Measurement of Input Usage Efficiency in Cotton Production in Diyarbakir Province, Turkey

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Abstract

This study aimed to measure the technical efficiency for cotton farms in Diyarbakir province in Turkey. Technical efficiency scores of cotton farms were calculated with Data Envelopment Analysis (DEA), which is a linear programming method of non-parametric. The sample for this study was 134 cotton farms in Diyarbakir province of Turkey selected using the proportional sampling method. Data collection was carried out following 2017-2018 growing seasons. Data were collected through a survey using questionnaire. The data were analysed by using basic descriptive statistics, Kolmogorov–Smirnov test, Pearson correlation analysis, independent t-test, Mann Whitney U test, Correlation analysis, Tobit regression, and data envelopment analysis models. In the DEA analysis, size of cotton production area (ha), machine and human labour (h), N-P-K fertilizer (kg), pesticides (litres), fuel (litres), seeds (kg) and number of irrigations are used as input parameters whereas cotton yield (kg) is used as output parameter. The study results revealed that the scale efficiency score of cotton farms in Diyarbakir was 0.89 on average and ranged from 0.53 to 1.00. Additionally, cotton farms in the studied area could reduce their inputs by 3% and still produce the same level of cotton output. The Tobit analysis results showed that factors such cotton yield, N and K fertilizers have a positive effect on efficiency, whereas land size, P fertilizers, pesticides, machine, fuel, labour and seed have a negative effect on efficiency. The results imply that by improving knowledge of farmers about input usage and modern techniques of cotton production may increase technical efficiency. Also, policy makers should focus on technical training programs about input usage and improving production management.

Keywords: efficiency analysis, data envelopment analysis, Tobit model

1. Introduction

Cotton is one of the major industrial crops in Turkey. Turkey is the world's seventh largest cotton producer and accounts for 3.29% of the global cotton producing area. In the world, about 74.4 million tons of cotton seed is produced on an area of 33.0 million hectares (FAO, 2017) According to statistical data in 2018, cotton production and area under cultivation was 2.6 million tons and 518.634 hectares, respectively in Turkey (TurkStat, 2018). Turkey was a net cotton exporter up until 20 years ago. Currently, Turkey is a net cotton importer due to insufficient subsidies, a changing price party that is unfavourable to cotton selling prices and insufficient crop production (Dagistan et al., 2009). Cotton agriculture is very important in South Eastern Anatolia region of Turkey. About 56.41% of the total Turkish cotton production area was in this region. In 2018, cotton production were 1449701 tons in this region, from this 16.87% belongs to Diyarbakir province (TurkStat, 2018).

Nowadays determination and comparison of the farm performance become more important. The most appropriate method for this comparison is to determine the efficiency score (Dalgic et al., 2018). Performance measurement is an important issue for at least two reasons. One is that in a group of units where only limited number of candidates can be selected, the performance of each must be evaluated in a fair and consistent manner. The other is that as time progresses, better performance is expected. Hence, the units with declining performance must be identified in order to make the necessary improvements. The performance of a decision-making unit (DMU) can be evaluated in either a cross-sectional or a time- series manner, and Data Envelopment Analysis (DEA) is a useful method for both types of evaluation (Mohammadi and Ranaei, 2011). DEA is the non-parametric method, and can handle easily multiple input and multiple output cases. Moreover, in DEA application, inputs and outputs can have very different units of measurement without requiring any a priori trade-offs or any input and output prices. Given these highly desirable features of the non-parametric methods, it is not surprising that they have recently become very popular among researchers (Gul et al., 2009).

There have been many studies on technical efficiency analysis of various agricultural products such as tobacco (Abay et al., 2004), dairy (Gunden et al., 2010; Parlakay et al., 2015), greenhouses (Hediari et al., 2011a; Ozturk and Engindeniz 2018), tomato (Engindeniz and Ozturk 2013; Gunduz et al., 2016), olive (Cukur et al., 2013), rice (Haryanto et al., 2015; Wagan et al., 2019), goat (Gul et al., 2016),cherry (Ozden and Oncu, 2016), grape (Ormeci Kart et al., 2018), sunflower (Oguz et al., 2019), peach (Aydin, 2019).

In this study, it is aimed to determine the technical efficiency of cotton farms and to identify the determinants of technical efficiency among cotton farms in Diyarbakir province in Turkey. Data envelopment analysis method, has been used for the technical efficiency. Tobit regression was used to estimate the factors influencing technical inefficiency. This study would be helpful to policy makers, researchers and farmers to develop cotton production efficiency. The rest of this study is organized in the following sequences. Section 2 reviews the selected previous literatures about technical efficiency of cotton production, while Section 3 presents the research method on which the analysis of the study is based, section 4 explores the results and discussion, finally section 5 shows the conclusion of the study.

2. Literature Review

Several research studies were conducted on the technical efficiency of cotton production in the world.

Battase and Hassan (1998) estimated technical efficiency of cotton farmers in the Vehari District of Punjab, Pakistan using stochastic frontier analysis. That study reported that 60% of total farms had technical efficiencies greater than 0.95. That study's results indicate that delaying the first irrigation was associated with higher technical efficiency and increasing in number of intercropping caused to reduce in the technical efficiency.

Gunden (1999) computed technical efficiency of cotton production in Menemen district, Turkey with the DEA and determined production and input losses caused by inefficiency. In that study results were compared between left-right side. They found that there was exists technical inefficiency in cotton production in the province and left side was more successful than right side in input usage.

Shafiq and Rehman (2000) used DEA to compute cotton farms' technical and allocative efficiency in the Pakistan's Punjab. They found that, there were a considerable number of farms that were both technically and allocatively inefficient in the 'cotton–wheat' system of Pakistan.

Chakraborty et al., (2002) compared technical efficiency for cotton growers in west Texas using stochastic frontier analysis (SFA) and DEA. They reported that irrigated farms were 80% and non-irrigated farms were 70% efficient. Their findings showed that the irrigated farms could be reduce their expenditures on other inputs by 10%, and the non-irrigated farms could be reducing their expenditures on machinery and labour by 12% and 13%, respectively, while producing the same level of output.

Tashrifov (2005) examined the level and determinants of technical efficiency for a sample of cotton growing regions in Tajikistan. That study used unbalanced panel data of 11 years covering the transition period 1992-2002. In that study 34 cotton-producing regions were analysed with a translog stochastic production frontier, including a model for regional-specific technical inefficiencies. That study revealed that the technical inefficiency effects were found to be highly significant in indicating the ranges and variation in regional outputs.

His results showed that market reforms had a significant positive impact on technical efficiency of cotton production.

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

Wossink and Denaux (2006) investigated the quantification of pesticide use efficiency for producers of transgenic cotton versus conventional cotton in North Carolina, USA with DEA in order to test for the improvement promised by the genetically engineered crop. They indicated that differences in environmental efficiency were found significant between herbicide tolerant and stacked gene (herbicide tolerant and insect resistant) cotton and between stacked gene and conventional cotton.

Gul et al., (2009) analysed technical efficiency of cotton farms by using the DEA in Cukurova region in Turkey. Gul et al (2009) used Tobit regression analysis to identify determinants of technical efficiency. Their results indicate that cotton farmers could be save inputs by at least 20% while remaining at the same production level. They found that technical efficiency is impacted by farmers' age, education level and groups of cotton growing areas.

Neba et al., (2010) evaluated the technical efficiency of cotton farms in the northern part of Cameroon through the use of a parametric production frontier. The evaluation approach used is a stochastic type which shows that in spite of the fact that cotton yields in Cameroon were amongst the highest in sub-Saharan Africa, efficiency indexes were still as low as 60% in average. That study claimed that the characteristics of the producer as well as environmental factors all influenced technical efficiency.

Tsimpo (2010) estimated the technical efficiency of cotton farms in Tajikistan using a stochastic frontier production function, and derived the optimal farm size.

That study suggested that an inverse relationship between productivity and farm size did not hold. The relationship between farm size and technical efficiency was more complex than what is normally believed.

Adzawla et al., (2013) examined the social, economic and environmental factors influencing cotton production in Yendi Municipality in Northern Ghana. A multi-stage sampling technique was used to select 91 small holder cotton farmers in 8 communities in the Municipality and translog stochastic frontier model was applied to analyze the technical efficiency. They found individual farm level technical efficiency ranged between 0.70 and 0.99 with a mean of 0.88.

Cobanoglu (2013) compared the technical efficiency of cotton production in Turkey's Aegean region using SFA and DEA. Data were obtained from 198 cotton farms using structured questionnaire interviews. That study determined while efficiency scores for cotton farms differed between the SFA and the DEA models, the mean efficiency scores were quite low for the CRS DEA model compared with the VRS DEA and SFA approaches. The mean efficiency measure (0.91) obtained from the stochastic frontier was higher than that calculated from the VRS DEA (0.77) and CRS DEA (0.25). That study suggested that more efficient political instruments need to be adopted to review current subsidies because of increasing outlays for diesel oil used in cotton farming.

3. Material and Method

The study was conducted in Diyarbakir province which is located in the South-eastern Anatolia Region of Turkey. The province is located at an altitude of 670 m above sea level and its geographical coordinates are 37°55´ N longitude and 40°14´ E latitude. This city is warm and dry in the summer and cool in the winter (Ipek, 2016). In this study, data was collected from 134 cotton farmers during the 2017/18 cropping season through questionnaire administration in the Diyarbakir province of Turkey. A random sampling method was used. The sample size was calculated using the proportional sampling method (Newbold, 1995). The permissible error in the sample size was defined to be 5% for a 95% confidence interval., Data on inputs such as size of cotton production area (ha), machine and human labour (h), N-P-K fertilizer (kg), pesticides (litres), fuel (litres), seeds (kg) and number of irrigation and output such as yield (kg) were collected. In addition to the data obtained by questionnaire, some previous research findings and data from some organizations such as Food and Agricultural Organization (FAO), Turkish Statistical Institute (TurkStat) were also utilised during the study.

The methods used in the paper are basic descriptive statistics, Kolmogorov–Smirnov test, Pearson correlation analysis, Tobit regression, independent t-test, Mann Whitney U test and data envelopment analysis models. The distribution of the data was tested for normality by Kolmogorov–Smirnov test.

Correlation analysis was performed to examine the relationship between output and inputs. Correlation analysis is a family of statistical tests to determine mathematically whether there are trends or relationships between two or more sets of data from the same list of items or individuals. The tests provide a statistical yes or no as to whether a significant relationship or correlation exists between the variables (Childress, 1985; Heiadri et al., 2011b). The value of a correlation coefficient can vary from minus one to plus one. A minus one indicates a perfect negative correlation, while a plus one indicates a perfect positive correlation. A correlation of zero means there is no relationship between the two variables. When there is a negative correlation between two variables, as the value of one variable increases, the value of the other variable decreases, and vice versa. In other words, for a negative correlation, the variables work opposite each other. When there is a positive correlation between two variables, as the value of one variable increases, the value of the other variable also increases. The variables move together (Puniya and Singh, 2019).

In this study, efficiencies of cotton farms were measured using data envelopment analysis. The DEA models for estimating technical efficiency were based upon the assumptions of constant returns to scale (CRS) and variable return to scale (VRS). Farmers have more control over their inputs than their outputs. For his reason, the input-oriented DEA model is used in this study (Tipi et al., 2009, Oruk and Engindeniz, 2018). MaxDEA software was used to calculate the DEA scores.

The input-oriented DEA model based on the constant return to scale is stated as follows (Färe and Grosskopf, 1994; Coelli et al., 2006).

$\min_{\theta,\lambda} \theta$,

subject to $-y_i + Y\lambda \geq 0$

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

$\lambda \geq 0$

The value of θ obtained will be the efficiency score for the i-th decision-making unit. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence technically efficient decision-making unit, according to the Farrell (1957) definition. Thus, the linear programming problem needs to be solved N times and a value of θ is provided for each farm in the sample (Coelli et al., 2006). Banker et al., (1984) (BCC), extended the earlier work of Charnes et al., (1978) by providing for variable returns to scale (VRS).

The input-oriented DEA model based on the VRS is stated as follows: (Färe and Grosskopf, 1994; Coelli et al., 2006)

min θ,λ θ,

subject to –yi +Yλ≥ 0

θxi – Xλ≥ 0

N1'λ=1

λ≥ 0

where, N1 is an N ×1 vector of ones.

Technical efficiency scores can be obtained by running constant returns to scale (CRS) DEA model to achieve total or overall technical efficiency (TECRS) and variable returns to scale (VRS) DEA model to achieve pure technical efficiency (TEVRS). If there is a difference between the scores of technical efficiencies under CRS and VRS for a certain farm, the difference indicates that a farm is scale-inefficient. Scale efficiency measure can be calculated by dividing the total technical efficiency by pure technical efficiency:

SE = TECRS/ TEVRS

If SE = 1, then a farm is scale-efficient, its combination of inputs and outputs is efficient both under CRS and VRS and the farm is operating under increasing returns to scale. If SE <1, then the combination of inputs and outputs is not scale-efficient and the farm is operating under decreasing returns to scale (Aldeseit, 2013; Gunden et al., 2006).

After generating the technical efficiency of every sampled farm by using DEA method, Tobit regression was used to estimate the factors influencing technical inefficiency. The efficiency parameters vary between 0-1, they are censored variables and thus a Tobit model needs to be used (Naceur and Mongi, 2013).

4. Results and Discussion

The main objective of this study was to determine the technical efficiency of cotton farms using DEA technique. Basic descriptive statistics used in the analysis are presented at Table 1.

Table 1: Basic statistics of the inputs and outputs

Variables	Mean	Minimum	Maximum	Standard deviation	Measurement
Outputs					
Cotton Yield	55.14	33.50	85.00	9.22	Kg ha^{-1}
Inputs					

Land	10.79	1.20	28.00	5.81	Ha
N fertilizers	2.32	0.42	4.25	0.66	Kg ha^{-1}
P fertilizers	0.98	0.00	2.69	0.54	Kg ha^{-1}
K fertilizers	0.08	0.00	0.61	0.16	Kg ha^{-1}
Pesticides	0.08	0.05	0.12	0.01	Litters ha^{-1}
Machine	0.18	0.13	0.30	0.02	Hours ha^{-1}
Fuel	2.45	1.26	5.43	0.84	Litters ha^{-1}
Labour	1.33	1.03	1.95	0.14	Hours ha^{-1}
Seed	0.26	0.16	0.35	0.02	Kg ha^{-1}
Number of irrigations	4.22	0.00	11.00	3.27	Number

Source: Own calculation

The mean values of yield, seeds and N-P-K fertilizers were 55.14, 0.26, 2.32, 0.98 and 0.08 kg ha-1, respectively. Baran (2016) reported that the amount of chemical fertilizers and seeds used for cotton production was 10.79 kg ha-1, 2.15 kg ha-1, respectively in Adiyaman province. The mean value of land was 10.79 ha. The mean values of machine and labour were 0.18 and 1.33 h ha-1, respectively. The mean values of pesticides and fuel were 0.08 and 2.45 litters per hectare, respectively. The mean values of number of irrigations was 4.22 per hectare.

Table 2 shows the correlation between inputs and output used in cotton production in the studied area. The highest correlation value found was P- N fertilizer and number of irrigation -N fertilizer as 0.35.

Table 2: Correlation Coefficients Between the Inputs and Outputs

	Land	N fertilizers	P fertilizers	K fertilizers	Pesticides	Machine	Fuel	Labour	Seed	Number of irrigations	Cotton Yield
Land	1.000										
N fertilizers	-0.040	1.000									
P fertilizers	0.024	0.353**	1.000								
K fertilizers	-0.158	-0.202*	-0.402**	1.000							
Pesticides	0.050**	0.166	0.172*	0.042	1.000						
Machine	-0.287**	0.173*	0.114	0.048	0.065	1.000					
Fuel	-0.272**	-0.096	-0.076**	0.042*	-0.208	0.033*	1.000				
Labour	-0.024	0.296**	0.238**	-0.080	0.185	0.287**	0.006**	1.000			
Seed	-0.244**	0.136	-0.032	-0.056	0.065	0.052	0.016	-0.011**	1.000		
Number of irrigations	-0.303**	0.350**	-0.029	0.158**	0.066*	0.214*	0.245**	0.256**	0.123	1.000	
Cotton Yield	-0.093	0.009*	0.179**	-0.019	0.113	0.119	-0.136	0.038	0.123	0.022*	1.000

Source: Own calculation
* and ** represents 5% and 1% levels of significance

Efficiency scores of cotton farms were given in Table 3. The mean values of overall technical, pure technical, and scale efficiency were 0.87,0.97, and 0.89, respectively.

Table 3: The overall, pure and scale efficiencies

Efficiency measures	Mean	Std.deviation	Min	Max	Efficient farms (%)

Overall technical efficiency	0.865	0.133	0.504	1.000	30.60
Pure technical efficiency	0.971	0.041	0.847	1.000	55.22
Scale efficiency	0.889	0.119	0.533	1.000	30.60

Source: Own calculation

In this study the scale efficiency value was relatively higher than other studies. In previous studies in Turkey Gunden (1999) determined scale efficiency as 0.68 in Menemen, Binici et al., (2006) determined it as 0.79 in Harran, Gül et al., (2009) determined it as 0.79 in Cukurova and Cobanoglu (2013) determined it as 0.33 in Turkey's Aegean region. On the other hand, Solakoglu et al (2013) determined technical efficiency as 0.65 with stochastic frontier analysis when 2001-2008 period and 14 cities (Aydin, Denizli, Mugla, Izmir, Manisa, Sanliurfa, Gaziantep, Diyarbakir, Mardin, Osmaniye, Kahramanmaras, Adana, Antalya, Hatay) were taken into account and Cobanoglu (2013) calculated it as 0.91. The results showed that cotton farmers within the studied area could reduce their inputs by 3% without reducing their cotton production. By eliminating scale inefficiency, the cotton farms can increase their average technical efficiency level from 86.5% to 97.1%. Gul et al., (2009) reported that cotton farmers can save inputs by at least 20% while remaining at the same production level.

Distribution of technical efficiency coefficients calculated for farms were given in Table 4.

Table 4: Frequency distribution of technical efficiency scores

	CRS		VRS		SE	
Technical Efficiency Level	Cases	Percentage	Cases	Percentage	Cases	Percentage
0.100-0.200	0	-	0	-	0	-
0.201-0.300	0	-	0	-	0	-
0.301-0.400	0	-	0	-	0	-
0.401-0.500	0	-	0	-	0	-
0.501-0.600	6	4.48	0	-	3	-
0.601-0.700	11	8.21	0	-	9	-
0.701-0.800	26	19.40	0	-	17	12.69
0.801-0.900	28	20.90	11	8.21	30	22.39
0.901-0.999	22	16.42	49	36.57	33	24.63
1.000	41	30.60	74	55.22	41	30.60
Total	134	100.00	134	100.00	134	100.00

Source: Own calculation

Out of the 134 cotton farms in the sample, 41 farms (30.60% of cotton farms) under constant return to scale (CRS) and 74 farms (55.22% of all cotton farms) under variable return to scale (VRS) were found to be fully efficient. 22 farms under constant return to scale and 49 farms under variable return to scale had efficiency levels over 90%. Of the remaining farms had efficiencies varying from 50 to 90%. Akturk and Kiral (2002) determined efficiency score of cotton producing farms with the DEA in Soke Valley in Turkey and found that 12% of total farms were efficient. This farm efficiency ratio was lower than determined in this study.

Returns to scale distribution of cotton farming in Diyarbakir is presented in Table 5.

Table 5: Summary of returns to scale results

Characteristics	Number of farms	Cotton Land	Cotton Yield
CRS	41	9.47	61.81
DRS	-	-	-
IRS	93	11.36	52.19

Source: Own calculation

In terms of scale efficiency, 69.40% of farms show increasing returns to scale (IRS). These findings accord with this presented in Gul et al., (2009) which reported that 77.21% of farms had increasing returns to scale.

Differences between efficient and inefficient tomato farms were investigated using some variables and results were given in Table 6.

Table 6: The differences between technically efficient and inefficient cotton farms under constant return to scale

Variables	Efficient farms	Inefficient farms
Number of farms	41	93
Cotton Yield***	61.81	52.19
Land*	9.47	11.36
N fertilizers**	2.13	2.40
P fertilizers**	0.83	1.04
K fertilizers***	0.16	0.05
Pesticides	0.08	0.08
Machine	0.18	0.18
Fuel***	2.14	2.58
Labour***	1.28	1.36
Seed	0.26	0.26
Number of irrigations**	3.39	4.58

Source: Own calculation

*, ** and *** represents 10%, 5% and 1% levels of significance

As can be seen in the table, technically inefficient farms had higher usage of fuel, labour, N and P fertilizers and irrigation compared to technically efficient farms. The mean values of number of irrigations was 3.39 per hectare in efficient farms. Dagistan et al., (2009) indicated that cotton sowing fields are becoming infertile due to excessive irrigation since cotton should not be irrigated more than three times.

Tobit regression analysis are given in Table 7. The dependent variable in the model is the VRS efficiency score.

Table 7: Results of Tobit model for efficiency scores

Variables	Coefficient	Std.Error	z-score	p value
Constant	1.3442	0.0428	31.410	0.0000***
Cotton Yield	0.0001	0.0000	2.815	0.0049***
Land	−0.0002	0.0000	−5.016	0.0000***
N fertilizers	0.0011	0.0004	2.649	0.0081***
P fertilizers	−0.0024	0.0005	−4.709	0.0000***
K fertilizers	0.0048	0.0016	2.983	0.0029***
Pesticides	−0.0442	0.0170	−2.600	0.0093***
Machine	−0.0624	0.0118	−5.304	0.0000***
Fuel	−0.0016	0.0170	−5.245	0.0000***
Labour	−0.0065	0.0018	−3.501	0.0005***
Seed	−0.0449	0.0097	−4.606	0.0000***
Number of irrigations	−0.0013	0.0009	−1.500	0.1335

Source: Own calculation
*, ** and *** represents 10%, 5% and 1% levels of significance

The Tobit analysis results showed that factors such cotton yield, N and K fertilizers have a positive effect on efficiency, whereas land size, P fertilizers, pesticides, machine, fuel, labour and seed have a negative effect on efficiency. These parameters were statistically significant at 1% level. Adzawla et al., (2013) also found labour and fertilizer to positively influence technical efficiency. Number of irrigations was found to have a negative effect on efficiency. But this parameter was not statistically significant. Many authors found positive relationship between efficiency and farm size (Helfand and Levine, 2004; Bozoglu and Ceyhan, 2007; Tipi et al., 2009; İbrahim and Omotesho, 2013), whereas many authors reported the opposite (Squires and Tabor, 1991; Adzawla et al., 2013).

5. Conclusion

The study aimed at calculating technical efficiency of cotton farms according to the DEA methodology and determining the factors influencing technical efficiency of farms in the Diyarbakir province of Turkey. The technical efficiency scores of the cotton farms range from 0.501 to 1.000. The average technical efficiency score with DEA-CRS was calculated as 0.87, whereas this value was 0.97 with DEA-VRS. The scale efficiency of the farms analysed was determined as 0.89. Comparative analyses showed that efficient farms were in a better condition for yield levels, labour use, N and P fertilizers and irrigation than inefficient farms. It was found that farms could achieve production efficiency through decreasing their input use by 3% to produce the same amount of cotton. This can be provided through educating farmers on technological innovations and input usage such as labour, pesticides, fertilizer, fuel, water.

Furthermore, farmers should apply fertilizers according to the recommended amount per decare and they should not irrigate more frequently than required. In addition, good agricultural practices and organic farming methods should be extended in order to decrease input use. Also, policy makers should focus on technical training programs about input usage and improving production management.

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