



Efficiency Analysis of Silage Maize Production in the Province of Canakkale

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Research Article

Received: 23 March 2013

Accepted: 15 May 2013

Published: 17 August 2013

Abstract

Aims/ objectives: This study offers an efficiency analysis of maize silage production in the province of Canakkale. As a next step, the role of various socio-economic factors on efficiency has been examined to find out which socio-economic factors could be improved to attain higher efficiency levels.

Place and Duration of Study: In 15 villages of the province of Canakkale during Summer 2011.

Methodology: 15 villages in the province of Canakkale, which have similar climate conditions, production structures and technical properties, are determined. Then, 70 silage maize growing farms are randomly selected from these 15 villages. Data regarding input-output relations and socio-economic properties of farms were collected for the production season of 2009-2010 in the summer of 2011. Technical, allocative and economic efficiency measures are derive for this sample by employing parametric stochastic frontier analysis and nonparametric data envelopment analysis (DEA). Finally, socio-economic factors affecting efficiency levels are estimated with a Tobit estimation procedure.

Results: The analysis shows that the mean technical, allocative and economic efficiencies are found to be 76.9%, 87.1% and 77.8%, respectively, with the parametric approach and 84.2%, 78.2% and 64.7% with DEA. It is found out that the efficiency rankings of the sample producers based on the two approaches are very much correlated, indicating that there is an agreement between the two approaches. Both approaches show that there are considerable inefficiencies in maize silage production in the region. Analysis of the role of various socio-economic factors on productive efficiency shows that the size of the farm, number of irrigations and irrigation interval are found to be important determinants of efficiency.

Conclusion: Both approaches show that there are serious inefficiencies in maize silage production in Canakkale implying that there is a lot of room for improvement.

Keywords: Silage maize, efficiency analysis, parametric stochastic frontier, nonparametric DEA.

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1 Introduction

Corn is the most widely grown (785 mt) cereal in the world with a double grain yield per unit area coming after wheat and barley. In Turkey, corn is produced on approximately 550 thousand hectares with an annual production of 3.5 mt, which constitutes nearly half of the total amount produced in the Mediterranean region [1]. Interestingly, maize cultivation as forage as a side branch of maize agriculture has begun to constitute a big part of the whole production recently. This fact could be easily grasped by looking at the increase in the planting area that is separated for maize silage in Turkey. While the planting area of maize silage was around 1.5 million decares¹ in 2004, it went up to 2.9 million decares in 2008, a period of only four years. Similarly, while the total production of maize silage was 6.8 mt in 2004, it has increased to 11.5 mt in 2008 [2]. This increase is owing to the evidence that maize silage in the diet of dairy cows and sheep leads to higher milk yield, milk protein content and better meat quality. Maize is a better choice as an animal feed compared to other crops due to its rich protein, oil and starch content [3]. Additional to its rich dry matter content, maize silage is obtainable more economically compared to other crops with the same level of organic content [4]. All these reasons have led to the escalation of maize silage production. The region of Canakkale has been no exception and maize grown for silage now comprises an important part of the whole agricultural production. This observation is not surprising considering the fact that Canakkale is one of the most important centers of the milk and dairy product industry in Turkey. As a result, silage maize production in the region has become more common to cover the needs of the local industry [5].

Especially for developing countries like Turkey, the efficient use of limited resources is vital to have a better competitive position. The aim of each producer that behaves rationally, is expected to be increasing the amount of output obtained as a result of production with existing resources. If this is the case, the producer is then to be called efficient. There are two main approaches that are used for efficiency analysis: the parametric stochastic frontier production function approach developed by [6], [7] nonparametric data envelopment analysis (DEA) developed by [8]. Both approaches have their own strengths and weaknesses that are summarized by [9]. While the stochastic frontier approach is able to deal with stochastic noise and permits statistical tests of hypotheses pertaining to production structure and the degree of inefficiency, it imposes an explicit parametric form for the underlying technology and an explicit distributional assumption for the inefficiency term. On the other hand, the main strengths of the DEA approach are to avoid parametric specification of technology as well as the distributional assumption for the inefficiency term. However, a frontier estimated by DEA is likely to be more sensitive to measurement errors or other noise in the data since DEA is deterministic and attributes all the deviations from the frontier to inefficiencies. Given these strengths and weaknesses of the parametric and nonparametric DEA approaches, it is relevant to compare the efficiency analysis results of the two approaches with the same data set.

There are three different types of efficiencies that previous studies define and determine: technical, economic and allocative efficiencies. Accordingly, technical efficiency is defined as producing the maximum output from the minimum quantity of inputs. Second, economic efficiency could be defined as using resources in a way such that costs are minimized and optimal inputs are selected. Last but not least, allocative efficiency is the success of choosing the most suitable combination of inputs to minimize the cost of production by considering the costs of inputs [10]. Agricultural efficiency analyses, which look at these different types of efficiencies for various products, are particularly important for economies that are heavily based on agriculture like Turkey. Although there have been previous efficiency analyses of various crops in different regions of Turkey, there exists not many for silage maize. Accordingly [11], which derives technical, economic and allocative efficiencies of corn producers in Sanliurfa, finds out that number of irrigation and irrigation interval are very important determinants of efficiency levels. On the other hand, [11] estimates technical and economic

¹ A metric unit of area used in the former Ottoman geography of the Middle East and the Balkans.

efficiencies for peanut farming in the provinces of Adana and Osmaniye and shows that number of irrigations is negatively correlated with the efficiency level but insignificant. However, the authors find that nitrogen dose is significant and positively correlated. Once we take a broader look that is not only limited to Turkey but includes other developing countries, a literature review by [12] points out that the average technical, allocative and economic efficiencies of 14 developing countries are 72%, 68% and 43%, respectively. One can realize that these average efficiency levels are much lower compared to current paper's results which indicates the efficiency of silage maize production in the province of Canakkale, Turkey lies comparably at a higher level.

In this regard, the main purpose of this study is to estimate the technical, allocative and economic efficiencies for a sample of producers growing maize for silage in the region of Canakkale by employing nonparametric DEA and parametric stochastic approaches. It is important to be able to understand how efficiently the production of maize silage is executed by the farmers in the villages of Canakkale in order to give some suggestions for improvement if necessary, considering the fact that no similar study has been done for the region before. Furthermore, this paper determines the effects of socio-economic factors, which are expected to be in relation with production, on the estimated efficiency levels.

2 Analytical Framework

2.1 Parametric Approach

This section presents briefly the details of the parametric technique used in this study. It follows the [13] cost decomposition procedure to estimate technical, allocative and economic efficiencies as used in many earlier studies [14], [15], [16].

The firm's technology may be represented by a stochastic production frontier as follows:

$$Y_i = f(X_i; \beta) + \epsilon_i \quad (2.1)$$

Here in equation (2.1), Y_i denotes output of the i th producer; X_i is a vector of actual input quantities used by the i th producer; β is a vector of parameters to be estimated and ϵ_i is the composite error term defined as

$$\epsilon_i = v_i - u_i \quad (2.2)$$

by following [6], [7]. It is assumed that v_i s are independently and identically distributed $N(0, \sigma_v^2)$ random errors, independent of the u_i s. And, u_i s are nonnegative random variables, associated with technical inefficiency in production. They are assumed to be independently and identically distributed and truncations (at zero) of the normal distribution with mean μ and variance σ_u^2 ($|N(\mu, \sigma_u^2)|$). Estimators for β and variance parameters $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma^2$ are obtained by the maximum likelihood estimation of equation (2.1).

Equation (2.1) yields after subtracting v_i from both sides:

$$\tilde{Y}_i = Y_i - v_i = f(X_i; \beta) - u_i \quad (2.3)$$

where \tilde{Y}_i is the observed output of the i th firm, which is adjusted for the stochastic noise captured by v_i .

For a given level of output \tilde{Y}_i , the technically efficient input vector for the i th firm, X_i^t , is derived by simultaneously solving equation (2.3) and the input ratios $X_1/X_i = k_i$ ($i > 1$), where k_i is the ratio of observed inputs, X_1 and X_i . The dual cost frontier may be written in a general form as follows, by assuming that the production function in equation (1) is self-dual (e.g., Cobb-Douglas):

$$C_i = h(W_i, \tilde{Y}_i; \alpha) \quad (2.4)$$

Here in equation (2.4), C_i is the minimum cost of the i th firm with the output level \tilde{Y}_i , W_i is a vector of input prices for the i th firm, and α is a vector of parameters. The economically efficient input vector for the i th firm, X_i^e , can be derived by applying Shephard's lemma:

$$\frac{\partial C_i}{\partial W_k} = X_k^e(W_i, \tilde{Y}_i; \psi) \quad k = 1, 2, \dots, m \quad \text{inputs} \quad (2.5)$$

where ψ is a vector of parameters. Then, the observed, technically efficient and economically efficient costs of production for the i th firm are given as $W_i'X_i$, $W_i'X_i^t$ and $W_i'X_i^e$, respectively. From these cost measures, one may compute technical (TE) and economic efficiencies (EE) for the i th firm as follows:

$$TE_i = \frac{W_i'X_i^t}{W_i'X_i} \quad (2.6)$$

$$EE_i = \frac{W_i'X_i^e}{W_i'X_i} \quad (2.7)$$

By using equations (2.6) and (2.7), one may derive the allocative efficiency (AE) as follows (Farrell 1957):

$$AE_i = \frac{W_i'X_i^e}{W_i'X_i^t} \quad (2.8)$$

2.2 Nonparametric Approach

Technical, economic, allocative efficiencies may be alternatively obtained by employing the nonparametric, DEA approach. This section provides a short overview of this approach [8], [18], [16].

Suppose that there are n producers or firms, each of which produces a single output by using m different inputs. Here, Y_i is the output produced and X_i is the $(m \times 1)$ vector of inputs used by the i th firm. Denote Y as the $(1 \times n)$ vector of outputs and X as the $(m \times n)$ matrix of inputs of all n firms in the sample. Finally, W_i is the $(m \times 1)$ vector of input prices for the i th firm.

The solution of the following DEA model gives the technical efficiency (TE) measure under constant returns to scale (CRS):

$$\min_{\theta_i^{CRS}, \lambda} \theta_i^{CRS}$$

$$\text{subject to } Y\lambda - Y_i \geq 0$$

$$\theta_i^{CRS} X_i \geq X\lambda$$

$$\lambda \geq 0 \quad (2.9)$$

Here in equation (2.9), θ_i^{CRS} is a TE measure of the i th firm under CRS and λ is an $(n \times 1)$ vector of weights attached to each of the efficient firms. In order to obtain the TE score for each of the n firms, a separate linear programming problem needs to be solved. It is given that $\theta^{CRS} \leq 1$ and if $\theta^{CRS} = 1$, so the firm is technically efficient and lies on the frontier. On the other hand, if $\theta^{CRS} < 1$, the firm is technically inefficient and lies below the frontier. Then, the technically efficient cost of production of the i th firm is given by $W_i'(\theta_i^{CRS} X_i)$ under DEA with CRS.

In addition to DEA with CRS, one may get a variable returns to scale (VRS) DEA model easily by adding an additional constraint, which is $\sum_{i=1}^n \lambda_i = 1$, to the model in equation (2.9). If we denote the TE measure of the i th firm under DEA VRS model as θ_i^{VRS} , then the technically efficient cost of production of the i th firm is given by $W_i'(\theta_i^{VRS} X_i)$.

After having the TE measure, the following cost-minimizing DEA model of [18], [19] needs to be solved in order to get a measure of total economic efficiency (EE):

$$\begin{aligned} & \min_{x_i^* \lambda} W_i' X_i^* \\ & \text{subject to } Y \lambda - Y_i \geq 0 \\ & X_i^* - X \lambda \geq 0 \\ & \lambda \geq 0 \end{aligned} \quad (2.10)$$

where X_i^* is the cost-minimizing or economically efficient input vector for the i th firm, Y_i is the output and W_i is the input price vector. Then, one may compute the total economic efficiency (EE) index for the i th firm with the following formula:

$$EE_i = \frac{W_i' X_i^*}{W_i' X_i} \quad (2.11)$$

Equation (2.11) thus gives the ratio of the minimum cost to the observed cost. This ratio is comparable to the economic efficiency measure in equation (2.7) that is derived under the parametric approach. By using equations (2.9) and (2.11), one may get the allocative efficiency measure as follows:

$$AE_i = \frac{EE_i}{\theta_i^{C(V)RS}} = \frac{W_i' X_i^*}{W_i' (\theta_i^{C(V)RS} X_i)} \quad (2.12)$$

Here $\theta_i^{C(V)RS}$ denotes the technical efficiency measure of the i th firm either under CRS or VRS models.

2.3 (Socio-economic) factors affecting efficiency

The next important step of the efficiency analysis is to determine the socio-economic factors that have effects on the estimated efficiency levels. For this purpose, one may regress the estimated efficiency scores on a set of socio-economic factors that are suspected to be important determinants of (in)efficiency. A tobit regression model is more appropriate since the values of the dependent variable (efficiency scores) should lie within a certain interval (0 – 1).

This two-step procedure, which first estimates the efficiency scores and then regresses these scores on a set of independent factors, is criticized by some researchers [20], [21]. They assert that the socio-economic factors should be included directly in the first step, which is the estimation of an efficient frontier. Despite these criticisms, the two-step procedure has kept its popularity. Additionally, it is also not easily possible to apply such a one-step estimation procedure to the nonparametric DEA technique without prior assumptions whether the socio-economic factors have a positive or negative effect [22]. Therefore, this paper also employs the two-step procedure, which can be applied both to parametric and nonparametric approaches.

3 Data and Details of the Empirical Analysis

3.1 Data and description of variables

15 villages in the province of Canakkale, which have similar climate conditions, production structures and technical properties, were determined in order to obtain data. Then, 70 silage maize growing

farms are randomly selected from these 15 villages by taking into account suggestions of earlier studies and that each group of planting areas with different sizes is represented enough in the study. Data regarding input-output relations and socio-economic properties of farms were collected for the production season of 2009-2010 in the summer of 2011.

For the efficiency analysis, while maize silage yield (kg/daa) is the output (Y -dependent) variable, labor (X_1) (hour/daa), machine (X_2) (hour/daa), amount of seed (X_3) (kg/daa) and nitrogen (X_4) (kg/daa) used constitute the input (independent) variables. Table 1 presents the summary statistics. Below we define the input prices which are necessary to derive the dual cost frontier in the parametric approach and to solve the cost-minimizing nonparametric DEA model. This study uses Frontier 4.1 program to estimate the dual cost frontier of the parametric approach. On the other hand, DEAP 2.0 program was used to estimate the results of the DEA approach.

Table 1: Summary statistics of variables used in the efficiency analyses

	Min	Max	Mean	Std. Dev.
Yield (Y)	490.00	1205.00	789.33	135.47
Labor(X_1)	3.21	8.07	5.26	0.88
Machine (X_2)	1.02	4.17	1.62	0.73
Seed(X_3)	1.12	2.76	1.85	0.24
Nitrogen(X_4)	6.49	30.00	16.79	4.90
Education(Z_1)	0.00	1.00	0.21	0.18
No. of irrigations(Z_2)	2.00	10.00	5.30	1.79
Irrigation Int.(Z_3)	6.00	20.00	12.00	3.00
Area(Z_4)	40.00	184.00	80.50	69.00
Age(Z_5)	24.00	58.00	37.00	8.00

W_1 represents the price of labor (TRY/hour), which is computed by dividing the total labor expenses by total labor hours. W_2 is the price of machine (TRY/hour), which is calculated by dividing the total yearly machine expenses (maintenance-repair, gas-oil and rental expenses) by total machine hours. W_3 and W_4 represent the unit prices (TRY/kg) of seed and nitrogen. Additionally, the following socio-economic factors are utilized to determine their influence on productive efficiency. The education level (Z_1) of the farmer is a dummy variable and it takes the value of 1 for high school or higher education and 0 otherwise. The number of irrigations and the irrigation interval are denoted by Z_2 and Z_3 , respectively. The size of the maize silage planting area (Z_4) is another important variable. Finally, the age of the producer (Z_5) is included in the analysis.

3.2 Empirical Models

The Cobb-Douglas stochastic production frontier under the parametric approach is given as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{i1} + \beta_2 \ln X_{i2} + \beta_3 \ln X_{i3} + \beta_4 \ln X_{i4} + \epsilon_i \quad (3.1)$$

where i refers to the i th farm in the sample, Y is output and X s are input variables as defined in the previous section 3.1, β s are parameters to be estimated and ϵ_i is the composite error term.

It is possible to derive the following dual cost frontier from the production function in equation (3.1):

$$\ln C_i = \alpha_0 + \alpha_1 \ln W_{i1} + \alpha_2 \ln W_{i2} + \alpha_3 \ln W_{i3} + \alpha_4 \ln W_{i4} + \alpha_5 \ln \tilde{Y}_i \quad (3.2)$$

where i refers to the i th farm in the sample, C is the minimum cost of production, W s are input prices as defined previously, α s are parameters and \tilde{Y}_i is the output adjusted for stochastic noise term v as it is given in equation (2.3).

Last but not least, the following model is employed to analyze the role of socio-economic factors on efficiency:

$$EI_i = \delta_0 + \delta_1 Z_{i1} + \delta_2 Z_{i2} + \delta_3 Z_{i3} + \delta_4 Z_{i4} + \delta_5 Z_{i5} + \omega_i \quad (3.3)$$

where i refers to the i th farm in the sample; EI is the efficiency index, Z s represent various socio-economic variables as defined in the previous section 3.1, δ s are parameters to be estimated, and ω is a random error that is assumed to be normally distributed.

4 EMPIRICAL RESULTS

4.1 Parametric Approach

The maximum likelihood estimation of equation (3.1), which is the stochastic production frontier, was done by using the Frontier 4.1 program created by [23]. The results of this estimation are presented in Table 2.

Table 2: Estimates of Stochastic Production Frontier

	Coefficient	Std. Error	t-stat
Intercept	5.679***	0.137	31.991
ln(Labor)	0.163***	0.052	2.833
ln(Machine)	0.178***	0.035	3.913
ln(Seed)	0.124	0.132	0.970
ln(Nitrogen)	0.011	0.024	0.026
γ	0.095***	0.023	5.194
σ^2	0.911***	0.047	6.231
Log Likelihood	43.652	-	-

Table 1: *

*** indicate significance 1% level.

The signs of the estimated coefficients of input variables are positive as expected. That means an increase in each input leads to an increase in output. While the coefficients of labor and machine are found to be significant, the coefficients of seed and nitrogen are insignificant. Moreover, the estimated variance parameter γ is also significantly different from zero. This implies that a big part of the variation in maize silage output in the region of Canakkale stems from inefficiency effects. By making use of the estimated stochastic production frontier of Table 2, it is possible to derive the dual cost frontier, which is given as follows:

$$\ln C_i = 1.081 + 0.307W_{i1} + 0.351W_{i2} + 0.265W_{i3} + 0.004W_{i4} + 1.385\ln\tilde{Y}_i \quad (4.1)$$

Table 3 presents the summary statistics and the frequency distributions of the estimated technical (TE), allocative (AE) and economic efficiency (EE) indices from the parametric approach. It is seen that the mean technical, allocative and economic efficiency indices are estimated as 76.9%, 87.1%

and 77.8% respectively, under VRS and 75.7%, 86.7%, 68.0% under CRS. These scores indicate that the inefficiencies in maize silage production in the region of Canakkale are not trivial. Another observation from Table 2 is that the majority of producers fall into the ranges of 71 – 80%, 81 – 90% and 71 – 80% (61 – 70%) of technical, allocative and economic efficiency indices, respectively.

Table 3: Frequency distributions of efficiency measures with parametric and DEA approaches

Efficiency %	Parametric Approach			DEA		
	TE	AE	EE	TE	AE	EE
< 0.50	1(1)	0(0)	2(8)	0(1)	1(1)	7(13)
0.51-0.60	6(7)	2(3)	5(13)	2(3)	4(6)	20(19)
0.61-0.70	11(10)	9(9)	12(20)	8(8)	13(15)	32(31)
0.71-0.80	21(23)	15(18)	25(16)	13(12)	24(26)	10(6)
0.81-0.90	19(17)	25(27)	18(8)	28(26)	22(19)	1(1)
0.91-1.00	11(11)	18(11)	6(4)	19(20)	4(2)	0(0)
1	1(1)	1(2)	2(1)	0(0)	2(1)	0(0)
Mean (%)	76.9(75.7)	87.1(86.7)	77.8(68.0)	84.2(82.3)	78.2(76.1)	64.7(64.4)
Min (%)	46.4(43.8)	53.9(53.6)	41.2(38.3)	51.3(50.9)	42.7(42.3)	40.8(40.5)
Max(%)	100(100)	100(100)	100(100)	98.3(97.6)	100(100)	82.6(81.0)

Table 2: *

Figures in parentheses are the corresponding values for the CRS.

4.2 DEA Approach

The DEAP 2.0 program was used to estimate DEA models. As with the parametric approach, Table 3 presents the estimated measures of the technical, allocative and economic efficiencies. The estimated mean technical, allocative and economic efficiency measures are as follows, respectively: 84.2%, 78.2% and 64.7% under VRS and 82.3%, 76.1% and 64.4% under CRS. Under the DEA approach, a big mass of producers fall into the ranges of 81 – 90%, 71 – 80% and 61 – 70% of technical, allocative and economic efficiency indices, respectively. The DEA approach also confirms that there are considerable inefficiencies, especially in the form of economic inefficiency.

In order to check how well the two different approaches agree on efficiency measures of the farms in the sample, Spearman rank correlation coefficients are computed. The results of this analysis are presented in Table 4. It is clearly seen that rank correlations of technical (TE), allocative (AE) and economic (EE) efficiencies are positive and highly significant. Thus, the efficiency analyses of the two different approaches are very much comparable.

4.3 Socio-economic factors affecting efficiency levels

The model in equation (3.3) was estimated with a Tobit estimation procedure. The results of this estimation may be found in Table 5. Education has a negative but insignificant effect on efficiency levels. The negative relationship between education and efficiency implies that farmers with high school or higher education work more inefficiently compared to farmers with lower education levels. Although this may look peculiar at first sight, an explanation for that could be as follows: producers

Table 4: Spearman rank correlations of efficiency measures

		PAR_{CRS}	PAR_{VRS}	DEA_{CRS}	DEA_{VRS}
TE	PAR_{CRS}	1	0.975***	0.876***	0.883***
	PAR_{VRS}	0.975***	1	0.891***	0.865***
	DEA_{CRS}	0.876***	0.891***	1	0.953***
	DEA_{VRS}	0.883***	0.865***	0.953***	1
AE	PAR_{CRS}	1	0.921***	0.792***	0.807***
	PAR_{VRS}	0.921***	1	0.787***	0.774***
	DEA_{CRS}	0.792***	0.787***	1	0.942***
	DEA_{VRS}	0.807***	0.774***	0.942***	1
EE	PAR_{CRS}	1	0.763***	0.546***	0.531***
	PAR_{VRS}	0.763***	1	0.502***	0.529***
	DEA_{CRS}	0.546***	0.502***	1	0.745***
	DEA_{VRS}	0.531***	0.529***	0.745***	1

Table 3: *

*** indicate significance 1% level.

with lower education levels concentrate more on agriculture as the core business compared to producers with higher education levels, who may have additional activities. Yet this effect is not significant. The impact of education on efficiency levels has been largely examined in previous literature. Interestingly, these studies mostly show that there does not seem to exist a significant relationship between education and efficiency especially in developing countries as it has been shown in this paper [24], [14]. However, there are also a few studies like [25] which finds, on the contrary, a positive and significant relationship between the education level of corn producers in Nepal and efficiency.

Another result from Table 5 is that farm size has a positive and significant effect on efficiency levels, suggesting that large farms on average operate more efficiently than small farms. This result is not very surprising considering the fact that small producers have very limited marketing opportunities compared to large producers. One other advantage of large producers is usually that they have a lower labor price per unit of output.

The number of irrigations is another important determinant of efficiency. It has a positive and very significant effect on technical efficiency since irrigation is an important element in maize agriculture. On the other hand, it has a negative and significant effect on allocative and economic efficiency levels. Similar to the number of irrigations, the irrigation interval also has a significant and positive effect on technical efficiency. A previous study [7] also determines the same positive effect of number of irrigations and irrigation interval on (corn) technical efficiency in the province of Sanliurfa, Turkey which we reconfirm here.

Finally, the age of the producer has a positive but insignificant effect on efficiency levels. An earlier study by [26] also finds a positive relationship between the age of corn producers in Ethiopia and efficiency but this effect is significant in their case.

Overall, these results imply that efficiency of silage maize production in the region of Canakkale could be increased by exploiting economies of size meaning larger planting area and with the right

amount of irrigation.

	Parametric Approach			DEA		
	TE	AE	EE	TE	AE	EE
Intercept	0.518***	0.821***	0.729***	0.374***	0.853***	0.737***
Education	-0.003	-0.008	-0.002	-0.002	-0.009	-0.003
Irrigation No	0.035***	-0.032**	-0.015***	0.049***	-0.026**	-0.009**
Irrigation Int.	0.004**	0.005	0.001	0.007**	0.004	0.003
Size	0.001**	0.006**	0.001**	0.003**	0.005**	0.002**
Age	0.002	0.004	0.007	0.003	0.003	0.007

Table 4: *

** and *** indicate significance at 5% and 1% levels, respectively.

5 Conclusions

This study estimates technical, allocative and economic efficiency measures for a sample of maize silage producers in the region of Canakkale by employing parametric and nonparametric DEA methods. The mean technical, allocative and economic efficiencies under variable returns to scale (VRS) are found to be 76.9%, 87.1%, 77.8%, respectively, with the parametric approach, and 84.2%, 78.2% and 64.7% with DEA. The same measures under constant returns to scale (CRS) are 75.7%, 86.7%, 68.0%, respectively, with the parametric approach, and 82.3%, 76.1% and 64.4% with DEA. Rank correlation analysis has revealed that the efficiency indices of the sample producers are highly correlated, indicating that the results from the two different approaches are highly comparable.

Both approaches show that there are considerable inefficiencies in maize silage production in Canakkale. In this respect, there is a lot of room for improvement to operate at fully productive efficiency levels. In order to get some idea how to improve the productive efficiency, the role of various socio-economic factors on efficiency has been examined. Firstly, size of the planting area has a positive and significant effect on efficiency, implying that there is room to increase efficiency by exploiting economies of size. Additionally, the number of irrigations and the irrigation interval are important elements that affect technical efficiency. Then it is possible for producers to increase their technical efficiency with frequent and a sufficient amount of irrigation. Producers may try to increase their technical efficiencies by following the suggestions of their technical consultants more closely about the details of irrigation. However, it should be kept in mind that irrigation is a very sensitive issue in maize silage agriculture and the optimal amount depends on many other factors like the soil type. Finally, education and age do not seem to be significant determinants of efficiency for the sample of maize silage producers.

Competing Interests

The authors declare that no competing interests exist.

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