found for the efficiency of pest control cost. In the follow-up Tobit regression, differences in production environment and in farm, farmer and field characteristics are accounted for so that the contribution of seed type to efficiency can be observed. The regression results confirmed the importance of stacked gene cotton for improving the environmental efficiency of pesticide use in cotton. In contrast, seed type was not significant in explaining differences in cost efficiency.

Günden (1999) estimated technical efficiency of cotton production in Menemen using Data Envelopment Analysis (DEA) and determined production and input losses casued by inefficiency. The researcher found that technical efficiency score was 0.677 in the province. With respect to these findings, current production could be increased 32.3%.

Binici et al. (2006) investigated the technical efficiency of cotton production on the Harran plain in Turkey. Compared with results from other studies of farm production in developing countries, the study found that the sample of 54 cotton farmers located in Harran Plain, are producing at a high level of efficiency. Nevertheless, 72% of the farms are using inefficient levels of inputs. A statistically significant, positive relationship between a farmer's education and a farm's technical efficiency underscores the need for public investment in rural education. Chemicals, urea, tractor, and labor inputs are used most inefficiently.

The severe economic stress confronting cotton producers today has prompted research efforts in production and marketing risk management strategies. Yet it is equally important to assess the production and scale efficiency of specific farming units, which can help producers focus on necessary adjustments within their operations and improve productivity.

The first objectives of this study are to measure the technical and scale efficiency of cotton farms. To this end, a modified input oriented DEA approach was applied to 79 farms located in Çukurova region of Adana and Hatay province, Turkey. Other objectives are to investigate the relationship between the farm output and the inputs given the assumption of a specific technology, and to analyze the slack input variables in terms of their excess use in the production process. And also the objective of this paper is to give some idea to policy makers for their future decisions on improving cotton farms efficiencies by revealing and explaining variations in technical efficiencies of cotton farms and determining the causes of inefficiencies.

MATERIALS AND METHODS

The data used in this study was collected through a questionnaire study from cotton farmers in Cukurova region of two provinces of Turkey. These provinces (Adana and Hatay) account for about 83 and 82% of Çukurova's cotton lint harvested area and production (SIS, 2003), respectively. The survey provides detailed cross-sectional information on revenues and production costs for the surveyed farms during 2004-2005 production period. Sample farms were selected with a stratified sampling procedure. A total of 79 cotton growing farms were interviewed for the analysis. Farm groups and interviewed farm numbers are given Table 1.

Efficiency is generally measured using either parametric or non-parametric methods. Parametric methods include deterministic frontier production functions, stochastic frontier methods, and panel data models (Battese, 1992). Data Envelopment Analysis (DEA) is a nonparametric method widely used in efficiency measurement studies. In this research DEA was used for calculated efficiency of cotton farming.

Mathematical development of DEA can be traced to Charnes and

Cooper (1978) who introduced their basic CCR (Charnes-Cooper-Rhodes model) 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 (Banker-Charnes-Cooper model) model.

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):

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

$$\text{subject to}$$

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

Where;
is a scalar,
N1' is convexity constraint,
is N x 1 vector of constants,
Y represents output matrix, X represents input matrix.

The value of 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 value of one (1) indicates that the firm is technically efficient according to the Farrell (1957) definition. However, slacks are not handled in Farrell definition of efficiency. According to a more strict efficiency definition known as Koopmans criteria (1951), a firm is only technically efficient if it operates on the frontier and furthermore, all associated slacks are zero.

In DEA, the performance of a farm is evaluated in terms of its ability to either shrink usage of an input or expand the output level subject to the restrictions imposed by the best-observed practices. This measure of performance is relative, in the sense that the efficiency of each decision-making unit (DMU) is evaluated against the most efficient DMU, and it is measured by the ratio of actual output to maximal potential output (Chakraborty et al., 2002).

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 (1996, 1997) developed such a multi-stage methodology and a computer program which implements a robust multi-stage model among other options.

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 (1) implies that the farm is scale efficient and a value less than one (< 1) 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.

A second concern is related to making a choice between input and output oriented models. Although it is reported that 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 that an input oriented DEA model was chosen.

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

Input/Output Variables	
Average population in farm (person)	4.96
Male	54.6%
Female	45.4%
Head of farm education level*	5.59
Cotton growing experience of the farm head (year)	29.62
Farmer age (year)	48.86
Agricultural Income out of Farm (YTL)	28.48
Off-farm Income (YTL)	200.00

*year

One output and seven inputs were used in the DEA model. The only output is the cotton yield per unit area (kg/da). The inputs included are (1) pure nitrogen applied to unit area (kg/decare-da), (2) pure phosphorus applied to unit area (kg/da), (3) amount of seed used in cotton unit area (kg/da), (4) total labor used (h/da) in cotton farming from land preparation through harvest (both family and hired labor), (5) total machinery working hours (h/da), and (6) total pesticide cost (YTL/da) and (7) number of irrigiation.

Interviwied farm numbers, socio-economic characteristics of cotton growing farmers and summary statistics related to variables used in the analysis are given in Tables 1, 2 and 3, respectively. When coefficients of variations were taken into consideration, it was clearly seen from Table 3 that the greatest variations were in fertilizer use, labour use and pesticide cost. Those great variations may be an indicator of mismanagement problems.

The software DEAP version 2.1 developed by Coelli (1996) were used to estimate DEA scores. Farms' efficiency scores were calculated under constant and variable return to scale assumptions (CRS and VRS). And 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, cotton harvesting areas groups, farmers' experience level and number of parcels were used.

RESULTS AND DISCUSSION

Çukurova region consists of Adana, Hatay, çel and Osmaniye provinces and take the first place with regard to agricultural production in Turkey. The principle agricultural products of the region are wheat, maize, citrus, cotton and groundnut. About 39% of agricultural land area is being irrigated.

In surveyed enterprises, some socio-economic indicators of cotton farms were also assessed (Table 2). Average age of the cotton growers was 48.86 years in surveyed enterprises. There was no significant difference between both farm groups with respect to growers' age and education level. Farmers' educational level was 5.59 years. Average family sizes in survey households were 4.96 people. There was no significant difference between both farm groups with respect to demographic characteristics. Of this family size, 54.6% were men, and 45.4% were women.

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

Input/Output Variables	Minimum	Maximum	Mean	S.D. *
Output				
Cotton yield (kg da^{-1})	181.82	570.00	395.35	101.38
Inputs				
Fertilizer-N (kg da^{-1})	0.48	39.60	24.96	10.57
Fertilizer-P (kg da^{-1})	0.06	13.13	5.61	3.44
Seed (kg da^{-1})	2.00	8.33	5.90	1.98
Labour (h da^{-1})	5.86	60.72	13.56	11.17
Machinery operating time (h da^{-1})	0.56	13.46	2.91	2.63
Cost of pesticide (YTL da^{-1})	67.96	416.00	151.90	79.75
Number of irrigation	2.00	15.00	5.47	2.48

1 hectare = 10 decars(da); * S.D, Standard deviation.

Table 4. Frequency distributions of technical efficiency scores obtained with DEA model.

Efficiency Scores	DEA		
	CRS	VRS	SE
1.00	16	26	17
0.90-1.00	4	20	12
0.80-0.90	15	18	15
0.70-0.80	10	6	14
0.60-0.70	14	6	9
0.50-0.60	6	3	3
0.40-0.50	4	0	4
0.30-0.40	4	0	5
<0.30	6	0	0
Minimum	0.23	0.55	0.37
Maximum	1.00	1.00	1.00
Mean	**0.72**	**0.89**	**0.79**
S.D.	0.23	0.12	0.19

In the region, particularly after the 1960s, the increase in use of water in agriculture led to increase in harvest and production and caused variety in production. As a result, the region's state of agricultural production (in terms of good quality seed usage) became better than those of other cities.

The results showed that growers use chemical fertilizer 2.02 times during the production period. Nitrogen fertilizer 24.96 kg da^{-1} and phosphoros fertilizer 5.61 kg da^{-1} fertilizer were applied through May, June, July and August period.

Most cotton land in the region was irrigated by irrigation channel and in surveyed areas, irrigation number was 5.47 times. Irrigation was applied from May to August.

According to the results of the questionnaire study, it was clearly understood that most of the farmers were in the habit of using mixed commercial fertilizers; dissemination of extension knowledge on a fertilizing strategy based on soil analyses was carried out, and more farmers carried out soil or leaf analysis. These may have helped in improving fertilization efficiencies.

Table 4 shows the results of the input oriented DEA analysis. 16 farms under CRS and 26 farms under VRS were found to be fully efficient. However, 6 farms under CRS showed a performance below 0.30. Predicted technical efficiencies differ among sample farms, ranging between 0.23 and 1.00, with a mean technical efficiency of 0.79. These results indicate that there are some opportunities for improving resource use efficiency. Sample farms may reduce their input costs by 21 % on the average while remaining at the same production level.

For the inefficient farms, the causes of the inefficiency may either be that the farm is not taking advantage of the economies of scale (inappropriate scale) or inefficient combination of inputs (misallocation of resources). Since the mean scale efficiency of the sample farms is relatively high (0.89), it could be concluded that inefficiencies are mainly due to improper input use and also inappropriate scale.

Previous studies by Günden (1999) estimates technical efficiency of cotton production in Menemen using Data Envelopment Researcher and found that technical efficiency score was 0.677 in the province. Aktürk (2000) found that cotton production technical efficiency score was 0.839 in Soke. Binici et al. (2006), investigate the technical efficiency of cotton production on the Harran plain in Turkey and found that the sample of 54 cotton farmers are producing at a high level of efficiency.Mean scale efficiency of the sample cotton farms is 0.79. Of these, 17 show constant returns to scale, 61 show increasing returns to scale. There are 1 farm practicing under decreasing returns to scale conditions.

Table 5 depicts the characteristics of optimal, sub-optimal and super optimal farms. As it is seen from the table, there are great differences between cotton yield per da and mean gross return per unit.

The mean input slacks and excess input use percentages are given in Table 6. Since a slack indicates ex-

Table 5. Characteristics of farms with respect to returns to scale.

	Number of farms	Yield (kg da^{-1})	Cotton planting area (da)	Mean gross return (YTL da^{-1})
Sub-optimal	61	367.80	97.00	214.12
Optimal	17	482.18	116.65	268.22
Super-Optimal	1	570.00	30.00	318.00

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 da^{-1})	25	1.77	24.96	7.08
Fertilizer-P (kg da^{-1})	44	1.78	5.61	31.72
Seed (kg da^{-1})	30	0.79	5.90	13.35
Labour (h da^{-1})	22	2.32	13.56	17.15
Machinery operating time (h da^{-1})	22	0.35	2.91	11.97
Cost of pesticide (YTL da^{-1})	26	14.97	151.90	9.86
Number of irrigiation	32	0.71	5.47	12.93

Table 7. Results of Tobit model for efficiency scores.

Variable	Coefficient	Std. Error	z-score	Significance
C	0.787	0.145	5.420	0.000*
Farmer age	-0.011	0.004	-2.992	0.003*
Experience level	0.013	0.004	3.499	0.001*
Cotton area groups	0.044	0.017	2.637	0.008*
Landed property	0.030	0.035	0.852	0.394
Number of parcels	-0.006	0.010	-0.590	0.556
Education level	0.012	0.024	0.507	0.613
R-squared		0.216		
Adjusted R-squared		0.139		

* Significiant at 1% level.

cess 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 phosphorus fertilizer, labour, seed and number of irrigiation use. In the region, some producers showed traditional behaviour in using agricultural inputs. For example, choosing the amount of input in using fertilizer, individual experience, believing their fathers' experiences are more effective than the results of soil analysis, etc. Therefore, it is important improving and following broadcasting strategies for the use of fertilizers and other inputs in the aim of improving effectiveness. Previous studies have also found that chemical, tractor, and labor inputs are used most inefficiently (Günden, 1999; Binici et al., 2006).

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 (Ray, 2004). Results of the Tobit regression analysis are given in Table 7. Farmer's age was included as variable equal and this variable was statistically significant even at 5% level and this parameter had a negative sign. Farmer's experience level on cotton farming was found to have a positive effect on efficiency. This parameter was statistically significant at 5% level. So, it could be said that, farmer's experience level has a positive effect on technical efficiency.

Cotton area size group of the farmer was also found to have a positive effect on efficiency. This parameter was statistically significant at 5% level. So, it could also be said that, cotton production area size has a positive effect on technical efficiency. Number of parcels was expected to have an adverse effect on efficiency, because it increased total cost and also caused an increase in machinery and labor use. Same as expected, this parameter had a negative sign, but was not significant at 10%

level. Formal education of the farmer was found to have a positive effect on efficiency. But this parameter was not statistically significant.

Conclusions

This study set out to provide technical efficiency (TE) of cotton production in Çukurova region and to explain variations in technical efficiency among farms. Farm specific technical efficiencies were computed using 2004/2005 cotton production data by interviewed from Çukurova region in Turkey. An input oriented DEA approach was used to generate technical efficiency estimated using DEAP software (Coelli, 1996).

Results show that, mean technical efficiency is estimated at 79 percent. Therefore, there is a 21% scope for increasing cotton production by using the present technology. However, TE ranges between 23 to 100 percent among the cotton producers in Çukurva region.

The greatest excesses were observed in phosphorus fertilizer, labour, seed use and number of irrigiation. All these excesses adversely affect technical efficiencies of cotton farming. Inefficiencies indicate a wrong mixture of these inputs. It has been observed that more sodium and less potassium than required amounts have been used for cotton by producers in the region. Thus, producers in the region must be educated about the use of fertilizers by the broadcasters and convinced to use fertilizers according to the results of soil analysis in order to improve their effectiveness. Our finding and findings of previous studies imply that education programs should be available to all farmers regardless of the size of their farm.

The scope of this study is limited since it investigates only the efficiency of cotton production in Cukurova region of Turkey. Due to climatic conditions, agricultural indicators effect results of efficiency studies and results vary from year to year.

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