Technical Efficiency of Sunflower Production in Trakya Region by DEA

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The objective of this paper is to determine how efficiently the resources are used in sunflower production in Turkey. The data used in efficiency measurements covers the provinces Tekirdag, Kırklareli and Edirne in Trakya region which is the most important area of sunflower seed production. The production area of sunflower is about 307 thousand hectares, 57% of total sunflower sown area in Turkey and the amount of production is 498 thousand metric tons, 62% of the total sunflower production. 197 farmers were interviewed face to face to obtain the data. Efficiency measurements are made by means of the Data Envelopment Analysis (DEA) with respect to constant return to scale for each province. The Efficiency scores is decomposed into pure technical efficiency and scale efficiency for getting more information from the measurements. Total sunflower production (kg) is used as the output and land (decar); labour (hour), tractor use (hour), nitrogen fertilizer use (kg), seed use (kg) and pesticide (kg) are considered as the main inputs. Average technical efficiency score covering all the provinces is estimated as 0.672. Although none of the provinces produces sunflower efficiently, Tekirdag province is relatively more successful in input use. Tekirdag province has the highest pure technical efficiency and scale efficiency score. Considering all the regions, the reason for inefficiency is not optimal production but not producing a certain output with minimum input. Yield is a factor that increases efficiency.

Keywords: data envelopment analysis; technical efficiency; sunflower

Veri Zarflama Yöntemiyle (DEA) Trakya Bölgesinde Ayçiçeği Üretiminin Teknik Etkinliği

Bu çalışmanın amacı, ayçiçeği üretiminde kaynakların ne kadar etkin kullanıldığını belirlemektir. Etkinliğin ölçülmesinde kullanılan veri seti, en önemli ayçiçeği üretim yeri olan Trakya bölgesindeki Tekirdağ, Kırklareli ve Edirne illerinden toplanmıştır. Trakya bölgesi, yaklaşık 307 bin hektar ekiliş alanıyla Türkiye'deki toplam ekiliş alanının %57'sini ve 498 bin ton ile toplam üretim miktarının %62'sini karşılamaktadır. Veriler, 197 üretici ile karşılıklı görüşme yoluyla elde edilmiştir. Etkinlik ölçümleri, her bir il için ölçeğe göre sabit getirili veri zarflama yöntemi yardımıyla yapılmıştır. Etkinlik değerleri, ölçümlerden daha fazla bilgi elde edebilmek için saf teknik etkinlik ve ölçek etkinliğine ayrıştırılmıştır. Çalışmada çıktı olarak toplam ayçiçeği üretimi (kg), temel girdiler olarak ekiliş alanı (da), işgücü (saat), traktör çekigücü (saat), azot kullanımı (kg), tohumluk (kg) ve pestisid kullanımı (kg) dikkate alınmıştır. Bölge genelinde ortalama teknik etkinlik 0.672 olarak hesaplanmıştır. Hiç bir ilin ayçiçeği üretiminde etkinliği sağlayamadığı, bununla birlikte Tekirdağ ilinin kaynak kullanımı açısından diğerlerine göre daha başarılı olduğu belirlenmiştir. En yüksek saf teknik etkinlik ve ölçek etkinliği değeri yine Tekirdağ iline aittir. Tüm iller dikkate alındığında, etkin olmayan üretimin nedeni, hem optimal ölçekte üretim yapamamak, hem de mevcut üretimi en az girdi kullanarak gerçekleştirememektir. Verim, etkinliği arttıran bir faktördür.

Anahtar Kelimeler: veri zarflama yöntemi; teknik etkinlik; ayçiçeği

Introduction

Vegetable oils have an important role in human nutrition. According to nutrition specialists, vegetable oil consumption per capita must be at least 23-25 kg in a year. On the other hand, per capita vegetable oil consumption is 17-18 kg/year in Turkey (Unakıtan, 2003). Although Turkey's total vegetable oil production is sufficient for the current population, Turkey will need more vegetable oil in the next years due to its increasing population. Sunflower oil is an important part of total vegetable need with the production amount of 800-850 thousand tons and the imported amount of 500-650 thousand tons by years (Oilworld, 2002).

Sunflower oil and olive oil have a great role in Turkish consumption pattern. Hence, an amount of sunflower oil that can at least meet the domestic need is compulsory. Trakya region is the main agricultural area where a great part of the production is obtained. Agricultural lands allocated to Sunflower production is 307 thousand hectares, 57 percent of the total sunflower area, and production amount is 498 thousand tons in this region, 62 percent of the total sunflower production.

The main objective of this paper is to determine how efficiently the resources are used in sunflower production. The data used in efficiency measurements covers the provinces Tekirdag, Kırklareli and Edirne in Trakya region which is the most important area of sunflower seed production. In this framework, it is aimed to measure overall efficiency level of the provinces and expose efficiency differences among the provinces for giving the necessary keys to the agricultural policies regarding sunflower production and input use.

Agricultural economists have examined the sources of inefficiency over the past several years. Some of the studies that have analyzed efficiency at farm level are Fraser and Cordina (1999), Shafiq and Rehman (2000). Besides Günden, Miran, and Sarı (1998), Günden, Miran and Türkekul (1999), Günden, Karlı, and Miran (1999), Günden and Miran (2001), Abay, Miran and Günden (2004) have analyzed productivity and efficiency using DEA related to Turkey.

Material and Methods

Efficiency measurement

The efficiency of a production unit is a comparison between observed and optimal values of its output and input (Lovell, 1993). Most of the literature related to efficiency measurements depends on the study by Farrell (1957) that he explained his ideas considering a simple unit producing one output with two inputs under the assumption of constant return to scale which is the basis for modern efficiency measurements. Farrell (1957) stated that efficiency consists of two components, technical efficiency and allocative efficiency. Technical efficiency is the ability of obtaining maximum output by using certain amount of input while allocative efficiency is the ability of input use at a rate which makes the profit maximum. Farrell (1957) employed input oriented approach in the efficiency measurement. This approach measures technical inefficiency as proportional increase in input use by keeping output constant. As an alternative way, technical inefficiency can be measured as a proportional increase in output by keeping input use constant which is called output-oriented approach. Farrell (1957) suggested the use of either a non-parametric piece-wise linear convex isoquant or a parametric function. In non parametric method, efficient production frontier is constructed by taking all the observations included in the sample into consideration and efficiency score of each production unit is measured according to the frontier.

The constant return to scale (CRS) DEA

DEA is commonly used to evaluate the efficiency of a number of farms or Decision Making Units (DMUs). DEA, a nonparametric mathematical programming method, depends on the views of Farrel (1957) on efficiency. It involves the use of linear programming to construct an efficiency frontier (piece-wise). The frontier provides a relative measurement of each unit. The frontier that comprises efficient units is the expected target for other units which are inefficient.

The first DEA model was suggested by Charnes, Cooper and Rhodes (1978) and was based upon the assumption of constant return to scale. In this study, input oriented CCR model, a form of envelopment, was used to measure efficiency of sunflower production mathematical form was expressed as follows;

$$\begin{aligned} &\text{Min}_{\lambda,\theta}\ \theta \\ &\text{st}\quad -y_i + Y\lambda \geq 0 \\ &\qquad \theta x_i - X\lambda \geq 0 \qquad\qquad (1) \\ &\qquad \lambda \geq 0 \end{aligned}$$

where θ is a scalar and λ is vector of constants in Nx1. θ is the i^{th} unit's efficiency score (i=1,2,…,197). The estimated θ will satisfy the restriction $\theta \leq 1$ with a value $\theta = 1$ indicating a technically efficient farm in sunflower production. When the linear programming problem above is solved, 197 efficiency scores are obtained. y_i in the equation set is the amount of sunflower production of the i^{th} farm, Y is the matrix (1x197) of covering the amounts of sunflower production for all farms. x_i is the i^{th} farm's level of input use. In this study includes six inputs such as land, labour, tractor use, nitrogen, seed use and pesticide. X indicates the input matrix of 6x197.

The variable return to scale (VRS) DEA

Banker, Charnes ve Cooper (1984) re-developed the DEA model, which is depended upon the assumption of constant return to scale (CRS), considering the variable return to scale (VRS). The use of the CRS specification when not all firms are operating at the optimal scale results in measures of technical efficiency (TE) which are confounded by scale inefficiency (SE). The use of the VRS specification permits the calculation of these SE effects (Coelli et al, 1998).

The CRS linear programming problem can be easily modified to account for VRS by adding the convexity constraint N1'λ =1.

$$\begin{aligned} &\mathrm{Min}_{\lambda,\theta}\ \theta, \\ &\mathrm{st}\quad -y_i + Y\lambda \geq 0 \\ &\qquad \theta x_i - X\lambda \geq 0 \qquad (2) \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0 \end{aligned}$$

where N1 is an Nx1 vector of ones.

Scale efficiency

Total technical efficiency measure (TECRS) obtained from constant return to scale DEA is decomposed into pure technical efficiency (TEVRS) and scale efficiency (SE). If there is a difference in CRS and VRS TE scores for a particular firm, then this indicates that the firm has scale inefficiency, and that the scale inefficiency can be calculated from the difference between the VRS and CRS TE scores.

Total Efficiency (TE_{CRS}) = Pure Technical Efficiency (TE_{VRS}) * Scale Efficiency (SE)

Total technical efficiency covers both technical efficiency and scale efficiency. Scale efficiency points out the losses due to non-optimal production size (Färe et al, 1985). In other words, if the efficiency score decreases when the activity size increases or decreases, then it refers to a scale inefficiency. The decomposition of scale efficiency gives pure technical efficiency. The purpose of the decomposition is to determine the source of inefficiency.

The sample of sunflower producers

The data were collected from sunflower producers in the region by face to face interviews. The sample size was found as 197 farmers using the following equation;

$$n = \frac{Np(1-p)}{(N-1)\sigma^2_{\hat{p}x} + p(1-p)}$$

At 99% confidence level and 10% error level with p=0.5 and q=0.5 is used for getting the maximum sample size. Distribution of the sample size by provinces is given in Table1 (Newbold, 1995).

In the formula:

n : Sample size
N : Total number of producer
p : Proportion for the sunflower producers (for maximum sample size, 0.5 was accepted).
$\sigma^2_{\hat{p}x}$: Variance

Table 1. Number of interviews by provinces

Province	Number of Interviews
Tekirdag	53
Kırklareli	64
Edirne	80
Total	197

Data and variables

In efficiency measurements, total sunflower production (kg) were used as the output and land (decar), labour (hour), tractor use (hour), nitrogen (kg), seed (kg) and pesticide (kg) are considered as the main inputs.

Data on each variable was in the basis of plot. Total sunflower production is the dependent variable in DEA model. Land is the sunflower production field expressed as decar. Data of labour, including family labour, is a total hour calculated step by step in the production process. Tractor use in hour was also gathered step by step and computed as a total. Different fertilizers used for sunflower production were converted to nutrient values in kg with respect to N (nitrogen). Sunflower seed and chemical spray named Triflin were considered separately as total.

The results showed that the recent average yield of sunflower seed was 174.79 kg/da in Trakya region which is quite higher than last several years, possibly by the effect of rainfalls in 2002 production term in Trakya region except Edirne province. In addition, Edirne does not agricultural fields of productive as much as Tekirdag fields. This is an important factor for low sunflower seed yield.

According to the data analysis, average plot size is 42 decars in Tekirdag. This is higher than those of other provinces due to the high number of wealthy farmers in Tekirdag province.

Table 2 shows that man labour usage is equal to 4 hours per decare in Tekirdag. Because of the orobange weed, labour usage is higher than normal. Nitrogen use was calculated different in three provinces. Nitrate usage of Tekirdag province was calculated very high. Intense rainfall prevented the accumulation of chemicals in the soil and more fertilizer was required. In contrast, nitrate use was too low in Edirne due to more chemical accumulation in soil. Nitrate use in Kırklareli is approximately the same as the region's average use.

Average tractor usage is equal to 1 hour per decare and seed is 380 gram per decare in Trakya region. Also, pesticide usage is approximately 150 gram per decare. These are almost equal in each three provinces.

Table 2. Mean of Sunflower Output and Main Inputs Used

Variable	**Unit**	**Province**	**Mean**
Sunflower Yield*	Kilograms	Tekirdağ	203.61
		Kırklareli	193.30
		Edirne	138.53
		All provinces	174.79
Land	Decar	Tekirdağ	41.85
		Kırklareli	27.08
		Edirne	33.10
		All provinces	33.50
Labour use	Hours/Decar	Tekirdağ	4.03
		Kırklareli	3.51
		Edirne	3.26
		All provinces	3.58
Tractor hours	Hours/Decar	Tekirdağ	1.05
		Kırklareli	0.97
		Edirne	1.00
		All provinces	1.01
Nitrogen fertilizer use	Kg nutrient /Decar	Tekirdağ	8.55
		Kırklareli	4.56
		Edirne	2.24
		All provinces	4.97
Seed use	Kg nutrient /Decar	Tekirdağ	0.37
		Kırklareli	0.38
		Edirne	0.38
		All provinces	0.38
Pesticide	Kilograms /Decar	Tekirdağ	0.15
		Kırklareli	0.15
		Edirne	0.16
		All provinces	0.15

*Significiant by analysis of variance (one-way) for $p<0.05$

Results

In this study, input oriented efficiency scores were calculated in general and with respect to the each province. The scores seek the answers for the question "how much can the input levels be decreased proportionally without any change in the current output levels". From the standpoint of the study, calculations were made on "how much land, labour, tractor use, nitrogen, seed and pesticide of an inefficient plot can be decreased proportionally in reference to efficient plots on the efficiency frontier provided that the current production level of the inefficient plot is kept constant". For each plot, an efficiency score was calculated between 0 and 1 (or 0% and 100%) taking the reference set or the efficiency frontier into consideration.

Average technical efficiency score (the CRS case) in general covering all the provinces is 0.672 (Table 3). This score means that the same amount of production in plots can be obtained even if the inputs used for the sunflower production are decreased by 32.8 %. Efficiency was divided into two components, pure technical efficiency and scale efficiency in order to discriminate the sources of inefficiency. Low pure technical efficiency score points out a shortcoming in minimum input use while low scale efficiency shows a production in non-optimal scale. Then we can say that the reasons for inefficiency are not to be able to produce sunflower with the minimum input use and deviation from the optimum scaled production.

The number of the plots, which are within the reference set or on the efficiency frontier, whose efficiency score is 1.00 is 19. In other words, on 9.64 % of the plots the current outputs are obtained by the use of minimum level input. 22.33% and 11.17 % of the plots meet the pure technical efficiency and scale efficiency, respectively. These imply that inefficiency is the main result of technical inefficiency, approximately 23%, although scale is a problem as well.

Table 3. Results of the DEA Models

Efficiency	Efficiency scores (for 197 DMU)		
	Total Efficiency (the CRS case)	Pure Technical Efficiency (the VRS case)	Scale Efficiency
Minimum	0.262	0.339	0.350
Maximum	1.000	1.000	1.000
Mean	0.672	0.774	0.867
Number of DMU equal to %100	19	44	22
Rate of DMU equal to %100	9.64	22.33	11.17

When total technical efficiency scores are evaluated by provinces;

The Tekirdag province's total technical efficiency score is 0.744 as an average. The Kırklareli province's mean is 0.701 and lastly the same score for the Edirne province is 0.600 (Table 4). There is a statistically significant difference among provinces by total technical efficiency scores. The maximum of mean efficiency scores is of the Tekirdağ province and the minimum is of The Edirne province.

When technical efficiencies and scale efficiencies are examined: The plots that provide technical efficiency are mostly seen in the Edirne province (18 plots). Tekirdag (15 plots) and Kırklareli (11 plots) are the following provinces. The highest pure technical efficiency score is of the Tekirdağ province, 0.813, and the smallest score is of the Edirne province, 0.744. Approximately 26 percent of inefficiency depends on technical inefficiency in the Edirne province (Table 4).

Table 4. Results of DEA models by provinces

Province	Number	Efficiency of DMU	Mean	Eff=100	% Efficient
Tekirdağ	53	Total Efficiency*	0.744	8	4.06
		Pure Technical Efficiency	0.813	15	7.61
		Scale Efficiency	0.914	8	4.06
Kırklareli	64	Total Efficiency*	0.701	6	3.05
		Pure Technical Efficiency	0.778	11	5.58
		Scale Efficiency	0.896	8	4.06
Edirne	80	Total Efficiency*	0.600	5	2.54
		Pure Technical Efficiency	0.744	18	9.14
		Scale Efficiency	0.814	6	3.05

*Significiant by analysis of variance (one-way) for $p<0.05$

Table 5. Characteristics of frontier DMU

Input/output variables	Mean on frontier DMU	Mean of all provinces
Sunflower yield (kg/decar)*	244.76	169.09
Inputs		
Land (decar)	26.16	34.28
Labour use (h/decar)	2.73	3.65
Tractor hours (h/decar)	0.86	1.02
Nitrogen fertilizer use (kg nutrient/decar)	4.66	4.99
Seed use (kg/decar)	0.39	0.38
Pesticide (kg/decar)	0.14	0.15

*Significiant by analysis of variance (one-way) for $p<0.05$

Among the provinces the highest scale efficiency is of the Tekirdag province. The average farm size is larger than the others in the province. The smallest scale efficiency score is of Edirne province. Considering all the provinces, the reason for inefficiency is not optimal production but non frontier production or not producing a certain output with minimum input.

Sunflower yield of the farms on the frontier and the yield of all provinces are statistically different from each other. Frontier farms have higher yield of sunflower with 244.76 (Table 5). There is not a significant difference among other inputs use. It can be said that yield is a factor that increases efficiency expected.

Conclusion

In the research, technical efficiency of sunflower production was measured using data envelopment analysis under the CRS and VRS assumptions. Results of this study showed that sunflower is not produced efficiently in the provinces and average technical efficiency score for all the provinces was estimated 0.672. This score means that the same amount of production in plots can be obtained even if the inputs used for the sunflower production are decreased by 32.8 %. In other words, one could decrease the input use without a decrease in total production. Farmers included in Tekirdag province are relatively more efficient than the others. This means that they produce the same amount of sunflower by the use of less amount of the resources. The interpretation of this result is that the sunflower farmers in Tekirdag province use the resources relatively more efficiently due to having the more yield. Considering all the provinces, inefficiency is caused by producing a certain amount of output with minimum input rather than optimal production or non frontier production. It is straightforward that extension works targeted to farmers should focus on the attempts for the less use of chemical fertilizer and sprays etc. Moreover, the policies which are interested in transferring the excessively used resources to alternative crops without any negative effect on the current amount of sunflower production should also be noted.

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