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TECHNICAL EFFICIENCY OF PEANUT GROWING FARMS IN TURKEY

Tuna Alemdar, Hilal Işik
Çukurova University, Adana, Turkey

Abstract. This paper analyses technical efficiency of peanut growing farms 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 employing 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 peanut farmers can save inputs by at least 8% while remaining at the same production level. Factors strongly affecting efficiency level of the farmers were found to be farmer age, peanut specific farming experience, farm location, overall farm size.

Key words: Efficiency, Data Envelopment Analysis, Peanut Farming, Turkey

INTRODUCTION

Peanut, the third most important oil seed in the world is also a good rotation plant leaving a rich soil for the next crop to be planted. In 2005, 25 million hectares of land was planted to peanuts in the world [FAO 2006]. Turkey's peanut cultivation area and production was 26.000 ha, and 80.000 tons in 2005, respectively. Approximately 0.1 % of Turkey's agricultural land is planted to peanut. Peanut exports account for 0,003 % of total agricultural exports in 2004 [FAO 2006].

Although peanut farming is not mechanized to the desired level, worldwide comparisons reveal that Turkey ranks among the top in terms of peanut yield in the world. This fact indicates that Turkey has a great export earning potential in peanut sector. However, Turkey's share of peanut in world trade is as low as 0.02%.

There are large variations in both resource use and output levels between different peanut growing regions in Turkey. A farm level analysis may help to give a clear understanding of gap between potential and actual efficiency levels in peanut farming.

Corresponding author – Adres do korespondencji: Tuna Alemdar, Hilal Işik, Çukurova University, Faculty of Agriculture, Department of Agricultural Economics, 01330, Adana, Turkey

Data Envelopment Analysis is a widespread efficiency analysis method used throughout the world. In recent years it is also being used to analyze agricultural production in Turkey. Iţýklý et al [2001], Abay et al [2004], Ören and Alemdar [2006] applied DEA to tobacco production. Alemdar and Ören [2006a, 2006b] estimated technical efficiencies of wheat growing farms in Southeastern Anatolia with DEA.

Although considerable amount of researches were conducted on peanut production and costs, those are mostly focused on farm budget analyses [Gül, Iţýk 2004; Iţýk, 2003; Paksoy, Boydak 2001]. On the other hand, this study approaches the problem from a management perspective. The objective of this paper is to give some idea to policy makers for their future decisions on improving peanut farming efficiencies by revealing and explaining variations in technical efficiencies of peanut growing farms and determining the causes of inefficiencies.

The rest of the paper is organized as follows: the next section describes survey area, data, and analytical procedure employed in this study. The final section summarizes the findings and draws conclusions.

MATERIALS AND METHODS

The data used in this study is a part of a broader survey accomplished to make economic analysis of peanut growing farms in three provinces of Turkey. These three provinces (Ýçel, Adana and Osmaniye) account for about 80% of Turkey's peanut production [Anonymous 2001]. The survey provides detailed cross sectional information on revenues and production costs for the surveyed farms during 2000-2001 production period. Sample farms were selected with a stratified sampling procedure. A total of 75 peanut growing farms were interviewed for the analysis.

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. 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 in Fig. 1 for N Decision Making Units (DMU), each producing M outputs by using K different inputs [Coelli et al 1998]:

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

subject to

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

where

x_i : Input vector of the farm to be analyzed

y_i : Output vector of the farm to be analyzed

θ : Efficiency score of the i^{th} farm

λ : N x 1 vector of constants

Y : Output matrix

X : Input matrix

Fig. 1. Input Oriented BCC Model
Rys. 1. Model BCC zorientowany na nakłady
Source: Authors elaboration.
Źródło: Opracowanie własne.

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 peanut yield per unit area (kg/ha). The inputs included are (a) amount of seed used in unit area (kg/ha), (b) pure nitrogen applied to unit area (kg/ha), (c) pure phosphorus applied to unit area (kg/ha), (d) total labor used (hours/ha) in peanut farming from land preparation through harvest (both family and hired labor), (e) total machinery working hours (hours/ha), and (f) total pesticide costs (million TL/ha). All explanatory variables are expressed as technical units, except pesticide costs. Summary statistics related to variables used in the analysis, socio-economic characteristics of peanut growing farmers and farmers are given in Table 1, Table 2 and Table 3 respectively.

When coefficients of variations are taken into consideration, it is clearly seen from Table-1 that the greatest variations are in fertilizer and pesticide use. Those great variations may be an indicator of mismanagement problems.

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, Rehman 2000]. Thus, a Cobb-

Table 1. Summary statistics for variable used in the efficiency analysis
Tabela 1. Statystyki podsumowujące dla zmiennej w analizie wydajności

Input/Output Variables	Min	Max.	Mean	SD a	CV % b
Output:					
Peanut yield (kg/ha)**	400	4900	2860.40	824.85	28.84
Inputs:					
Seed (kg/ha)	70.00	150.0	105.49	20.74	19.66
Fertilizer-N (kg N/ha)	0.00	336.00	86.89	61.80	71.13
Fertilizer-P (kg P205/ha)	0.00	264.00	53.39	49.79	93.25
Labour (h/ha)	67.14	1122.50	468.92	205.53	43.83
Machinery (h/ha)	11.60	177.50	50.50	32.07	63.51
Pesticide (YTL/ha)	0.00	100.00	25.92	26.17	100.96

[a] Standard Deviation [b]Coefficient of Variation

Source: Authors elaboration.
Źródło: Opracowanie własne.

Table 2. Socio-economic characteristics of peanut growing farmers
Tabela 2. Charakterystyka społeczno-ekonomiczna rolników uprawiających orzeszki ziemne

Characteristics of farmers	Frequency
Age of the Farm Head	
<=30 years	2
31–40 years	23
41–50 years	16
51–60 years	20
above 60	14
Education (years of schooling)	
No schooling	8
Up to 5 years	40
Up to 8 years	7
10–12 years	15
More than 12 years	5
Peanut farming experience	
Up to 5 years	3
6–10	14
11–20	33
21–30	16
more than 30 years	9

Source: Authors elaboration.
Źródło: Opracowanie własne.

-Douglas type of production function was fitted to the data and results of this econometric estimation were given in Table 4.

Adjusted r square value given in Table 4 shows that the production function explain only about 24% of the relationship between inputs and output. All factors except phosphorus fertilizer have expected (positive) signs and were found to have a positive impact on peanut yield. Seed and pesticide were found statistically significant at 1% level. Nitrogen and machinery inputs are also statistically significant but at 5% level. Though

Table 3. Socio-economic characteristics of peanut growing farms
Tabela 3. Charakterystyka społeczno-ekonomiczna gospodarstw rolnych z uprawą orzeszków ziemnych

Characteristics of farms	Frequency
Farm location (province)	
Icel	19
Adana	20
Osmaniye	36
Total farm area	
0,1–1 ha	12
1–5 ha	26
> 5 ha	37
Number of peanut plots	
1 plot	46
2–3 plots	21
> 3 plots	8

Source: Authors elaboration.
Źródło: Opracowanie własne.

Table 4. Coefficients of Cobb-Douglas production function
Tabela 4. Współczynniki funkcji produkcji Cobba-Douglasa

Variables	Coefficients		S.E.	t
Intercept	3.760	*	1.147	3.613
Ln (Seed)	0.672	*	0.217	2.424
Ln (Fertilizer-N)	0.040	**	0.021	1.977
Ln (Fertilizer-P)	–0.0006		0.014	–0.046
Ln (Labor)	0.052		0.076	0.696
Ln (Machinery)	0.134	**	0.071	2.026
Ln (Pesticide)	0.0035	*	0.012	3.316
Adjusted r2	0.241			
F Value	5.655	*		

S.E.: Standard error; t: t-statistics
* Significant at 1 % level.
** Significant at 5% level

Source: Authors elaboration.
Źródło: Opracowanie własne.

not significant, negative sign of phosphorus input may be an indication of the fact that is being used beyond the optimal level.

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. Some of them are not used in the analysis since a variation was not observed in terms of these variables. 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, education and peanut growing experience of the farm head, number of peanut plots (land fragmentation), total farm area and location of farms.

RESEARCH FINDINGS AND DISCUSSION. TECHNICAL EFFICIENCY OF FARMS

Results of the input oriented DEA analysis are given in Table 5. 26 farms under CRS and 40 farms under VRS were found to be fully efficient. 14 farms under CRS and 1 farm under VRS showed a performance below 0.60. Predicted technical efficiencies differ among sample farms, ranging between 0.55 and 1.00, with a mean technical efficiency of 0.92 (Table 5). These results indicate that there are some opportunities for improving resource use efficiency. Sample farms may reduce their input costs by 8% on the average while remaining at the same production level.

Table 5. Frequency distributions of technical efficiency scores
Tabela 5. Rozkład częstości dla wyników technicznej wydajności

	Data Envelopment Analysis		
Efficiency Scores	CRS	VRS	SE
1.00	23	39	24
0.90–1.00	8	10	15
0.80–0.90	10	11	16
0.70–0.80	9	9	10
0.60–0.70	10	5	3
0.50–0.60	8	1	2
0.40–0.50	4	0	3
< 0.40	3	0	2
Mean	0.79	0.92	0.86
Minimum	0.19	0.55	0.19
Maximum	1.00	1.00	1.00
Standard deviation	0.21	0.12	0.18

CRS : Constant Returns to Scale assumption
VRS : Variable Returns to Scale assumption
SE : Scale efficiencies

Source: Authors elaboration.
Źródło: Opracowanie własne.

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 (0.86), 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 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 nitrogen, phosphorus fertilizer and pesticide use.

Since peanut fixes free nitrogen in the air to soil particles, nitrogen fertilizer may not be required for areas where peanut is grown for long years. Recommended amount of pure nitrogen is 40–60 kg per ha [Arýođlu 1999]. As it is seen from Table 1, mean pure nitrogen application is about 87 and kg/ha. This is above the recommended level.

Table 6. Input slacks and number of farms using excess inputs
Tabela 6. Straty nakładów oraz liczba gospodarstw rolnych stosujących nadmierną ilość nakładów

Input	Number of farms	Mean slack	Mean input use	Excess input use (%)
Seed	8	1.71	105.49	1.62
Fertilizer-N	42	28.83	86.89	33.19
Fertilizer-P	24	11.86	53.39	22.22
Labor	24	43.02	468.92	9.17
Machinery	15	5.74	50.50	11.37
Pesticide costs	20	5.41	25.92	20.86

Source: Authors elaboration.
Źródło: Opracowanie własne.

Phosphorus slack 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.

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 [Ray 2004]. Results of the Tobit regression analysis are given in Table 7.

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 dummy variable was found to have a statistically positive sign (5% level). This result indicates that younger farmers are more efficient than the older ones.

Table 7. Results of Tobit Model for Efficiency Scores
Tabela 7. Wyniki modelu Tobit dla wyników wydajności

Variables	Coefficients		S.E.
Constant	0.8808	*	0.0915
Age of the farmer (years)	–0.1296	**	0.0060
Education of the farmer (years)	0.0147		0.0079
Peanut farming experience (years)	0.0058	*	0.0022
Total Land Size (ha)	0.0046	**	0.0022
Number of peanut plots	–0.0262		0.0188
Location of the farm (dummy)	–0.1162	**	0.0487

S.E. Standard Error adjusted r2 = 0,21 log likelihood = –7,17
* Significant at 1% level.
** Significant at 5% level.

Source: Authors elaboration.
Źródło: Opracowanie własne.

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 applying new technologies. However this parameter is not statistically significant even at 5% level.

Years of peanut farming experience is expected to have a positive effect on efficiency since efficiency increases with experience. The coefficient of peanut farming experience is positive, implying that the more the farmer deals with peanut farming, the more efficient he becomes. This parameter is statistically significant at 1%.

Total farm area was found to have a positive effect on efficiency. This implies that larger farms have an advantage on the smaller farms. This parameter is significant at 5% level. Number of plots is expected to have an adverse effect on efficiency, since fragmented farms creates difficulties in machinery and labor use. This parameter has a negative sign as expected, however is not significant even at 10% level.

Finally, the Tobit model includes a location dummy. The sample farmers were selected from three different provinces located in the Mediterranean climatic region of Turkey. Although located in the same climatic zone, some possible variations in climatic, social and economic conditions that cannot be represented by any variable may affect the efficiency of farmers. Those possible provincial differences in climate, natural resources and socio-economic conditions are accounted fro through the inclusion of a dummy variable. Location dummy is 0 for Ýçel and Adana and 1 for Osmaniye.

This parameter has a negative sign indicating that technical efficiency decreases while going towards Osmaniye. There is evidence that the possible provincial differences appear to have affected technical inefficiency of farms.

This study reveals that most important determinant of an efficient peanut farming is crop specific farming experience. Location and age were also found to have significant contributions to efficiency.

CONCLUSIONS AND RECOMMENDATIONS

Efficiency of peanut growing farmers was found to be as high as 92%. High average efficiency score, high percentage of efficient farmers, may be an indicator of the fact that peanut farming is a highly standardized agricultural practice in Turkey. Yet, peanut farmers can save inputs by at least 8%, while remaining at the same production level. Age, peanut specific farming experience, farm location, and overall farm size were found to be statistically significant determinants of efficiency. Farm location, representing regional differences, is the most influential factor. Further investigation of this subject may reveal competitive advantages of the three provinces. Farming experience was found to have a more significant contribution to the efficiency of farmers than formal education. Though not statistically significant, land fragmentation has a negative effect on efficiency as expected.

The greatest excess use is in nitrogen fertilizer input, followed by phosphorus and pesticides. Negative sign of phosphorus fertilizer and small coefficient of pesticides in Cobb-Douglas production function are also a sign of excess chemical use. This finding has strong implications since it reveals that improving efficiency will also contribute to environmental protection.

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.

This study reveals large variations between technical efficiencies in different peanut cultivated regions. It is recommended that the results be verified with other efficiency measurement methods (such as stochastic frontier analysis) which take into consideration stochastic nature of agricultural production. Determinants of efficiency differences can also be studied on provincial basis. However, an appropriate model covering all components of whole farming system and measuring efficiency separately for each province would require a more detailed and larger data set.

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WYDAJNOŚĆ TECHNICZNA GOSPODARSTW ROLNYCH Z UPRAWĄ ORZESZKÓW ZIEMNYCH W TURCJI

Streszczenie. W artykule przedstawiono wydajność techniczną gospodarstw rolnych z uprawą orzeszków ziemnych w Turcji. Dane zebrano w trakcie badań przeprowadzonych w sezonie 2000–2001. Analizę przeprowadzono w dwóch etapach. W pierwszym etapie, wyniki technicznej efektywności obliczono przy zastosowaniu zorientowanej na nakłady granicznej analizy danych (DEA). W drugim etapie, zastosowano analizę regresji Tobit w celu zidentyfikowania determinantów technicznej wydajności. Wyniki wskazują, że rolnicy uprawiający orzeszki ziemne mogą zaoszczędzić ok. 8% nakładów przy nie zmienionym poziomie produkcji. Wśród czynników mających silny wpływ na poziom wydajności produkcji wyszczególniono wiek rolnika, doświadczenie w uprawie orzecha ziemnego, położenie gospodarstwa rolnego oraz ogólną powierzchnię gospodarstwa.

Słowa kluczowe: wydajność, graniczna analiza danych DEA, uprawa orzeszków ziemnych, Turcja

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