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Technical Efficiency Analysis of Tobacco Farming in Southeastern Anatolia

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Abstract: The technical efficiencies of tobacco farms in Southeastern Anatolia were estimated with parametric and non-parametric methods. Data obtained from 149 tobacco farms were used in the empirical analysis. Results obtained with an output oriented Data Envelopment Analysis (DEA) were compared to those obtained from Stochastic Frontier Analysis (SFA) and the differences are discussed. According to the results of the DEA model, mean efficiency of tobacco farmers was found to be 0.45 and 0.56 for Constant and Variable Returns to Scale (CRS and VRS) assumptions, respectively. Mean technical efficiency obtained with the SFA model was found to be 0.54. A strong correlation was found between the results obtained with output oriented VRS-DEA and SFA models. Based on these results, it was concluded that the sample tobacco farms would be able to increase their technical efficiency by 45% through better use of the available resources, while applying current technology. However, further studies are required in order to determine the causes of the observed inefficiencies.

Key Words: Technical efficiency, tobacco, Turkey, Data Envelopment Analysis, Stochastic Frontier Analysis

Güneydoğu Anadolu Bölgesinde Tütün Tarımının Teknik Etkinlik Analizi

Özet: Bu çalışmada Güneydoğu Anadolu bölgesinde tütün yetiştiren işletmelerin teknik etkinlikleri parametrik ve parametrik olmayan yöntemlerle tahmin edilmiştir. Ampirik analizde tütün yetiştiren 149 işletmeden elde edilen veriler kullanılarak çıktı odaklı Veri Zarflama Analizi (VZA) yöntemiyle elde edilen sonuçlar Stokastik Etkinlik Sınırı yöntemiyle elde edilen sonuçlarla karşılaştırılmış ve aradaki farklılıklar tartışılmıştır. VZA modeli sonuçlarına göre tütün yetiştiren işletmelerin ortalama etkinlikleri, sırasıyla ölçeğe sabit ve ölçeğe değişken getiri varsayımları altında 0.45 ve 0.56 olarak belirlenmiştir. Stokastik Etkinlik Sınırı modeliyle elde edilen ortalama etkinlik değeri ise 0.54 olarak hesaplanmıştır. Buna göre ürün yönelimli ölçeğe değişken getiri varsayımlı Veri Zarflama Modeli ile Stokastik Etkinlik Sınırı modelinden elde edilen sonuçlar arasında güçlü bir korelasyon bulunmaktadır. Bu sonuçlar örnek tütün yetiştiren işletmelerin mevcut teknoloji altında kaynakları daha iyi kullanarak teknik etkinliklerini % 45 oranında arttırabileceklerini göstermektedir. Ancak bu etkinsizliğin nedenlerinin belirlenebilmesi için ilave çalışmalara gerek duyulmaktadır.

Anahtar Sözcükler: Teknik etkinlik, tütün, Türkiye, Veri Zarflama Analizi, Stokastik Üretim Sınırı Analizi

Introduction

Turkey is a major tobacco producer and exporter, ranking fifth in global tobacco production with a 2.5% share of the market. Tobacco production makes an important and relatively stable contribution ($400-500 million) to export revenues each year and accounts for 22.3% of total agricultural exports (Özgüven et al., 2005).

Contributions of tobacco to the Turkish economy are not limited to production and export revenues. Being an industrial crop, tobacco provides an important source of employment and is a significant source of livelihood for many families through farming, processing, trading, and other tobacco-related activities. There are 334,000 tobacco farmers in Turkey (TZOB, 2004) and tobacco production employs some 1.5 million people, and more are employed in other tobacco-related activities (DPT, 2001).

Different techniques are used in tobacco farming for a variety of reasons. Compared to other crops, irrigation

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and chemical use are not as common since they adversely affect leaf quality. For this reason, tobacco can be considered a crop that is relatively less dependent upon climatic conditions with respect to yield and crop quality. Production depends on intensive family labor because mechanization is very limited in this activity. In fact, tobacco production is an industry that appreciates the potential of the underutilized labor market in Turkey's rural regions. Therefore, it is regarded as a crop that mitigates migration problems.

Due to intensive labor requirements, tobacco is mostly grown on small plots. Considering the great disparities in land distribution and fragmentation in Turkey, tobacco production also makes good use of existing farm structures. Inequalities in income distribution arising from disparities in land distribution can be reduced, to a certain extent, in this way. Tobacco can be grown on sloping lands and on farms with limited irrigation facilities. This fact increases its importance to mountainous regions where alternative income sources are very limited.

Rapid increases in tobacco production beginning in 1987, and the expansion of tobacco farms in less than optimal areas resulted in increased stock costs and decreased leaf quality. As a result, the Turkish government developed policies to more effectively control tobacco farming. Quota applications and the development of alternative crops are among those policies. A quota system, introduced in 1995, was instituted each year (except 1997) with quotas set at varying levels. Despite returning some benefits, the quota system also had some drawbacks, such as increasing migration (Işıklı et al., 2001).

Both quota and alternative crop systems require efficient resource use. Efficiency may help in saving and transferring resources to alternative production areas.

Southeastern Anatolia is one of the most important tobacco producing regions of Turkey. Adıyaman province, which was chosen to represent Southeastern Anatolia in this study, produces about two-thirds of the tobacco grown in this region. Tobacco farming has much greater socioeconomic significance for the study area as compared to other regions of Southeastern Anatolia, since it is a region with sloping land, small-scale farms, high labor potential, and limited alternative income sources. Due to the indispensable function of tobacco farming in this region, efficiency studies play an important role in determining alternative policies.

Technical efficiency studies of tobacco farming have been conducted in the region. Using primary data collected from farmers and employing Data Envelopment Analysis (DEA) methodology, Işıklı et al. (2001) estimated the technical efficiency of tobacco production in Turkey, calculated input losses, and explained their implications for the Turkish economy. According to their results, mean technical efficiency of the all regions was found to be as low as 0.453. Eastern and Southeastern regions were relatively more efficient, with a regional efficiency score of 0.862.

Abay et al. (2004) found a strong positive relationship between input use efficiency in tobacco farming and sustainability of agriculture. They used data obtained from 300 farmers in different regions of Turkey and DEA methodology. According to their results, mean technical efficiency was found to be 0.456 for all regions, and Eastern and Southeastern Anatolia were relatively more successful regions in terms of input use.

The purpose of this study was to investigate the technical efficiencies of tobacco producing farms located within Adıyaman province in Southeastern Anatolia. Both parametric and non-parametric methods were used for this purpose in order to obtain more reliable results.

Materials and Methods

Following the 2000/2001 production period, a survey was conducted in Adıyaman Province, which produces two-thirds of the tobacco grown in Southeastern Anatolia. Ten villages in Adıyaman (8 in Central District and 2 in Kahta District) were chosen as the study areas based on their respective shares in tobacco production. Samples were selected with a simple, random stratified sampling procedure based on the size of the land allocated to tobacco farming. A total of 149 farms, which obtained more than half of their gross production-value from tobacco farming were selected for the study. Data on inputs and tobacco yields collected from farmers were used in the technical efficiency analysis.

Wheat was the most common field crop grown in the farms surveyed, followed by tobacco and barley. However, tobacco had a greater importance in terms of income and employment opportunities. In these farms, tobacco accounted for more than half (about 60%) of the annual crop production value. About 80% of the farms surveyed grew tobacco on land smaller than 0.4 ha. Almost 90% of the farmers farmed their own land. The farms studied allocated about one-fifth of their farmland to tobacco farming. Mean farm land allocated to tobacco was around 1.4 ha. For the cost and production structure of tobacco farming and other detailed information please refer to following documents: Bayaner et al., (2001); AERİ, (2001).

All the surveyed farmers operated under similar climatic, topographic, and structural conditions. Soils were heavy-textured, farms were small and consisted of more than one plot, and fields were sloping and stony. A great majority of the farmers sold their products to the Turkish Tobacco Monopoly and tried to meet its quality standards. In general, tobacco was not irrigated because the quality of tobacco leaves decreases with irrigation. Additionally, chemicals were used, within certain limits, for this reason. However, there were some farmers who sold their products to merchants and end users other than the Turkish Monopoly. These farmers used extra chemicals and irrigation to increase yields.

Efficiency of production units can be measured by parametric and non-parametric methods. Both methods construct a production frontier indicating maximum production attainable under current technology, and evaluates production of each unit with respect to this frontier. Distance from the frontier measures efficiency of the production unit. However, each method uses a different approach to construct production frontiers.

In DEA, a piecewise linear production frontier is constructed from observed data. No a priori functional and distributional forms are assumed in the analyses. Multiple inputs and outputs can be easily handled. These are strengths of the DEA approach. However, DEA is a deterministic model and all deviations from the production frontier are attributed to inefficiencies. Since random errors and statistical noise are not taken into consideration, DEA is very sensitive to measurement errors.

In contrast, Stochastic Frontier Analysis (SFA) makes a distinction between statistical noise and inefficiency. However, SFA is criticized for assuming a priori distributional forms for the inefficiency component and imposes an explicit functional form for the underlying technology. This is the major weakness of the SFA approach.

In agricultural economics literature, use of SFA is recommended because of the inherent nature of uncertainty associated with agricultural production (Coelli et al., 1998). Since each method has some strengths and weaknesses, both were employed in this study to obtain more reliable results. Same data sets were used in both analyses and the results were compared.

One output and five inputs were used in the models. The only output was the tobacco leaf yield per unit area (kg ha^{-1}). Inputs included fertilizer-N, fertilizer-P, labor, draft power, and pesticide costs (1000 TL ha^{-1}). Expenses for these inputs consisted of almost all of the variable costs in tobacco farming.

Fertilizer-N parameter represents nitrogen applied (kg N ha^{-1}), fertilizer-P is phosphorus applied (kg P_2O_5 ha^{-1}), and labor (h ha^{-1}) represents total amount of family labor and hired labor used in tobacco production, from land preparation through harvest. Draft power (h ha^{-1}) represents hours worked with draft animals in production, from land preparation through harvest. Pesticide cost (1000 TL ha^{-1}) is the only non-physical parameter in the model and represents total costs of pesticides. Some descriptive statistics on input and output parameters are presented in Table 1. As it is seen from Table 1, large variations exist in the inputs used.

DEA is a collection of non-parametric methods to measure production efficiency of farms. DEA originated from Farrell's (1957) work; however, it became more popular following the work of Charnes et al. (1978).

SFA measures production efficiency with respect to the relationship between observed production and corresponding production potential. An output oriented DEA model was chosen to make the results of analysis more comparable with those obtained from SFA..

Suppose there are N farms producing M outputs with K inputs. An output oriented DEA model to maximize efficiency for each farm can be constructed as below:

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

Input/Output Variables	Min.	Max.	Mean	S.D.*
Output :				
Tobacco yield (kg ha^{-1})	100.00	1700.00	522.62	343.74
Inputs :				
Fertilizer-N (kg N ha^{-1})	1.08	591.82	106.77	92.54
Fertilizer-P (kg P_2O_5 ha^{-1})	0.65	209.36	61.29	41.39
Labor (h ha^{-1})	209.90	5386.30	1472.90	1004.88
Draft power (h ha^{-1})	2.19	272.11	42.09	44.58
Pesticide (1000 TL ha^{-1})	20.00	12140.00	4634.03	3501.65

* Standard deviation

$$\text{Max}_{\varphi,\lambda} \quad \varphi$$

subject to

$$-\varphi y_i + Y\lambda \geq 0$$

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

$$N1'\lambda = 1$$

$$\lambda \geq 0$$

In the above mathematical model, φ can take any value between one and infinity. The proportional increase in output that could be achieved by the i-th decision making unit (DMU),with input quantities held constant, is indicated by (φ-1). Y is (M x N) the output matrix, X is (K x N) the input matrix, y_i is the output of i-th farm, N1´ is a vector of (N x 1) and a convexity restriction, and λ is (N x 1) a vector of intensity variables. The ratio of $1/\varphi$ defines a technical efficiency score between zero and one (Coelli et al., 1998).

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

The original specification of the stochastic frontier production function is given below (Aigner et al., 1977; Meeusen and van den Broeck, 1977):

$$Y_i = X_i \beta + V_i - U_i \qquad (1)$$

In Equation (1) Y_i denotes the production of the i-th DMU, β represents a (K x 1) dimensional vector of input parameters to be estimated, and X_i is (K + 1) row vector. Its first element is "one". There are 2 disturbance terms in this equation: V_i and U_i. The random error (V_i) accounts for measurement errors, other random factors, and effects of other unspecified input variables in the production function. On the other hand, U_i is a non-negative random variable associated with inefficiency. V_i terms are assumed to be independently and identically distributed N (0, σ_v^2) random errors, independent of the U_is; U_is are non-negative random variables, which are also assumed to be independently and identically distributed and truncated at zero of the normal distribution with mean μ and variance σ_u^2. A Cobb-Douglas production function was assumed for simplicity and convenience.

The maximum likelihood estimates for all the parameters of the SFA were estimated with FRONTIER version 4.1 software (Coelli, 1996b). This software estimates the $\gamma = \sigma^2/\sigma_s^2$ parameter, which takes a value between zero and one. A value of $\gamma = 0$ indicates that the deviations from the frontier are due entirely to noise, while a value of one would indicate that all deviations are due to technical inefficiency.

The ratio of the observed output of the i-th farm relative to the potential output estimated by equation (1) provides the technical efficiency of i-th farm. Hence technical efficiency denoted by TE_i is given by:

$$TE_i = \exp(-u_i) \qquad (2)$$

Technical efficiencies vary between zero and one.

Results

Efficiency scores obtained with parametric (SFA) and non-parametric methods (DEA) are compared in Table 2.

Table 2. Frequency distributions of technical efficiency scores obtained by SFA and DEA models.

Efficiency Scores	SFA	DEA		
		CRS	VRS	SE
1.00	-	17	33	18
0.90-1.00	-	3	7	46
0.80-0.90	12	4	7	28
0.70-0.80	19	9	5	20
0.60-0.70	42	7	12	19
0.50-0.60	20	16	13	7
0.40-0.50	14	14	14	7
<0.40	42	79	58	4
Mean	0.54	0.45	0.56	0.82

Of the 149 tobacco farms studied, 17 farms under CRS and 33 farms under VRS were fully efficient. Seventy-nine farms under CRS and 58 farms under VRS showed a performance below 0.40. No farm was found to be fully efficient with SFA, and the highest efficiency score was 0.88.

In addition, slack variables were analyzed. A slack variable indicates excess of an input. A farm can reduce its expenditure on an input by the amount of slack variable, without reducing its output. Mean input slacks and excess input use percentages are presented in Table 3.

Table 3. Input slacks and number of farms using excess inputs.

Input	Number of farms	Mean slack	Mean input use	Excess input use (%)
Fertilizer-N	63	37.9	106.8	35.49
Fertilizer-P	49	10.2	61.3	16.64
Labor	61	430.9	1472.9	29.26
Draft power	44	11.0	42.1	26.13
Pesticide costs	54	913.6	4634.0	19.72

The greatest excess was in nitrogen fertilizer input, followed by labor and draft power. According to these results, the sampled farms could reduce their nitrogen fertilizer use by 35% and their labor use by 29%, while maintaining the same levels of production. Additional input savings are shown in Table 3.

In general, the cause of inefficiency may have been 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. In this study, scale efficiencies were relatively high; therefore, it seems that efficiencies were mainly due to improper input use.

Mean scale efficiency of the sample tobacco farms was 0.82. Of the 149 tobacco farms, 18 showed constant returns to scale, 50 showed increasing returns to scale, and 81 showed decreasing returns to scale. Characteristics of optimal, sub-optimal, and super optimal farms are provided in Table 4. As seen from the table, for the optimal farms, mean farm size and mean output were 1.272 ha and 924.4 kg ha^{-1}, respectively. The largest optimal farm was 2.5 ha.

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

	Number of farms	Mean farm size (ha)	Mean output (kg ha^{-1})
Sub-optimal	50	2.91	379.0
Optimal	18	1.27	924.4
Super Optimal	81	0.85	520.5

The statistics for the general likelihood test for $\gamma = 0$ had a value of 7.950. The null hypothesis that there is no technical inefficiency in the model is rejected at the 5% level, indicating the coefficients of the frontier production function are significantly different from the average production function estimated with the Ordinary Least Squares (OLS) model (Battese and Coelli, 1988; Coelli, 1996a).

Maximum likelihood estimates of the parameters are presented in Table 5. The signs of all the coefficients on labor and draft power parameters are positive, but only coefficients of phosphorus, labor, and pesticide are

Table 5. Coefficients of stochastic frontier function.

Variables	Coef.	S.E.	t
Intercept	4.318	0.427	7.776
Ln (Fertilizer-N)	0.008	0.051	0.160
Ln (Fertilizer-P)	0.085	0.059	1.442
Ln (Labor)	0.205	0.086	2.392
Ln (Draft power)	0.041	0.053	0.179
Ln (Pesticide)	0.004	0.176	5.860
σ^2	1.030	0.176	5.860
γ	0.877	0.055	15.946
Log-likelihood (H_1)	-152.173		
Log-likelihood (H_0)	-148.199		
Log-likelihood test	7.950		

Coef: Coefficients; S.E.: Standard error; t: t-statistics

significant. DEA results seem more realistic given the social and economic conditions of the region. However, further analyses are required.

Spearman correlation coefficients of the technical efficiency scores were computed in order to examine agreement between results obtained from DEA and SFA and are shown in Table 6. All correlation coefficients are positive and significant at the 0.01 level. This indicates a strong agreement between results. The strongest correlation is between SFA and DEA-CRS models.

Table 6. Spearman correlation coefficients among alternative efficiency measures.*

	TE-DEA (CRS)	TE-DEA (VRS)	TE-SFA
TE-DEA (CRS)	1.000		
TE-DEA (VRS)	0.911	1.000	
TE-SFA	0.802	0.719	1.000

* All the correlation coefficients are significant at the 0.01 level (2-tailed).

An additional analysis was carried out in order to determine if both approaches identified the same "best-practice" and "worst-practice" farms. For this purpose, farms were sorted according to their DEA and SFA efficiency scores in descending order. Top and bottom quarters of those lists (the first and last 37 farms) were compared. Sixty-two percent of the farms identified by SFA as "top 37 best-practice farms" also appeared in the "top 37 best-practice farm list" of VRS-DEA. The same analysis was applied for the bottom quarter (worst-practice). Of the farms having been identified by one method as having efficiency scores in the bottom quarter, 78% of them also appeared in the bottom quarter identified by the other method. Best and worst case practice correspondences (62% and 78%, respectively) were statistically different from 25% correspondence, which random chance would yield. As a result of this analysis, different estimates obtained by different methods were found to be consistent. Correspondence analysis is presented in Table 7.

Table 7. Correspondence (%) of best-practice and worst-practice farms across methods.

	DEA-CRS	DEA-VRS	SFA
Best practice farms			
DEA-CRS	-	78.38**	67.57**
DEA-VRS	78.38**	-	62.16
SFA	67.57**	62.16	-
Worst practice farms			
DEA-CRS	-	86.49**	72.97**
DEA-VRS	86.49**	-	78.38**
SFA	72.97**	78.38**	-

* Significantly different from 0.25 at 0.05 level.
** Significantly different from 0.25 at 0.01 level.

Efficiency scores given to each individual farm and mean efficiencies were different for different models. To a certain extent this is expected, since different models work under different assumptions.

Since DEA attributes any deviation from the frontier to inefficiencies, DEA efficiency scores are expected to be less than those obtained with SFA. However, this was not the case in the present study. SFA scores were lower than DEA scores, but mean scores were very close. When DEA frontier tightly envelopes data, this situation may occur. Other researchers have obtained the same result (see Sharma et al., 1997).

Therefore, it can be confidently stated that the efficiencies of the farms studied lie somewhere between 0.54 and 0.56.

Discussion

This study highlights the importance of using different analytic methods as complimentary tools to arrive at a definitive conclusion. Such a study may not give a single value, but a range within which true efficiency lies. The narrower the range, the more confident the researchers can be. In this study, this range was very narrow. Mean efficiency was between 0.54 and 0.56 when SFA and VRS-DEA models were considered. Also, both methods identified almost all the same farms as “best practice” and “worst practice” farms.

This value (0.55) was very low compared to the efficiency score (0.86) obtained for Eastern and Southeastern Anatolia. It is thought that the sampling area and size, difference in assumptions employed (input and output oriented DEA), and parameters used in the model may have caused the great difference observed.

The present study indicates that there are important resource-use inefficiencies in tobacco production in Southeastern Anatolia. The mean efficiency score was 0.55. This result indicates that technical efficiency can be increased by 45% through better use of available resources, while using current technology. This can be achieved by improving farmer-specific factors, including access to extension services.

There was not strong agreement on input use between the different analysis methods. DEA results on slacks showed that nitrogen fertilizer, labor, draft power, and pesticide costs could be reduced to a great extent, while maintaining the same level of production. Since there are other studies and evidence supporting this, this result seems realistic. When the opportunity cost of labor is too low and farmers do not have opportunities other than farming, labeling excess labor use (particularly family labor) as inefficient is a subject of debate. Moreover, since measurement of labor is very difficult, this parameter should be interpreted more cautiously. However, achieving efficiency may release some resources, which may be used in alternative areas. Therefore, policy should target providing a solution to hidden unemployment, increasing the size of farms, and a land consolidation program. Creating permanent off-farm employment and income opportunities will help in increasing efficiency.

This study reveals the existence of technical efficiency in tobacco production in Southeastern Anatolia. However, allocative efficiency is also important and should be studied. A more detailed study involving environmental variables may reveal the determinants of efficiency. These determinants may provide a clearer picture of particular farm aspects that could be targeted in order to increase efficiency.

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