DATA ENVELOPMENT ANALYSIS AND AN APPLICATION IN THE TOMATO SECTOR IN TURKEY

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ENVELOPMENT DATA ANALYSIS AND AN APPLICATION

IN THE TOMATO SECTOR IN TURKEY

Abstract

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In this study, the technical efficiency is evaluated for tomato producing greenhouses in Antalya, Turkey. The aims of the study are to help improve productive efficiency and level cost greenhouse produced tomatoes for export and local consumption. In the study, the efficiency of each greenhouse is tested with data envelopment analysis (DEA). DEA uses linear programming technique to determine the efficient frontier and companies each firm to that frontier calculates optimal levels of inputs and outputs by use to compare with actual quantities of inputs and outputs. DEA analysis it is possible to determine which inputs should be decreased all individual and by how much to achieve efficiency. Using DEA analysis, efficiency was determined under both constant returns to scale (CRS) and variable returns to scale (VRS). The technical efficiency score is 0.9739 for constant returns scale (CRS) and 0.9755 for variable returns scale (VRS). Two hundred forty-four of the two hundred eight one greenhouses were found to be efficient.

Efficiency scores were lower for other 37 inefficient farms (0.8020). Results were similar under the constant returns scale and variable returns to scale assumptions. New optimal input levels were provided for the inefficient farms.

Keyword: Data Envelopment Analysis (DEA), Technical Efficiency, Tomato Greenhouses, Performance

TABLE AND CONTENTS

LIST OF TABLES

LIST IF FIGURES

SYMBOLS AND ABBREVIATIONS

DEA	Data Envelopment Analysis
CRS	Constant Return Scale
VRS	Variable Return Scale
CCR	Charnes-Cooper-Rhodes Model
BCC	Banker-Chaenes-Cooper Model
DMU	Decision Making Unit
EMS	Efficiency Measurement System
DEAP	Data Envelopment Analysis Program
DS	Linear Programming Modul
QS	Linear Programming Modul
QSB	Linear Programming Modul
FAO	Food and Agriculture Organization
EU	European Union
USDA	United States Department of Agriculture
AMS	American Meteorological Society
TE	Technical Efficiency
da	Decades
Kg	Kilogram
Lt	Liter
kWh	Kilowatt hour
Sd	Standard deviation

1. INTRODUCTION

1.1. Data Envelopment Analysis (DEA)

Technology is an indispensable part of our lives in our age, and with the globalizing economy, it is essential for enterprises to keep up with changing conditions to maintain their presence in the market. For this purpose, and in line with the needs and desires of the public, technological innovations in the light of providing quality services, as well as using the limited resources at hand, the aim of this research is to find the most efficient way to perform production. Specifically, greenhouse tomato production in Turkey is investigated measure efficiency. Using DEA, it is a possible to show how close the efficient target is as it is actual outputs. Managers take measures to increase the performance using to implantation and profitability of their firms (Cooper, 1995). The DEA method is one of the principal ways to evaluate firm performance.

DEA method was first created in 1978 by Charnes, Cooper, Rhodes (CCR). CCR propose using linear programming to measure the effectiveness of all decision-making units. DEA method was first used only for the measurement of technical activity and applied with the assumption of constant returns to scale. In 1984, Banker, Charnes, and Cooper (BCC) applied it using variable returns for scale activity. BCC has altered CCR's linear programming model for the calculation of technical efficiency and scale return. Banker worked on calculating the concept of efficient scale and scale yield in 1984 (Sengupta, 1995).

DEA is a model for comparing the yields of homogeneous enterprises such as schools, hospitals, hotels, bank branches, and firms. The approach is the adaptation of the distance function that Shephard created in 1970 to BCC's output sets. DEA is used to measure the yield of homogeneous enterprises in which some output is produced with the same inputs. For example, following (Athanassopoulos, Gounaris and Sissouras, 1999): if a manufacturer B can generate unit input with x(B) and unit output y(B), all other similar manufacturers must be able to produce the same amount of output with the same amount of input. Since measurement can be completed without the need for an analytical production function, as in parametric methods, DEA is a non-parametric method.

DEA calculates the technical effectiveness of the decision-making units of an organization. Using DEA, it is possible to determinate technical efficiency by maximizing the output subject to the input quantity of the decision-making unit or by minimizing the input subject to the output amount. According to the DEA method, efficiency is the ratio of total weighted outputs to total weighted inputs, which requires weight values for inputs and outputs, where weight values should always be positive. According to Charnes and Cooper (1995), for an economic unit to be 100% effective, it must produce at the efficient envelope research that: increasing one or more of the inputs cannot increase any output or increasing output cannot be accomplished without increasing one or more input.

DEA is built as the ratio of output to input. It is easy to calculate the efficiency when there is only one input and one output. However, when there are multiple inputs and outputs, it is necessary to bring the input and output values together in a single activity criterion and to formulate these numerical data under linear programming. The producing factors used by the decision-making units are considered as inputs and the goods and services produced for this purpose are regarded as outputs (Banker et al., 2004).

DEA is based on the application of linear programming as an activity measurement technique based on the relationship of multiple inputs and outputs. Linear programming is a mathematical technique for the effective use of limited resources within a particular purpose and for finding the most appropriate combination among different alternatives. This technique is mostly used to solve optimal resource allocation problems. In a linear programming problem, the aim should be expressed in a clear and measurable manner. The degree of limiting the resources for this purpose should be determined, and consequently, linear equality or inequalities should be shown. DEA defines a single activity score determined by the linear programming model for multiple input and output variables (Barr, 2004). As a result of this process, the decision-making units which are equal to the objective function can be described as efficient and the decision-making units with an objective function value less than one can be characterized as ineffective or inefficient (Boussofiane, Dyson and Thanassoulis, 1991). The most important advantage of DEA is that it allows the effectiveness of decision-making units with multiple inputs and outputs to be reduced to a single value. In this way, in the event determination process, the price information and units are not needed and thus the inputs and outputs can be processed with different units. Furthermore, the technical and scale activities for each decision-making unit are calculated separately, so that the items that cause the decision-making unit to be ineffective can be easily identified (Bowlin, 1998). In DEA, as in parametric methods, there is no need for an assumption about a production function. Another feature is that it determines the limit rather than the measures of central tendency; that is, the decision-making units are compared with the units that are fully effective, not with the units which are effective on average (Cooper, Seitford and Tone, 2007).

Since DEA is a non-parametric method, it also has some limitations. This method is sensitive to measurement errors and excessive values because it is based on data. Input and output values should be cleared of possible errors and the values related to the organizational functioning process must be selected carefully. In addition, when calculating productivity, if new decision-making units are added to the model, or if some of the decision-making units in the model are removed, the calculated efficiency score and limit will change (Talluri, 2000). Therefore, we can conclude that regardless of organizational and environmental differences, productivity scores are related only to the model and data used in the analysis.

When making decisions using the DEA technique, the efficiency score is calculated by dividing the weighted total of the outputs by the weighted total of the inputs. But these calculations are very difficult with linear programming. Therefore, the output values of the decision-making units with the DEA will be maximized and the input-output weights will be selected and together with these weight values, the efficiency values of all other decision-making units will be equal to one less than (Golany, 1989). DEA measure of one are efficient, while the ones below one is inefficient.

While measuring the efficiency of institutions with DEA technique, measurement is made according to other decision-making units and firms. As a result of the analysis, all units are at or below the productivity limit (Serena Cinca, Callen and Molinero, 2005). Necessary measures should be taken in order to determine what kind of factors caused to units to become inefficient and what needs to be alone to make efficient. At the end of the analysis, decision-making units or firms which are not within the productivity limit are determined. Different options are offered for these decision-making units or firms to reach the productivity limit. Through the options offered, the aim is to bring decision-making units or firms closer to the productivity limit.

2. LITERATURE REVIEW

The fundamental philosophy of the DEA is based on the effective boundary theory that Farell (1957) described in his measurement of productive efficiency. The first study which is based on this article is the study of Charnes, Cooper, and Rhodes. Later, the CCR and BCC models of DEA are formed by Banker Charnes and Cooper (Özata, 2004). Data envelopment analysis is used in lots of fields with the aim of improving operational efficiency and profitability. The examples of the studies which are conducted in various fields can be summarized as follows:

Sherman (1984) investigates 15 hospitals using data envelopment analysis. He focuses on 3 inputs, 3 outputs and find 7 decision-making units out of 15 are efficient.

Vassıloglu ve Gıokas (1990) implemented data envelopment analysis to investigate commercial banks in Greece with the aim of measuring the relative activity in bank sector. Data from 1987 is used in the study in which 20 banks are included. Nine out of twenty are found to be efficient.

Chandra, Cooper, Li and Rahman (1998) measured the activity of 29 textile companies in 1994 with the data envelopment data analysis. The number of working staff and the total average of the annual investment are considered as inputs, and total annual sales is considered as output. The efficient and the inefficient companies are determined, and it is concluded that return to the scale is the key factor to utilize the inputs.

Serana-Cinca, Fuertes-Callen and Mar-Molinero (2003) measured the activity of the internet-based companies. The number of working staffs, expenses, and total assets are considered as inputs, and the number of the visitors is considered as outputs in the study which is conducted on 40 internet-based companies. Five internet-based companies out of 40 are found as efficient at the end of the analysis which used the data from 2000.

Bakırcı (2006) aims to determine the effectiveness of firms operating in the automotive industry. The study is conducted on the hypothesis of constant and variable return to the scale. Thirteen firms with data between 1999 and 2004 is used. Three firms are efficient in both years and 4 firms increased their activity scores in 2004.

Sreenivasa Murthy et al. (2009) studied the efficiency of tomato production in Karnataka. They found that most of the farms are inefficient. They separated farms into small, medium and high size and they determined middle-size farms were efficient. They find other groups are increasing technical efficiency with increasing returns to scale.

Behdioğlu and Özcan (2009) measure the efficiency of 29 commercial banks in Turkey using 4 inputs and 3 outputs implementing the data envelopment analysis method. In the study conducted using variable returs to scale and it is found that the banks with foreign capital have the highest efficiency values.

Kaya, Öztürk and Özer (2010) used data envelopment analysis for companies operating in the machinery sector in metal goods. Analysis involves 7 inputs and 3 outputs, and when the results of the study are interpreted by month, it is concluded that 14 companies out of 25 are efficient.

Altın (2010) conducted a data envelopment analysis to measure the financial activities of industrial companies traded on the ISE in the global crisis period in 2008. The study involves 142 companies and used financial data of 2008. In the analysis performed under the assumption of constant returns to scale. Five inputs and one output are used in the study and it is concluded that 12 companies out of 30 are found as efficient in terms of finance during the global crisis.

2.1. Method

The of data envelopment analysis is an important tool for performance measurement. The intended purposes of the data envelopment analysis are listed as follows (Green, Cook and Doyle, 1997): determination of inadequate sources and amounts of input and output for each of the ineffective decision-making units, classification of decision-making units according to their effectiveness levels; evaluation of management of decision-making units; evaluating the efficiency of the non-controlling programs and policies of decision-making units and distinguishing between program inefficiency and managerial ineffectiveness; establishing a quantitative basis for reassignment of resources for decision-making units; determination of effective units or effective input and output relations by comparison between decision-making units; examining and reviewing current standards for specific input and output relationships according to actual performance and comparison of results in previous studies (Charnes et al., 1978).

2.2. Applications

When the data envelopment analysis applications used for performance measurement in many areas are examined, it is seen that mostly hospital, education and company performances are studied. Data envelopment analysis has been gathered in the following subgroups (Depren, 2009):

Bank branch performance measurement practices, studies on measuring school activity, studies on the measurement of university activity, studies on the measurement of hospital activity, studies on measurement of airport activity (Kaynar et al., 2005)

Measurement of the effectiveness of some practices in the public sector, studies on measuring the effectiveness of health services, studies in the field of agriculture, studies on measuring postal service effectiveness, transportation studies, studies on measuring prison activity, studies in the field of pharmacy, studies in the field of mining, studies on electricity use, and studies on measuring restaurant activity (Timor, 2001)

Other uses of data envelopment analysis can be listed as follows (Thomas, 1996):

Use of Peer Groups: Data envelopment analysis defines each ineffective unit's corresponding cluster as unit effective unit and these units create peer groups with ineffective units. Each unit in the peer group takes the input-output orientation of the ineffective unit and becomes effective using the same weights as the ineffective unit.

Determining Effective Working Practices: Determining and itemizing good working practices does not only increase the effectiveness of relative ineffective units, but also increases effectiveness within relative effective units. Relative effective units are the source of good working practices. However, some of the effective units are better examples than others.

Targeting: In applications, it is often used to set targets to guide the improvement of performances of relatively ineffective units. It is possible to set targets at input and output levels with DEA.

Determining Effective Strategies: Data envelopment analysis can easily compare policies and programs that the units work within. In addition, it can evaluate the managerial and program activities with the appropriate solution of the model.

Observing Activity Changes During Time: A company whose effectiveness is determined by data envelopment analysis may lose its effectiveness in the following periods and lose its chance to be a reference.

Resource Assignment: Data envelopment analysis determines relative effective and ineffective units and provides insights for resource protection or output enhancement potentials for ineffective units.

Both methods make it convenient to assign resources to units. The determination of the relative effective and ineffective units gives the first indication of which direction the resources should be transferred in principle.

2.3. Advantages and Disadvantages of DEA

One of the major advantages of the DEA method is that it does not include limitations on the functional form of the production relationship between inputs and outputs. DEA can be applied simultaneously to multiple inputs and multiple outputs. One of the major disadvantages of the DEA is that it is very sensitive to variable selection and data errors. The main advantages and disadvantages are explained below.

2.3.1. Advantages of DEA

DEA is capable of processing input and output to get optimal results for a good efficiency score: it gives results based on individual observation, not average density: it determines the efficient and the inefficient decision-making units and finds the source of this inefficiency: it provides help to determine the units which will be reference to the inefficient decision-making units: it determines the most appropriate criteria to relative progress of each decision-making unit (Kalirajan and Shand, 1999).

It is assumed that DEA is a deterministic method which means the inputs and the outputs are not produced with a random mechanism. No functional distribution rule is necessary for the of nonparametric approach. Efficiency analysis is performed according to the boundary function created by the best observations, instead of the average function of statistical boundary estimation methods, targets are made by taking the best performing units as examples (Charnes, 1995).

The decision units whose activities are calculated with DEA are compared to those with relatively full efficiency. Inputs and outputs can have very different units. In this case, there is no need to use various assumptions and transformations in order to measure them under the same conditions (Sowlati, 2001, Cooper et al., 2007).

2.3.2. Disadvantages of DEA

DEA is sensitive to measurement error. Since DAE is a terminal point technique, measurement mistake can be cause to huge problems. DEA is enough to measure the performance of decision points. But this does not give a clue about the interpretation of the absolute effectiveness of the assessment. DEA is not a parametric technique, and, in this context, it is very difficult to apply statistical hypothesis tests to the results (Kale, 2009).

DEA is in the form of a static analysis. It makes a cross-sectional analysis between the decision point data in a single period. As a result of the analysis, a single activity estimator is obtained for each decision point. A separate linear programming model must be solved for all decision points. In this context, the solution of large problems with DEA can be time consuming in terms of calculation. Data Envelopment Analysis depends on the present sample. Although the decision-making units are good in measuring the relative efficiency, DEA cannot be used to determine absolute efficiency. Data Envelopment Analysis does not make a comparison to the maximum theoretical activity (Emrouznejad et al., 2008, Sowlati, 2001, Cooper et al., 2007).

2.4. DEA Process

The steps in the implementation of DEA are described below.

2.4.1. Selection of Decision Points

The choice of decision point is very important in terms of the accuracy of the results of the analysis. DEA is a comparative analysis and if the wrong decision units are analyzed, all analysis results are affected. The points to be considered in the selection of the decision point are as follows: decision points should be similar in terms of inputs and outputs used and produced, the same input and output combinations should be evaluated; there should be a similar set of resources for all decision points and all decision points must be operating in similar environmental conditions. Since the external environment is important on the efficiency of the enterprise (Wheelock and Wilson, 1999).

2.4.2. Selection of Input and Output Factors

The characteristics of the selected inputs should be as follows (Bakırcı, 2006).

- There should be common factors for all decision points.
- It should cover all activity levels and performance criteria to be reviewed.
- It should include all the measurable physical and economic resources.

The following formula defines the number of decision points (Bakırcı, 2006).

Minimum number of decision units = 2 x Number of Inputs x Number of Outputs

This is a general rule. It is necessity to have a correlation between inputs and outputs. Analysis of index numbers and normal measurements in inputs and outputs leads to error. Using unadjusted raw data reduces the error. Another point to be considered in DEA is that an increase in inputs causes a decrease in efficiency. However, the increase in output results in an increase in efficiency (Banker et al., 1984).

2.4.3. Model Selection

Many DEA models can be conducted according to the application areas and assumptions. Which model is selected or how a model is to be established depends on whether the inputs and outputs can be checked. If there is less or no control over inputs, an output-oriented model must be conducted. If the control over the outputs is less, an input-oriented model should be conducted. If, however, a focus cannot be achieved, it is appropriate to use additive models.

If the decision maker is concerned with the event status of the decision points and does not care about the type of activity, all models can be used. Additive models should not be used if the decision maker cares about the type of activity. Because additive models do not examine the separation of activities according to their types (Ersoy and Kavuncubaşı, 1995).

2.4.3.1. Basic DEA Models

There are different classifications of DEA models which are used for comparative activity analysis. The three most commonly used classifications. First is the CCR model that consists of fractional weighted for input and output under the hypothesis of constant returns use to scale; the BBC models which hypothesis of variable returns to scale; and the additive model which expresses models for input and output only (Charnes et al., 1985). DEA models are differentiated of according to: Input oriented, output oriented, and neutral, constant, or variable returns to scale (Adler et al., 2002).

2.4.3.2. CRR Models

CCR models are programming models working under the constant returns to scale hypothesis (Charnes, Cooper, and Rhodas, 1978). This model is implemented as a linear programming model and solutions are calculated for each decision-making unit. There are two structures of CCR models known as input oriented and output oriented. In case the decision-making unit, is trying to be increase efficiency by decreasing the inputs for the same level of outputs in input-oriented models or increasing the outputs for the same level of inputs in output-oriented models (Li et al., 2008).

2.4.3.3. BBC Model

This model is first suggested by R.D. Banker, A. Charnes and W.W Cooper 1984, and known with the abbreviation of BCC which are the initials of their names. The difference of this model from the CCR model is the activities of decision-making units, which are assuming to be constant returns to scale in CRR model while this situation is variable return to scale in BCC model. They show whether the decision-making units are producing to the optimal scale or not by measuring input and output activities (Banker et al., 1984: 1078).

2.4.3.4. Additive Model

Among all DEA models, the additive model can be described as an only model which is both input and output oriented (Banker et al., 1984). In this model bouth inputs and outputs are simultaneously altered. The main aim of the model is to find the input – output combination which provides the most progress by maximizing the total output subject to input use (Green et al., 1997).

This modelling resembles the BCC model of the DEA. The difference between additive modelling and BCC model is that the relative inefficiencies are removed, and all the inefficiencies are kept in slack and surplus variables. That is why the only point to be considered while making an analysis for inefficiency is that if the slack and surplus variables are equal to zero or not (Bowlin, 1998). If their decision-making units are efficient, they are also efficient in the additive model. However, when a DMU is inefficient, differences can occur because of the size and source of the inefficiency for these two methods of DEA analysis.

2.4.4. Interpretation of Results

There are many packages for the solution of DEA models. The most common ones are listed below;

- Excel add-in DEA-Solver,
- EMS (Efficiency Measurement System),
- Warwick DEA by University of Warwick,
- DEAP (It also analyzes the econometric efficiency).

Inaddition multi-purpose package programs including linear programming modules such as DS, Windows, QS, QSB can be used. These programs do not give a warning to the decision maker whether the input / output factors are selected incorrectly or not, and whether the wrong model is used. The decision maker on such matters must be more careful (Karasoy, 2000).

3. TOMATO INDUSTRY IN TURKEY

Tomato production is quite essential in the world because it is one of the vegetable crops which is mostly consumed by people in all countries. According to the United Nations Food and Agricultural Organization, approximately 170 million tons of tomatoes were produced for 2014 world – wide with over 12 million acres in production (FAO, 2017). China has the highest production, followed by the United States, and India. Turkey is ranked fourth. Near 70% of total tomato production is supplied by the first five producing countries (USDA-AMS, 2017). Turkey has significant output and exports for tomato production.

Annual tomato production in Turkey is approximately 12 million tons (Engindeniz, 2013). By Turkey produces match of its tomatoes in greenhouses. Turkey exported 574 279 tons of fresh tomatoes in exchange for $ 467000 in 2010 and 17109 tonnes of peeled tomatoes in exchange for 21.5 million $ (FAO, 2012). The tomato is an essential raw material of agro-industries. Significant research has been carried about the economic aspects and issues of tomato production in Turkey (Dağdeviren and Ferhatoğlu; 1987; Ergun, 1995; Çiçek et al., 1999; Çetin et al., 2000; Tanrıvermiş, 2000; Akçay et al., 2000). Economic analysis of enterprise that grows tomatoes was made by (Tatlıdil et al., 2003). The profitability of tomato production was determined by analyzing the cost, yield and price to reach the profitability of farms, (Engindeniz, 2006; 2007; Hayırlıoğlu, 2007; Turhan et al., 2008) Energy use was studied for each hectare in the tomato production areas by (Çetin and Vardar, 2008). However no study has yet investigated tomato production efficiency in Turkey using DEA.

4. MODEL AND METHODS

In this study, the technical efficiency in investigated using DEA to reach minimizing input production level tomato production for each greenhouse data for 281. Producers is used in the study. For the calculation of data envelopment analysis, excel-solver package program is used, and the DEA frontier package program supported the results of the report. The study includes many inputs and one output. Data Envelopment Analysis that is the base method of Farrell (1957), It is a nonparametric method to determine the best level of production. The DEA, analyses produce efficient inputs and outputs and efficiency scores between 0 and 1. An efficiency score is 1 is efficient, and less than 1, indicates inefficient or lower productivity. In this study, the DEA analysis is based on input minimization under constant return to scale and variable returns to scale.

DEA finds the minimum input use under the constant returns to scale and variable returns to scale. CRS and VRS aim are a decrease in inputs level when the output level is constant. If we think that there are A inputs, B outputs, and N farms, for the first farm(i), there are vectors xi and yi. From here first input matrix (X) is AxN and output matrix(Y) is BxN.

Efficiency is definitizing total weighted outputs divided to weighted inputs as a sum. The mathematical formula is $u, y_i \;/\; q' x_i$

In this formula, U is a vector for outputs (Bx1), and q is a vector for inputs (Ax1) as weights. The weights can be used to determine with mathematical programming a measure of efficiency

Formula:

$$Max_{u,q}(u'y_i \ / \ q'x_i) \quad \text{subject to} \quad u'y_j \ / \ q'x_j \leq 1 \quad j = 1,2 \ldots N$$

$$\text{And} \quad u, q \geq 0 \qquad \textbf{(1)}$$

From this formula, u and q are solved, and output level increased to a maximum level under all constraints. Measures must be equal to 1 or less. After this process, there are many solutions for this formula, and one for each firm, this formula must solve again.

Finally,

$$Max_{\mu,v}(\mu' y_i) \quad \text{subject to} \quad v'x_i = 1 \qquad \mu' y_j - v'x_j \leq 0 \ , \quad j = 1,2 \ldots N$$

$$\mu, v \geq 0 \qquad \textbf{(2)}$$

In this formula, u and q are changed to m and v. It is multiplier form for constant returns to scale in DEA. However, in this study can alternative model is used obtains minimized inputs.

The efficient is envelopment formed from:

$$Min_{\theta,\lambda}\theta \quad \text{subject to} \quad Y\lambda - y_i \geq 0 \qquad \text{And} \quad \theta x_i - x\lambda \geq 0 \qquad \lambda \geq 0 \qquad \textbf{(3)}$$

From formula, θ is a scalar and, λ is Nx1 vector of formula. For each farm, the estimated value is calculated for θ, to obtain efficiency scores. This process is made N times for each farm. It is an optimal scale for farms under the constant return scale. Also, an alternative formulation is calculation for the variable returns to scale, (Fraser and Cordina, 1999).

The variable returns to scale formula are:

$Min_{\theta,\lambda}\theta$ subject to $Y\lambda - y_i \geq 0$

And $\theta x_i - x\lambda \geq 0$ $N'\lambda \geq 0$ $\lambda \geq 0$ **(4)**

Where N is $Nx1$ vector of variable returns to scale. Variable returns to scale include efficient farms ($0.9 < TE \leq 1$). The efficiency scores under the variable return scale, is equal or higher than efficiency scores under constant returns to scale by Banker et al. (1984).

4.1. Data

In this study, the activities of tomato cultivators in Antalya were tested. This data is used to determine; total effective and ineffective decision units by calculating the relative complete activities of the operating producers; potential improvement percentages of ineffective producers to make decision-making units more effective; and sorting of all producers from the most effective tomato producer to the most ineffective tomato producer. For these purposes, the following operations have been carried out. The data one for 281 producers of tomatoes operating in different districts of Antalya, Turkey. For this study, three different regions of Antalya are selected: Antalya Serik, and Kumluca. Greenhouses consist of plastic and glass greenhouses. Researchers completed this survey with farmers in face to face meeting. Data one for inputs and output of tomatoes, and other social- economic variables. Common variables which can be measured, and standard is a for in all producers are used in DEA analysis.

Sixteen inputs and output are used; greenhouse area as a decare (input X1), fertilizer quantity as a kg (input X2), total seed number (input X3), pesticide quantity as liters (input X4), total gasoline quantity (Input X5), electricity quantity (input X6), fuel quantity (input X7), wood quantity (input X8), coal quantity (input X9), general labor (input X10), fertilizer labor (input X11), seedling labor (input X12), pesticide labor (input X13), irrigation labor (input X14), family labor (input X15), work to preparation soil (input X16), and 1 output that is total production of tomato (output Y1) variables were used in this study for producing tomato.

4.2. Input and Outputs

4.2.1. Inputs

Land area is measured by decares. Both owned and retied. Fertilizer, wood, and coal is measured by the kilogram. These inputs: Pesticide, gasoline, and fuel used by farmers is measured by the liter, electricity by kilowatt, and labor by days.

Input Variable:

Greenhouse area	Da	Total area size for each farm
Fertilizer quantity	Kg	Input name. It is called the decision unit
Seed	Number	Amount of seed used for operation
Pesticides	Lt	Total liter of pesticides used to produce tomato in a farm
Gasoline	Lt	Total liter was used for each the greenhouse as an annual

Electricity	kWh	Total amount of electricity is used for each greenhouse a year
Fuel	Lt	Total fuel was used for each greenhouse as liter for a year
Wood	Kg	Total wood was used in the greenhouse for a year
Coal	Kg	Total amount of cool used in a greenhouse for one year
Labor	Day	The total labor used in a greenhouse for a year
Fertilizer labor	Day	The labor amount used for fertilizer of greenhouse within a year
Seedling labor	Day	The labor amount used for seedling of greenhouse within a year
Pesticide labor	Day	The labor amount used for pesticide of greenhouse within a year
Irrigation labor	Day	The labor quantity used for irrigation processes in each farm for a year
Family labor	Number	Total labor used in a greenhouse from for family for a year
The labor of preparation soil	Day	Total labor used for preparation soil in a greenhouse for each year

4.2.2. Output

Total production of tomatoes used for output in tons. All data are for the year 2015.

Output Variable:

Total production (tone) Total annual production of tomato for each producer as ton.

4.2.3. An Example

The data for tomato producers for the year 2015 are shown in Table 1 for three farms.

Table 1. Data on the greenhouse in Antalya

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	Y1
Farm No	Greenhouse Area (Da)	Amount of Fertilizer (Kg)	Seedling (number)	Pesticide (Lt)	Amount of Gasoline (Lt)	Electric (kW)	Diesel Fuel (Lt)	Wood (Kg)	Coal (Kg)	Labor (day)	Fertilizer Labor (day)	Seedling Labor (day)	Pesticide Labor (day)	Irrigation (day)	Family (number)	Preparation soil (day)	Total Production (tons)
1	6	3100	6300	205	3000	2000	3000	0	0	49	12	13	9	4	3	49	40
2	8	2400	20000	400	3000	2000	3000	0	0	155	60	30	6	2	3	155	130
3	4	275	8000	95	500	2000	500	0	0	70	21	0	5	2	6	70	60

A linear programming model is necessary for DEA. The mathematical model for Greenhouse 1 given below. The problem aims to minimize the total weight for the inputs. The objective function is linear mathematical programming below. The second constraint is the weight of other greenhouses. The limitation will be the number of greenhouses considered in the analysis.

Minimize = 6 w_1 + 3100 w_2 + 6300 w_3 + 205 w_4 + 3000 w_5 + 2000 w_6 + 3000 w_7 + 0 w_8 + 49 w_{10} + 12 w_{11} + 13 w_{12} + 9 w_{13} + 4 w_{14} + 3 w_{15} + 49 w_{16} **(0)**

Subject to:

-40 t + 6 w_1 + 3100 w_2 + 6300 w_3 + 205 w_4 + 3000 w_5 + 2000 w_6 + 3000 w_7 + 0 w_8 + 0 w_9 + 49 w_{10} + 12 w_{11} + 13 w_{12} + 9 w_{13} + 4 w_{14} + 3 w_{15} + 49 $w_{16} \geq 0$ **(1)**

-130 t + 8 w_1 + 2400 w_2 + 20000 w_3 + 400 w_4 + 3000 w_5 + 2000 w_6 + 3000 w_7 + 0 w_8 + 0 w_9 + 155 w_{10} + 60 w_{11} + 30 w_{12} + 6 w_{13} + 2 w_{14} + 3 w_{15} + 155 $w_{16} \geq 0$ **(2)**

-60 t + 4 w_1 + 275 w_2 + 8000 w_3 + 95 w_4 + 500 w_5 + 2000 w_6 + 500 w_7 + 0 w_8 + 0 w_9 + 70 w_{10} + 21 w_{11} + 0 w_{12} + 5 w_{13} + 2 w_{14} + 6 w_{15} + 70 $w_{16} \geq 0$ **(3)**

One addition constraint that makes the weights some to one is needed to complete the model 1. That is:

6 w_1 + 3100 w_2 + 6300 w_3 + 205 w_4 + 3000 w_5 + 2000 w_6 + 3000 w_7 + 0 w_8 + 0 w_9 + 49 w_{10} + 12 w_{11} + 13 w_{12} + 9 w_13 + 4 w_{14} + 3 w_{15} + 49 w_{16} = 1 **(4)**

$w_1, t_r \geq 0.0001 \quad i = 1 \quad r = 1, 2, 3, \ldots\ldots, 16$ **(5)**

The solution was found by solver in Excel.

Objective Function Value

1

Table 2. The results of the solver solution

	Variable	Value	Row	Dual Quantities
(X1) t_1	Greenhouse Area (Da)	0	1	-1
(X2) t_2	Fertilizer (Kg)	0	2	-8.32667E-17
(X3) t_3	Seedling (Number)	0	3	-1.38778E-15
(X4) t_4	Pesticide (L)	0	4	1
(X5) t_5	Gasoline (L)	0.000466667		
(X6) t_6	Electric (kWh)	0.000383333		
(X7) t_7	Diesel Fuel (L)	0		
(X8) t_8	Wood (Kg)	0		
(X9) t_9	Coal (Kg)	0		
(X10) t_{10}	Labor (Da)	0		
(X11) t_{11}	Fertilizer Labor (Day)	0		
(X12) t_{12}	Seedling Labor (Day)	0		
(X13) t_{13}	Pesticide Labor (Day)	0		
(X14) t_{14}	Irrigation (Day)	0		
(X15) t_{15}	Family (Number)	0		
(X16) t_{16}	Preparation soil (Day)	0		
(Y1) w_1	Total Production (Tone)	0.016666667		

When looking at the programming results, it is seen that the objective function value is equal to one so that farm 1 is efficient. The Colum labelled variable illustrates quantity of inputs and output. Units are associated with each input and output in parenthesis. The maximum amounts are reported under value. Dual quantities indicate that a specific farm input is efficient or inefficient. The researchers have seen that, if the objective values equal to 1, farm 1 is efficient. However, if these values are less than 1 for farm 1, farm 1 is inefficient. When farm 1 is inefficient, the researcher looks at VALUES, and see which input values should decrease and by how much DUAL QUANTITIES, suggestion the presence of inefficient farms (Callen, 1991).

5. RESULTS

Results for Antalya, Turkey are reported in in Turkey. The results are three different areas. The three regions are close each to others, and have approximate properties like weather, soil, the design of the greenhouse. In businesses, both plastic and glass were used to produce tomato production. These farms produce tomatoes only between autumn and spring. The results of the descriptive statistics of 281 farms were given in Table 3 below.

Table 3. Descriptive statistics of input and outputs used for sample data

Type	Variable	Units	Mean	S.d.	Min	Max
Input 1	Greenhouse Area	Da	4.60231	2.7232	0.7	20
Input 2	Fertilizer	Kg	1034.06	925.04	100	8210
Input 3	Seedling	Number	6578.25	6514.9	144	60000
Input 4	Pesticide	Lt	326.53	317.27	0	2300
Input 5	Gasoline	Lt	197.278	537.73	0	3000
Input 6	Electric	kWh	1923.38	849.95	0	6500
Input 7	Diesel Fuel	Lt	536.566	977.49	0	4000
Input 8	Wood	Kg	464.643	926.84	0	10000
Input 9	Coal	Kg	158.007	282.74	0	2500
Input 10	Labor	Da	108.399	67.099	0	330
Input 11	Fertilizer Labor	Day	44	39.161	0	250
Input 12	Seedling Labor	Day	37.2491	42.282	0	400
Input 13	Pesticide Labor	Day	28.7367	26.752	1	140
Input 14	Irrigation Total	Day	7.23488	10.469	0	80
Input 15	Family	Number	4.24199	1.1581	1	6
Input 16	Preparation Soil	Day	108.399	67.099	0	330
Output	Total Production	Ton	42.6623	36.204	0.6	230

Some partial indicators of efficiency were evaluated. An output to input ratio was calculated for each of input and output. Sample correlation coefficients were calculated to see which variables have used them together. The results of the correlation analysis are present in Table 4. Many variables are not highly correlated.

Table 4. Technical efficiency scores

	Technical efficiency	Technical efficiency
	CRS Constant returns to scale	VRS Variable returns to scale
Mean	0.9739	0.9755
Std deviation	0.0960	0.0946
Min	0.0961	0.0961
Max	1	1

In table 4, estimated technical efficiency scores of farms are presented under the constant returns to scale. The mean of 281 farms is 0.973. The standard deviation is 0.096. The value of maximum is 1 and minimum is 0.096. The mean of variable returns to scale efficiency score is 0.975, and the standard deviation is 0.094. The minimum value is 0.096, and the maximum amount is 1. It is seen that TE scores have a higher average of mean and standard deviation in under VRS than CRS.

Table 5. The results of sample correlation analysis

	Greenhouse Area-Deca	Amount of Fertilizer-KG	seedling numbers	Pesticide - Lt	Amount of Gasoline -lt	Electric-kWh	Diesel Fuel-Lt	Wood _KG	Coal- KG	Labor - day	Fertelizer_Labor	Seedling_Labor	Pesticide_Labor	Irrigation Total	Family	Preparation soil	total production(tons)
Greenhouse Area-Decare	1																
Amount of Fertilizer-KG	0,221352	1															
seedling numbers	0,335741	0,303602	1														
Pesticide - Lt	0,143094	0,126053	0,117833	1													
Amount of Gasoline -lt	0,140403	0,260509	0,122497	-0,02545	1												
Electric-kWh	0,157019	-0,16762	-0,01623	0,062755	0,013783	1											
Diesel Fuel -Lt	0,209759	0,416359	0,066096	0,032673	0,458945	0,015513	1										
Wood _KG	0,16727	0,115448	0,085047	-0,04058	-0,03999	0,057834	-0,0514	1									
Coal- KG	0,159686	0,115745	0,068468	0,098256	-0,03894	-0,07881	-0,06285	0,045829	1								
Labor - day	0,019185	-0,21184	-0,04554	0,065277	-0,09489	0,171206	-0,21151	0,002203	0,112291	1							
Fertelizer_Labor	0,176525	-0,11366	0,057972	0,200609	-0,0753	0,205949	-0,14978	0,102973	0,162417	0,438732	1						
Seedling_Labor	0,218986	-0,09664	0,158833	0,016525	-0,00565	0,222547	-0,09444	0,042944	0,186008	0,394668	0,406596	1					
Pesticide_Labor	0,111155	-0,00624	0,011851	0,224852	0,003565	0,097931	-0,03965	0,027155	0,238459	0,494525	0,492817	0,351254	1				
Irrigation Total	0,051047	-0,07461	0,075868	0,048735	0,101251	0,146324	0,068735	-0,01862	0,021744	0,189581	0,254209	0,288227	0,210932	1			
Family	-0,0025	0,123059	0,037554	-0,05351	-0,0586	0,056093	0,004507	-0,04055	-0,15863	-0,04638	-0,14537	0,040338	-0,1471	-0,03563	1		
Preparation soil	0,019185	-0,21184	-0,04554	0,065277	-0,09489	0,171206	-0,21151	0,002203	0,112291	1	0,438732	0,394668	0,494525	0,189581	-0,04638	1	
Total production (tons)	0,250134	0,038381	0,051333	-0,08663	0,131926	0,057507	0,069037	0,119875	-0,09823	-0,01701	0,063962	-0,03106	0,065092	-0,01565	-0,05191	-0,01701	1

The results for all firms in the analysis are presented in Tables 6, 7, and 8. More farms appear to be efficient, under the variable returns to scale than under the constant returns to scale.

Table 6. Farm efficiency scores

Farm Name	VRS Efficiency	CRS Efficiency		Farm Name	VRS Efficiency	CRS Efficiency	
1	1.00000	1.00000		51	1.00000	1.00000	
2	1.00000	1.00000		52	1.00000	1.00000	
3	1.00000	1.00000		53	0.97848	0.97848	*
4	1.00000	1.00000		54	1.00000	1.00000	
5	1.00000	1.00000		55	1.00000	1.00000	
6	0.67643	0.67643	*	56	1.00000	1.00000	
7	1.00000	1.00000		57	1.00000	1.00000	
8	1.00000	1.00000		58	1.00000	1.00000	
9	1.00000	1.00000		59	1.00000	1.00000	
10	1.00000	1.00000		60	1.00000	1.00000	
11	1.00000	1.00000		61	1.00000	1.00000	
12	1.00000	1.00000		62	1.00000	1.00000	
13	1.00000	1.00000		63	1.00000	1.00000	
14	0.80719	0.80719	*	64	0.97583	0.97583	*
15	1.00000	1.00000		65	1.00000	1.00000	
16	1.00000	1.00000		66	1.00000	1.00000	
17	1.00000	1.00000		67	1.00000	1.00000	
18	1.00000	1.00000		68	1.00000	1.00000	
19	0.75758	0.75758	*	69	1.00000	1.00000	
20	1.00000	1.00000		70	0.83333	0.83333	*
21	1.00000	1.00000		71	1.00000	1.00000	
22	1.00000	1.00000		72	1.00000	1.00000	
23	1.00000	1.00000		73	1.00000	1.00000	
24	1.00000	1.00000		74	1.00000	1.00000	
25	1.00000	1.00000		75	1.00000	1.00000	
26	1.00000	1.00000		76	1.00000	1.00000	
27	1.00000	1.00000		77	0.93750	0.93750	*
28	0.98876	0.98876	*	78	0.92308	0.92308	*
29	1.00000	1.00000		79	1.00000	1.00000	
30	0.98876	0.98876	*	80	0.70305	0.69116	*
31	0.67339	0.67339	*	81	1.00000	1.00000	
32	1.00000	1.00000		82	1.00000	1.00000	
33	1.00000	1.00000		83	1.00000	0.72311	*
34	0.88889	0.88889	*	84	1.00000	1.00000	
35	1.00000	1.00000		85	1.00000	1.00000	
36	0.81906	0.81906	*	86	1.00000	1.00000	
37	1.00000	1.00000		87	1.00000	1.00000	
38	1.00000	1.00000		88	1.00000	1.00000	
39	1.00000	1.00000		89	1.00000	1.00000	
40	1.00000	0.93521	*	90	1.00000	1.00000	
41	1.00000	1.00000		91	1.00000	1.00000	
42	1.00000	1.00000		92	1.00000	1.00000	
43	0.88462	0.88462	*	93	1.00000	1.00000	
44	1.00000	1.00000		94	1.00000	1.00000	
45	1.00000	1.00000		95	1.00000	1.00000	
46	1.00000	1.00000		96	1.00000	1.00000	
47	0.76051	0.76051	*	97	1.00000	1.00000	
48	1.00000	1.00000		98	1.00000	1.00000	
49	0.86415	0.86415	*	99	1.00000	1.00000	
50	1.00000	1.00000		100	1.00000	1.00000	
Percent	78%	76%		Percent	90%	88%	

Table 7. Farm efficiency scores

Farm Name	VRS Efficiency	CRS Efficiency		Farm Name	VRS Efficiency	CRS Efficiency	
101	1.00000	1.00000		151	1.00000	1.00000	
102	1.00000	1.00000		152	1.00000	1.00000	
103	1.00000	1.00000		153	1.00000	1.00000	
104	1.00000	1.00000		154	1.00000	1.00000	
105	1.00000	1.00000		155	1.00000	1.00000	
106	1.00000	1.00000		156	1.00000	1.00000	
107	1.00000	1.00000		157	1.00000	1.00000	
108	1.00000	1.00000		158	1.00000	1.00000	
109	1.00000	1.00000		159	1.00000	1.00000	
110	1.00000	1.00000		160	1.00000	1.00000	
111	1.00000	1.00000		161	1.00000	1.00000	
112	1.00000	1.00000		162	0.89163	0.89163	*
113	1.00000	1.00000		163	0.94737	0.94737	*
114	1.00000	1.00000		164	1.00000	1.00000	
115	1.00000	1.00000		165	1.00000	1.00000	
116	1.00000	1.00000		166	1.00000	1.00000	
117	1.00000	1.00000		167	1.00000	1.00000	
118	1.00000	1.00000		168	0.40701	0.40701	*
119	1.00000	1.00000		169	1.00000	1.00000	
120	1.00000	1.00000		170	1.00000	1.00000	
121	1.00000	1.00000		171	1.00000	1.00000	
122	1.00000	1.00000		172	1.00000	1.00000	
123	0.90989	0.90989	*	173	1.00000	1.00000	
124	1.00000	1.00000		174	1.00000	1.00000	
125	1.00000	1.00000		175	1.00000	1.00000	
126	1.00000	1.00000		176	1.00000	1.00000	
127	1.00000	1.00000		177	1.00000	1.00000	
128	1.00000	1.00000		178	1.00000	1.00000	
129	1.00000	1.00000		179	1.00000	1.00000	
130	1.00000	1.00000		180	1.00000	1.00000	
131	1.00000	1.00000		181	0.96322	0.96322	*
132	1.00000	1.00000		182	0.77277	0.77277	*
133	1.00000	1.00000		183	1.00000	1.00000	
134	1.00000	1.00000		184	1.00000	1.00000	
135	0.79530	0.79530	*	185	0.38687	0.38687	*
136	1.00000	1.00000		186	1.00000	1.00000	
137	1.00000	1.00000		187	0.09615	0.09615	*
138	0.60000	0.60000	*	188	1.00000	1.00000	
139	1.00000	1.00000		189	1.00000	1.00000	
140	1.00000	1.00000		190	1.00000	1.00000	
141	1.00000	1.00000		191	1.00000	1.00000	
142	1.00000	1.00000		192	1.00000	1.00000	
143	1.00000	1.00000		193	1.00000	1.00000	
144	1.00000	1.00000		194	1.00000	1.00000	
145	0.74162	0.74162	*	195	1.00000	1.00000	
146	0.97959	0.97959	*	196	1.00000	1.00000	
147	1.00000	1.00000		197	1.00000	1.00000	
148	1.00000	1.00000		198	1.00000	1.00000	
149	1.00000	1.00000		199	1.00000	1.00000	
150	1.00000	1.00000		200	1.00000	1.00000	
Percent	90%	90%		Percent	86%	86%	

Table 8. Farm efficiency scores

Farm Name	VRS Efficiency	CRS Efficiency	
201	1.00000	1.00000	
202	1.00000	1.00000	
203	1.00000	1.00000	
204	1.00000	1.00000	
205	1.00000	1.00000	
206	1.00000	1.00000	
207	1.00000	1.00000	
208	1.00000	1.00000	
209	1.00000	1.00000	
210	1.00000	1.00000	
211	1.00000	1.00000	
212	1.00000	1.00000	
213	1.00000	1.00000	
214	1.00000	1.00000	
215	1.00000	1.00000	
216	1.00000	1.00000	
217	1.00000	1.00000	
218	1.00000	1.00000	
219	0.69565	0.69565	*
220	1.00000	1.00000	
221	1.00000	1.00000	
222	1.00000	1.00000	
223	0.67569	0.67529	*
224	0.99039	0.99039	*
225	1.00000	1.00000	
226	1.00000	1.00000	
227	1.00000	0.85853	*
228	0.88154	1.00000	*
229	1.00000	1.00000	
230	1.00000	1.00000	
231	1.00000	0.92545	*
232	1.00000	1.00000	
233	1.00000	1.00000	
234	1.00000	1.00000	
235	1.00000	1.00000	
236	0.93342	0.93342	*
237	1.00000	1.00000	
238	1.00000	1.00000	
239	1.00000	1.00000	
240	1.00000	1.00000	
241	1.00000	1.00000	
242	1.00000	1.00000	
243	1.00000	1.00000	
244	1.00000	1.00000	
245	1.00000	1.00000	
246	1.00000	1.00000	
247	1.00000	1.00000	
248	1.00000	1.00000	
249	1.00000	1.00000	
250	1.00000	1.00000	
Percent	92%	88%	

Farm Name	VRS Efficiency	CRS Efficiency
251	1.00000	1.00000
252	1.00000	1.00000
253	1.00000	1.00000
254	1.00000	1.00000
255	1.00000	1.00000
256	1.00000	1.00000
257	1.00000	1.00000
258	1.00000	1.00000
259	1.00000	1.00000
260	1.00000	1.00000
261	1.00000	1.00000
262	1.00000	1.00000
263	1.00000	1.00000
264	1.00000	1.00000
265	1.00000	1.00000
266	1.00000	1.00000
267	1.00000	1.00000
268	1.00000	1.00000
269	1.00000	1.00000
270	1.00000	1.00000
271	1.00000	1.00000
272	1.00000	1.00000
273	1.00000	1.00000
274	1.00000	1.00000
275	1.00000	1.00000
276	1.00000	1.00000
277	1.00000	1.00000
278	1.00000	1.00000
279	1.00000	1.00000
280	1.00000	1.00000
281	1.00000	1.00000
Percent	100%	100%

In table 6, 7, and 8, when looking at the distribution of efficiency scores for under the variable constant scale and constant return scale, many farms are close to efficient or efficient for all the model specifications. So, most farms producing tomatoes are efficient. This region provides the majority export tomatoes in Turkey. Inefficient farms can improve their production process, and they can reach better efficient level. The optimal results of the model specifications are given in Tables 9 and 10 for CRS and VRS. With these results, farmers can be advised on how to be more efficient. This will provide savings for each input, advise profits.

Results from the constant returns to scale specification in Table 9, Indicate that the must; significant decrease to improve efficiency in the input of irrigation labor (16.6%) with the input value down from 7.23 to 6.32. This value is followed by the inputs of coal, fertilizer labor, and pesticide labor with decrease of 15.4%, 13.4%, and 12.1% respectively. At the same time, the lowest input decrease under the constant returns to scale is in inputs of family labor and amount of gasoline with 4.5% and 5.2%.

Table 9. Constant return to scale

	Variable	Units	Mean	S.d.	Min	Max	Percent %
CRS	Technical efficiency		0.97	0.09	0	1	-
X1	Greenhouse Area	Decare	4.30	2.66	0	18	6.6
X2	Amount of Fertilizer	KG	944.43	909.30	6	8210	8.7
X3	Seedling	Number	6061.20	6399.44	144	60000	7.9
X4	Pesticide	Lt	290.45	283.17	0	1500	11.0
X5	Amount of Gasoline	Lt	187.06	537.84	0	3000	5.2
X6	Electric	KWh	1814.51	873.99	0	6500	5.7
X7	Diesel Fuel	Lt	485.45	930.27	0	4000	9.5
X8	Wood	Kg	419.68	917.82	0	10000	9.7
X9	Coal	Kg	133.69	273.91	0	2500	15.4
X10	Labor	da	101.38	66.87	0	330	6.5
X11	Fertilizer Labor	Day	38.11	37.05	0	250	13.4
X12	Seedling Labor	Day	33.01	39.95	0	400	11.4
X13	Pesticide Labor	Day	25.27	25.95	1	140	12.1
X14	Irrigation Labor	Day	6.32	9.88	0	80	16.6
X15	Family Labor	Number	4.05	1.22	0	6	4.5
X16	Preparation Soil Labor	Day	101.38	66.87	0	330	6.5
Y1	Total Production	Tons	42.66	36.20	0	230	0

Table 10. Variable return to scale

	Variables	Units	Mean	S.d.	Min	Max	Percent %
VRS	Technical efficiency		0,976	0.09	0,10	1	-
X1	Greenhouse Area	Decare	4.32	2.69	0	18	6.1
X2	Amount of Fertilizer	KG	943.38	906.92	66	8210	8.8
X3	Seedling	Number	6101.20	6475.12	144	60000	7.3
X4	Pesticide	Lt	287.98	281.08	0	1500	11.8
X5	Amount of Gasoline	Lt	187.06	537.84	0	3000	5.2
X6	Electric	KWh	1817.77	874.89	0	6500	5.5
X7	Diesel Fuel	Lt	485.45	930.28	0	4000	9.5
X8	Wood	Kg	427.70	925.36	0	10000	8.0
X9	Coal	Kg	132.53	273.59	0	2500	16.1
X10	Labor	da	101.54	66.75	0	330	6.3
X11	Fertilizer Labor	Day	38.37	37.23	0	250	12.8
X12	Seedling Labor	Day	33.40	40.03	0	400	10.3
X13	Pesticide Labor	Day	25.46	26.07	1	140	11.4
X14	Irrigation Labor	Day	6.31	9.88	0	80	12.8
X15	Family Labor	Number	4.06	1.23	0	6	4.3
X16	Preparation Soil Labor	Day	101.54	66.75	0	330	6.3
Y1	Total Production	Tons	42.66	36.20	0	230	0.0

In the variable returns to scale analysis is reported in Table 10, the most significant decrease is seen in the input of coal quantity (16.1%). This value is followed by the inputs of fertilizer, irrigation labor, and pesticide quantity with 12.8%, 12.8%, and 11.8% respectively. At the same time, the lowest decreases under the variable return scale were seen in inputs of family labor and amount of gasoline with 4.5% and 5.2%. These numbers are the same decreases for constant returns to scale. However, in the constant returns to scale table, while the input of irrigation labor is the first number, in the variable returns to scale table, the highest saving is for the input of coal. Others are similar for both CRS and VRS.

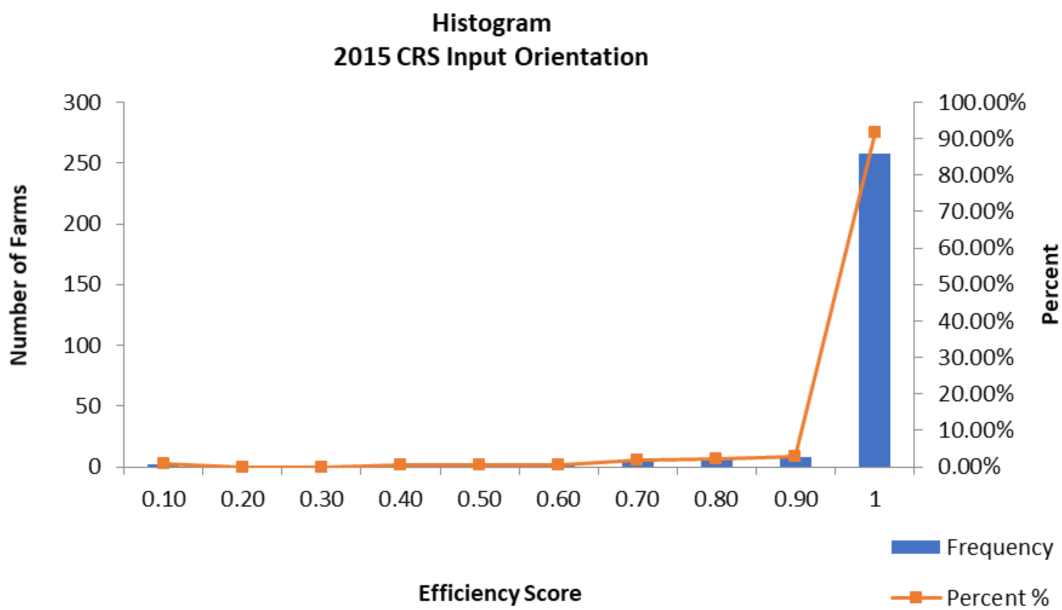

Figure 1. Histogram, 2015 CRS Analysis

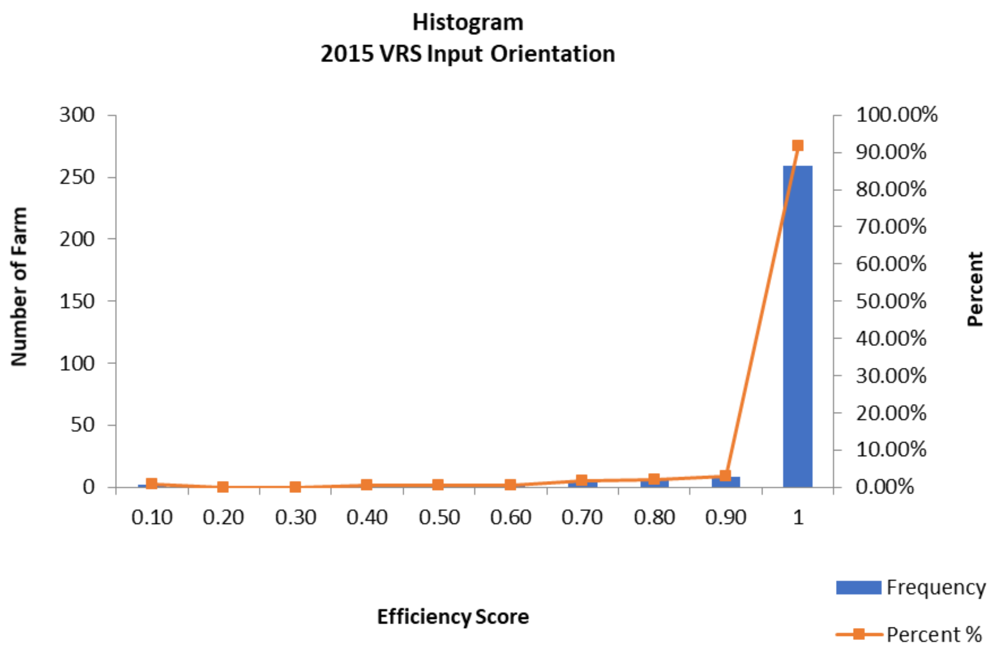

Figure 2. Histogram, 2015 VRS Analysis

In the analysis, 91,8% of farms continue produce efficient under the constant returns to scale. Results are similar under the variable returns to scale with 92%. There is a similar frequency distribution for the two analysis as well. The distributions of the of CRS and VRS efficiency scores are given in table 11 and 12.

The efficient and inefficient farms were tested, and it was illustrated in table 13 by CRS and table VRS. As a total, 244 farms efficient (TE =1) under the constant return scale and other 37 farms are inefficient (TE < 1) (Table 11).

Table 11. Technical efficient versus inefficient producers under constant return to scale (CRS)

	Variable Input	Unit	TE < 1 (n = 37)		TE = 1 (n = 244)		
			Mean	S.d.	Mean	S.d.	Percent %
CRS	Technical efficiency		0.802	0.192	1	0	19.8
X1	Greenhouse Area	Decare	2.104	0.912	4.631	2.685	54.6
X2	Amount of Fertilizer	KG	413.427	233.041	1024.955	946.172	59.7
X3	Seedling	Number	2694.757	1591.261	6571.687	6695.226	59.0
X4	Pesticide	Lt	120.576	59.51	316.205	294.638	61.9
X5	Amount of Gasoline	Lt	2.139	11.634	215.102	572.108	99.0
X6	Electric	KWh	1186.664	479.401	1909.713	881.469	37.9
X7	Diesel Fuel	Lt	9.108	23.436	557.684	978.423	98.4
X8	Wood	Kg	196.779	243.059	453.484	976.313	56.6
X9	Coal	Kg	22.094	58.763	150.615	289.404	85.3
X10	Labor	da	70.571	44.678	106.053	68.484	33.5
X11	Fertilizer labor	Day	22.045	15.113	40.549	38.761	45.6
X12	Seedling Labor	Day	20.183	14.547	34.951	42.173	42.3
X13	Pesticide Labor	Day	13.92	13.912	26.992	26.923	48.4
X14	Irrigation Labor	Day	2.541	2.207	6.893	10.454	63.1
X15	Family Labor	Number	3.182	1.188	4.18	1.169	23.9
X16	Preparation soil labor	Day	70.571	44.678	106.053	68.484	33.5
Y1	Total production	Tons	38.662	38.662	43.269	35.862	10.6

The efficiency score average of productive farms is, 1 but this number is 0.80 for other inefficient farms. When looking at the quantities of inputs, significant differences were seen. The average of greenhouse area input is 2.104 for productive farms and is 4.63 for the other 37 inefficient farms in Table 11.

The efficient farms had 19% higher technical efficiency scores than inefficient farms. Similarly, productive farms have higher input levels than other inefficient farms. When we look at Table 11 that is "Technically efficient farms versus inefficient producers under constant returns to scale," inefficient farms used approximately 50% less average input levels. These differences reached nearly 60% in the quantity of fertilizer, seedling number, irrigation labor and the amount of pesticide. It is interesting that this ratio is 98-99% in gasoline and fuel. This means that inefficient farms used nearly no fuel or gasoline when compared to efficient farms. After the efficiency analysis, the new values of inputs were developed for the other 37 farms to reach higher efficiency. These 37 farms should lower input levels than they currently use. Optimal values of input that are necessary for providing efficiency were calculated in this analysis. This evaluation is illustrated in Table 14 by comparing with the original value of input average and new values of input average. On average the quantity of fertilizer used for each in efficient farm per decare, is 4.2 kg. This amount should be decreased to 0.91 kg for each decare. Optimal seedling numbers should fall from 6554 to 2194, or 66% decrease. Optimal labor and electricity use should be decreased a substantial amount as well.

Table 12. Available value and suggested optimal input value for 37 inefficient farms

	Variable	Unit	Original Value Mean	Suggestion Value Mean	Percent (%) Change
CRS	Technical efficiency		0.802	1.000	24.7%
X1	Greenhouse Area	Decare	4.276	0.971	-77.2%
X2	Amount of Fertilizer	Kg	1055.000	407.666	-61.3%
X3	Seedling	Number	6554.000	2194.916	-66.5%
X4	Pesticide	Lt	385.162	145.567	-62.2%
X5	Amount of Gasoline	Lt	79.730	53.539	-32.8%
X6	Electric	kWh	1986.486	370.435	-81.3%
X7	Diesel Fuel	Lt	397.297	272.820	-31.3%
X8	Wood	Kg	525.676	235.774	-55.1%
X9	Coal	Kg	206.757	141.837	-31.4%
X10	Labor	Day	122.919	26.677	-78.3%
X11	Fertilizer labor	Day	66.000	29.432	-55.4%
X12	Seedling Labor	Day	52.000	19.241	-63.0%
X13	Pesticide Labor	Day	39.703	17.097	-56.9%
X14	Irrigation Labor	Day	9.378	4.853	-48.2%
X15	Family Labor	Number	4.649	0.503	-89.1%
X16	Preparation soil labor	Day	122.919	26.677	-78.3%
Y1	Total production	Tons	38.662	38.662	0.0%

6. CONLUSION and DISCUSSION

In this study, DEA was used to determine the technical efficiency for each farm, and to calculate new input or output benchmarks for inefficient farms. The determination of efficient or inefficient farms and the input levels required to reach efficiency is valuable information for making the Turkish tomato industry more profitable and competitiveness.

In this study, the inputs used in data envelopment analysis were greenhouse area, amount of fertilizer, seedling, pesticide, consumption of gasoline, electricity, diesel, wood, coal, and labor were used as inputs. Six labor inputs included for the labor of fertilizer, seedling, pesticide, irrigation system, family, and preparation soil. The total production level for each farm was used as application output. After the analysis of this data, the mean of 281 farms efficiency is 0.973 CRS, with standard deviation is 0.096. TE average score for CRS is 91,8%. As a total, 244 farms are efficient (TE =1) and other 37 farms are inefficient (TE < 1) under the constant returns to scale.

A previous study for Izmir, Turkey found technical efficiency of tomato growing with CRS technology to be 0,78 as an average for 86 farms (Engindeniz and Öztürk Coşar 2013).

Inefficient farms were analyzed with results from the DEA and existing values of input. New efficient scores that provide information on possible increases in profit Table 14.

The efficiency scores must be increased 19% to reach to 1 from 0.81 for the 37 inefficient farms be efficient. To provide this efficiency, input levels should be reduced. The highest reduction should be in family labor (89.1%). The 37 inefficient farms used 4.64 labor per day as the average in 2015.

These farms can achieve efficiency by using 0.50 labor for per day. Consumption of electricity should fall 81.3% from 1986.4 kWh to 370.4. General labor and preparation labor should fall by 78.3% from 122.9 to 26.6 for each year. The amount of diesel fuel should fall by 31.3, from 397.2 liters to 272.82 for per year. The quantity of coal consumption should fall 31.4% with the changes. The profit of inefficient producers; would rise profits would be:

Total production * Production price - Total production * Cost = Profit

Efficient farms;

20.005,84 - 10.103,68 = $9.902,16

Inefficient Farms;

17.875,75 - 11.311,29 = $6.564,46

After adjusting to optimal input use inefficient farms profit would be:

17.875,75 - 3.811,00 = $14.064,75

It is estimated that when each inefficient farm becomes efficient, each producer would be saving approximately $7.500,00 for 2015. With 37 inefficient farms representing 13.1% of the total 281 farms in this study, this saving could provide a significant contribution to the economy of Turkey.

Turkey received $365.279.000 from tomato exporting in 2015 (UIB, 2017). If the inefficient farms could be efficient, Turkey could export nearly $419.887.000, a 15% increasing.

Available agricultural sciences should organize educational activities to improve the growing technique of inefficient producers’ tomato. Demonstrations to increase outputs should be presented for greenhouses tomato producers.

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