EFFICIENCY IN TURKISH AGRICULTURE:
A FARM HOUSEHOLD LEVEL ANALYSIS

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Approval of the Graduate School of Social Sciences

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ABSTRACT

EFFICIENCY IN TURKISH AGRICULTURE: A FARM HOUSEHOLD LEVEL ANALYSIS

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This thesis analyzes the efficiency structure of Turkish agriculture in farm household level by using various models of stochastic frontier analysis. A household level survey conducted in 2002 and 2004 is used in the analysis. Firstly, an efficient production frontier is estimated by a panel data models. By using these estimates, relative importance of production factors and their interaction with various farm specific factors are inspected. The parameters of production frontier show that agricultural production is crucially dependant on land and there is an excessive employment of labor in Turkish agriculture. Secondly, the efficiency scores are estimated at farm household level. The results are reported according to NUTS-II regional classification and many other farm specific characteristics. The western parts of the country are found to be relatively more efficient and there is a high deviation in mean efficiencies of different regions. There is an increase in mean efficiencies of all regions from 2002 to 2004. Besides, crop patterns, farm size, education level of household chief and irrigation are found to be effective on efficiency.

Keywords: Technical Efficiency, Turkish Agriculture, Stochastic Frontier Analysis

ÖZ

TÜRK TARIMINDA VERİMLİLİK: ÇİFTÇİ HANE HALKI DÜZEYİNDE BİR ANALİZ

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Bu tez çeşitli stokastik sınır analizi modelleri kullanarak Türk tarımının verimlilik yapısını köy hane halkı düzeyinde incelemektir. Analizde 2002 ve 2004 yılları için hane halkı düzeyinde yapılmış bir ankete kullanılmıştır. Öncelikle panel veri modelleri kullanılarak verimli bir üretim sınırı kestirimi yapılmıştır. Bu kestirimler kullanılarak üretim faktörlerinin görece önemleri ve hane halklarına özel çeşitli faktörlerle etkileşimleri incelenmiştir. Üretim sınırının parametreleri tarımsal üretimin önemli ölçüde toprağa bağımlı olarak yapıldığını ve Türk tarımında fazla işgücü istihdamı olduğunu göstermektedir. İkinci olarak, çiftçi hane halkı seviyesinde verimlilik oranları hesaplanmıştır. Sonuçlar, NUTS-II bölgesel sınıflandırmasına ve hane halkına özel bir çok değişkene göre sunulmaktadır. Batı bölgelerinin göreceli olarak daha verimli olduğu bulunmuş ve değişik bölgelerin ortalama verimlilikleri arasında yüksek oranda bir sapma bulunmuştur. Bölgelere göre verimlilikte 2002'den 2004'e bir artış vardır. Ayrıca üretim deseni, çiftlik büyüklüğü, hane halkı reisinin eğitim seviyesi ve sulamanın verimlilik üzerinde etkili olduğu bulunmuştur.

Anahtar Kelimeler: Teknik verimlilik, Türk tarımı, Stokastik Sınır Analizi,

In memory of my primary school teacher Mustafa Eracar,

To the teachers of enlightenment

and to her...

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CHAPTER 1

INTRODUCTION

Agriculture has been on the reform agenda of governments in Turkey since mid-1990s. The main motive of this reform agenda was decreasing the burden of agricultural subsidies on the finances of the government, causing an important fiscal discipline problem. This burden was not only related to the budget, but also distributed through several funds and state economic enterprises, causing considerable difficulties for the financial discipline. Political and economic instability has postponed the reforms until the end of the decade. Economic crisis of 2001 has made these reforms inevitable. Subsidization system has been changed substantially by Agricultural Reform Implementation Program (ARIP). To a great extent, ARIP was developed and recommended by the international financial institutions in the framework of a Structural Adjustment Program and was backed by the governments.

The problems of Turkish agriculture stem from three interrelated pillars: Macroeconomic stability, microeconomic efficiency and international competitiveness. The focus of public discussions held just before and after 2001 crisis was on the macroeconomic implications of government purchases through the state economic enterprises and agricultural sales cooperatives to sustain a predetermined level of price. ARIP has largely been designed in response to these discussions. Although ARIP was a necessary step to transform the agriculture, it has not been sufficient to solve the main problems of Turkish agricultural sector. ARIP was mainly concerned with macro structure of agriculture and it has not been supported by additional measures to create appropriate incentives to reform the micro- structures such as production and marketing. The implementation of reforms in the last 5 years has revealed the fact that the problems of agricultural sector cannot be solved unless the appropriate measures to transform these micro-structures are added to the reform program.

Another series of discussions have started in the context of EU accession negotiations and ARIP experience. ARIP has revealed the fact that most of the macro level problems are reflections of profound micro problems. Changing subsidy payment methods or product patterns may not be effective unless the micro level problems are addressed. Discussions about EU accession, on the other hand, have shown that Turkey may have difficulties in the integration of the agriculture in the EU, unless substantial restructuring is envisaged for the sector.

Recently, the potential impact of the world market liberalization in the agricultural products with Doha development round of WTO Agreement on Agriculture has been added to the agenda of discussions on Turkish agriculture. Necessity to transform the agricultural sector to increase its competitiveness in international markets forms the basis of the discussions.

There is a special emphasis on the efficiency of producers in these debates. All three pillars mentioned above are closely related to the efficiency of production, in one way or the other. To alleviate the burden of support programs on the budget and on the consumers, macro level institutions should be designed to create necessary incentives for producers to increase their efficiency, since supporting inefficient producers forever cannot be a sustainable policy. Secondly, to be a decent member of the EU, Turkey needs to increase the efficiency in production since EU is not likely to accept to bear the full cost of inefficiency of Turkish farmers from the common budget. Lastly, Turkish producers cannot compete with foreign producers under increased market access in domestic markets and in the international markets. Thus, any reform program that claims to unravel major issues in Turkish agriculture should give priority to the measures that will increase the efficiency of farmers in the core of its policies.

To shed a light on the discussions about the inefficiency levels of Turkish producers, first the concept of efficiency needs to be clarified. Usually, efficiency is used as a synonym for yield or productivity in the literature. However, there is a wide discrepancy between these concepts and efficiency. Efficiency can be defined as ability to produce maximum amount of output by employing minimum amount of inputs while yield and productivity are partial efficiency measures. The literature about efficiency of Turkish agriculture generally discusses the partial efficiency measures. Partial efficiency measures do not give any information about the ability of producers to utilize inputs. However, efficiency structure of Turkish farm production remains to be an unexplored topic. It is apparent that appropriate policies to increase the efficiency of farmers cannot be devised without proper information about the current efficiency posture of the farms and effects of different factors on efficiency.

The aim of this thesis is to close this gap in the literature. For this purpose, farm household level efficiencies for a large sample of households are estimated and effects of farm characteristics on efficiency are explored by making the most of quantitative methods. Chapter II focuses on the analytical framework of efficiency measurement. Firstly, a detailed literature survey about efficiency measurement is given. Then, a general outline of neoclassical production theory is described. Definition of efficiency, the analytical framework and various approaches to estimate or calculate technical efficiency scores follow. Chapter III introduces the data set and the general characteristics of Turkish agriculture revealed by the data used in the analysis. It also provides a detailed discussion of the estimation results depicting the efficiency scores and effects of selected factors on efficiency. Last chapter is reserved for concluding comments.

CHAPTER 2

MEASUREMENT OF EFFICIENCY

2.1 Theoretical Background: Definitions and Analysis

Efficiency has always been on the agenda of economics literature, with all its aspects. There is a vast literature that tries to figure out the underlying reasons of efficiency. For example, Adam Smith (1776) analyzed the relationship between land tenure and economic efficiency in the Wealth of Nations. However, recognition of the need to define and analyze efficiency in economics is relatively belated. Mainstream economists have included efficiency only as an assumption in their analysis of production. Firms were supposed to attain their behavioral goals fully. This adjournment was due to the lack of data that was necessary to analyze the efficiency. The appropriate data started to appear with the establishment of international organizations in the 1950s. The progress in data collection and analysis methods has made the importance of inefficiency in real life apparent. Although the data available to researchers were still limited, as more and more precise micro level data became available, the fact that inefficiency is a rule rather than exception became apparent.

The popularity of efficiency analysis in the last three decades has been due to the rapid development in "calculation methods" as much as this adjournment. The tools used in efficiency measurement, namely stochastic frontier analysis (SFA) and data envelopment analysis (DEA), offer highly advanced, but easy to implement procedures for economists. The former employs econometric methods while the latter make use of linear programming.

First part of this chapter provides theoretical and historical backgrounds for SFA and DEA. Then in the second part, analytical framework and empirical models of DEA and SFA are presented. SFA will be discussed in more detail since it is used to analyze the data.

2.1.1 Historical Background

The attempts to shed light on the role of efficiency in the production theory have started to develop "non-homogeneously" after the 1950 (Fare, Grosskopf and Lovell, 1985). Koopmans, Debreu, Vincze and Eichron were pioneers of the modern approach that was formally stated by Farrell (1957). Farrell's seminal paper, in one way or the other, was the basis of all approaches developed by modern productivity literature. It is possible to find the roots of all approaches and methods developed in the last 30 years in Farrell's paper (Førsund and Sorofoglou, 2000).

The root of efficiency analysis goes back to the work of Cowles Commission on the formulation of Neo-Walrasian production theory. Neo-Walrasian production theory uses the activity analysis form of production technology that was developed by von Neumann, and provides a flexible basis to compare the efficient and inefficient input-output combinations (Fonseca, 2005a). Koopmans (1951) as the leading author tried to figure out the conditions under which an input output vector is efficient. He found that in input output vector could be efficient only if it has a positive normal, named as "shadow prices", to the production possibilities set. Koopmans did not make any decomposition for efficiency, and his analysis was focused on the type of efficiency that is known as technical efficiency today. Koopmans' definition of efficiency has a twofold, i.e. both input and output, orientation. This twofold orientation has been widely used by the literature (Fonseca, 2005b).

Debreu (1951), on the other hand, developed an index of efficiency by utilizing the maximum equi-proportinate reduction in all inputs consistent with corresponding output level. To calculate this coefficient Debreu uses *"... the relative positions of 'utilizable physical resources' to 'a natural concept, the minimal physical resources' required to achieve at least the 'optimum satisfaction unit'"*.

He calls this index as "*coefficient of resource utilization*". Debreu's objective was to find a measure of "*loss related to a non-optimal situation*" in a general equilibrium model. Although his analysis had micro basis, Debreu's main concern was not micro-level analysis of efficiency. He acknowledged the three sources of inefficiency in his paper, but did not make any decomposition of his coefficient to disintegrate the effects of each sources of inefficiency. Another point that Debreu emphasized is the duality between input and output oriented measures of his coefficient.

Farrell (1957) is accepted to break new ground for the efficiency analysis by providing a decomposition of efficiency based on an index that is derived from Debreu's coefficients of efficiency and he initiated a comprehensive understanding of efficiency (Fare et al., 1985). Farrell was greatly influenced by Koopmans (1951) and Debreu (1951).

Farrell criticizes the attempts to measure efficiency "…due to a pure neglect of the theoretical side of the problem" (Farrell, 1957). Before the analytical approach of Farrell, average productivity of labor was used as a measure of efficiency, or weighted average of inputs were compared to output. The former was ignoring the impact of the other factors of production on output, while aggregation errors were inescapable in the latter. Farrell's aim was to provide a measure of efficiency that "…takes account of all inputs, yet avoids index number problems". First, he estimated a production frontier from the "most efficient" observations in the first place. Then, he measured the efficiency of each observation with its distance from the estimated frontier production. His estimation was generalized to multiple input and output case, and to non-constant returns to scale technology.

Farrell decomposed efficiency into two parts, namely the technical and price efficiency. Although this was a challenging contribution, it was incomplete since Farrell has ruled out the structural inefficiency from his analysis (Fare et al., 1985).

The first empirical applications based on Farrell's work appeared in a series of papers written by Berkeley economists, Boles (1966), Seitz (1966), Sitorus (1966) and Brown (1966). The roots of Berkeley economists' work can be found in the comment of Hoffman (1957) on Farrell's paper following the presentation of Farrell. Hoffman states that dual simplex method, a newly developed linear programming solution algorithm, can be applied in the empirical part of Farrell's paper. Boles developed an explicit linear programming modeling based on this idea, Seitz and Sitorus applied the model to data and Brown (1966) provided an overview. Boles (1971) expanded the model further with multiple inputs and outputs. This model was similar to that of DEA developed in the late 1970s (Førsund and Sorofoglou, 2000). The works of Berkeley economists have been largely ignored by subsequent contributors (Kumbhakar and Lovell, 2000).

Two different approaches were developed after Farrell, one by Fare (1975) and the other by Fare and Grosskopf (Fare et al., 1985). Fare (1975) relaxed the Farrell's assumption about equi-proportionate reductions in input and enhancements in outputs. This approach was modified by Fare and Lovell (1978), and Zieschang (1984), while it was extended to multiple output technologies by Fare, Lovell and Zieschang (1983) (Fare, et al., 1985).

The solution to the problem about returns to scale raised in Farrell (1957) was resolved with the idea of scale efficiency. The idea was originally due to Frisch (1965). Førsund and Hjalmarson (1974) developed an index for scale efficiency and this index was implemented by Førsund and Hjalmarson (1979) and Banker et. al. (1984). Later, Fare, Grosskopf and Lovell (1994) showed the link of scale efficiency with overall (or economic) efficiency.

The second approach, developed by Fare and Grosskopf (1983a and 1983b), was based on the scale efficiency idea. They decomposed efficiency into three components, one of which is the structural efficiency that was missing in Farrell (1957). Most of the concurrent work, including this study, used three-component decomposition that will be discussed in detail in part 2.2.1.2.

The empirical applications on efficiency measurement encompassed both DEA and SFA methodologies. DEA applications depended on Aigner and Chu (1968). They developed a deterministic model by introducing Cobb-Douglas function as a benchmark and using linear and quadratic programming to find the efficient frontier (Førsund and Sorofoglou, 2000). Formal introduction of DEA is stated by Charnes, Cooper and Rhodes (1978) and their contribution is known as "CCR model". They tried to maximize the relative efficiency of each decision-making unit. The aim is to define a frontier envelopment surface for all sample observations (Murillo-Zamorano, 2004)[1]. CCR model formed the basis of many studies on the calculation of efficiency scores with linear programming.

CCR model has been extended in several directions. Charnes, Cooper and Rhodes (1981) showed how to incorporate with discrete variables. Fare, Grosskopf and Lovell (1983), Byrnes, Fare and Grosskopf (1984), Banker, Charnes and Cooper (1984) extended DEA to variable returns to scale (Murillo-Zamorano, 2004). Banker and Morey (1986) proposed a partial analysis for the factors of production that are not controlled by decision-making unit. Fare, Grosskopf and Lovell (1994) improved this model further by applying sub-vector optimization. Recent research about DEA has been directed to make statistical inference in non-parametric, deterministic linear programming frontier models. Grosskopf (1996) provides a survey about statistical inference, treats non-parametric regularity tests, sensitivity analysis and non-parametric statistical tests and shows that DEA estimators are maximum likelihood. Another recent research area on the agenda of DEA is bootstrap analysis to analyze sensitivity of efficiency scores. Ferrier and Hirschberg (1997) derived confidence intervals for the original efficiency levels. However, Simar and Wilson (1999a, 1999b) showed that bootstrap procedure yields inconsistent estimates allowing only asymptotic statistical inference (Murillo-Zamorano, 2004). However, Sengupta (2000) and Huang and Li (2001) developed more refined DEA models that incorporates statistical noise within non-parametric framework.

There is an illusion among the followers of CCR model that Farrell (1957) has been ignored until the development of DEA. However, the stochastic frontier tradition has 'discovered' the importance of Farrell (1957) quite prior to DEA analysts. Chu, Seitz, Timmer, Afriat and Richmond were pioneers of SFA

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[1] Although CCR model is accepted to state DEA, Førsund and Sorofoglou (2000) states that CCR model was not very 'original'. Quoting Førsund and Sorofoglou (2000):

> Charnes et. al. (1994) state that CCR model generalizes Farrell (1957) to a multiple input-output framework. But Farrell (1957) has a sub-heading for this generalization and Farrell develops a more general linear programming model for multiple input-output case. Charnes and Cooper say that Farrell (1957) and his followers state how to generalize to multiple input-output case, but 'they do not supply precise mathematical details with accompanying definitions and interpretations.' However Boles (1971) gives mathematical details with accompanying definitions and interpretations.

modeling. SFA depends on the idea that "…there exists some efficient function from which all the observed points deviate randomly but in the same direction" (Farrell, 1957). Afriat (1972) has stated the statistical foundations that were based on the deterministic model of Aigner and Chu (1968). He introduced the idea of efficiency distributions and modeled the efficiency scores as error terms in a log-linear econometric estimation of production function. These error terms are assumed to be symmetrically distributed. Richmond (1974) discussed the modified ordinary least squares (MOLS) model to estimate efficiency scores by conventional econometric methods. Gabrielsen (1975) developed the corrected ordinary least squares (COLS) while Greene (1980a) used maximum likelihood estimation (MLE) (Kumbhakar and Lovell, 2000). This approach was based on an idea that is stated by Winsten (1957) as a comment on Farrell (1957). Winsten suggested estimating efficient frontier by shifting a line that is fitted to averages, parallel to itself. An alternative way to estimate the efficient frontier was offered by Sturrock (1957), again as a comment on Farrell (1957). He offered to use top 10% or 20% as "*premium results*" to estimate efficient frontier. This idea is used by Berger and Humphrey (1991) in estimating a *thick frontier* (Førsund and Sorofoglou, 2000). Aigner, Amemiya and Poirier (1976) extended COLS by assigning different weights to positive and negative error terms.

The current SFA models depend on the idea of modeling efficiency scores as composed error terms developed by Aigner, Lovell and Schmidt (1977), Meusen and Broeck (1977), and Battese and Corra (1977). Aigner, Lovell and Schmidt (1977) decomposed the error term of Afriat (1972) to an independently and identically distributed "noise" which stands for the 'deviations from efficient frontier due to the chance factors and a one-sided error term that stands for the deviation from efficient frontier because of inefficiency (Kumbhakar and Lovell, 2000). The root of this idea is again dated back to a comment on Farrell (1957) by Sturrock (1957) who stated that there is a possibility of deviation from efficient frontier as a result of chance factors that has nothing to do with efficiency (Førsund and Sorofoglou, 2000).

Pitt and Lee (1981) extended cross-section analysis to a panel data. Schmidt and Sickles (1984) applied panel data models by using fixed and random effects.

Cornwell, Schmidt and Sickles (1990), Kumbhakar (1990) and Battese and Coelli (1992) introduced time-variable efficiency (Kumbhakar and Lovell, 2000). Lastly, technical efficiency effects models are introduced by Battese and Coelli (1996) to analyze the effect of factors that characterize the production process but are not among the arguments of production function. Battese and Broca (1997) has further developed technical inefficiency effects model to allow for non-neutrality between inputs and characteristic factors.

Recent developments in Bayesian approaches allowed models that are more flexible. Van den Broeck, Koop, Osiewalski and Steel (1994) and Koop, Osiewalski and Steel (1994) introduced the Bayesian analysis for cross-section data. Koop, Osiewalski and Steel (1997) has extended the analysis to panel data. Bayesian models are used extensively since they allow for a more detailed analysis. Bayesian approaches calculate exact finite sample properties of all features of interest… and surmount some of the statistical problems involved with classical estimation of stochastic frontier models." (Murillo-Zamorano, 2004).

2.1.2 Neo-classical Production Theory

The analytical framework that lies behind the efficiency measurement model is mainly developed by Farrell (1957). Farrell (1957) organized the ideas of Koopmans (1951), Debreu (1951) and Shephard (1953) to form an efficiency measurement framework. Although Farrell (1957) did not cite Shephard, his definition of efficiency utilizes the properties of distance functions. He combined the activity analysis of Koopmans and Debreu with the distance function idea of Shephard to obtain an analytical definition of efficiency. The ideas of Farrell (1957) are further organized and developed in Fare et al. (1985) that covers a more detailed general framework. A more practical description of this framework is given in Kumbhakar and Lovell (2000). The notation of Kumbhakar and Lovell (2000) will be used throughout this chapter, since it is more compatible with the recent literature. A brief description of the neo-classical production theory, will be followed by the neo-classical production theory with efficiency measurement in the rest of this chapter.

2.1.2.1 Representation of Production Technology with Sets

Neoclassical production theory is based on the explanation of relationship between inputs and outputs by utilizing the appropriate analytical framework. This relationship is determined by the production technology. The idea is simple: Inputs are converted to outputs via the production process. This transformation is constrained by the production technology.

Organizational unit of the neoclassical production theory is the firm. Firms are considered as rational agents, which has some behavioral motivations. Profit maximization is generally assumed as the underlying motivation but there are some extensions and generalizations. Fare et al. (1985) shows that the analytical framework that lies under the efficiency measurement can be modified to account for different behavioral assumptions. Profit maximization assumption is sustained in this study.

To establish the analytical framework we start by defining production vectors and production sets.

Definition 2-1: A production vector consists of information about the amounts of outputs (denoted by y) to be obtained by means of employment of inputs (denoted by x) that are denoted in production vector in the production process.

The behavior of the firm is not described directly by production vectors that are not subject to any constraints. The imposition of constraints that follow from production technology brings about the *feasibility* concept. Feasibility, in that sense, is the input-output relations that are obtainable by the firm given the technology constraints. The set of feasible production vectors is called as *production set.*

Definition 2-2: The set of production vectors that represents feasible input-output pairs with respect to the production technology is called as *production set*.

Production set, therefore, denotes the feasible plans that are available to the firm under the technology constraint (Mas-Colell, Whinston and Green, 1995). Production is set is generally denoted by $Y \subset R^l$. Formally:

$$Y = \{(x, y) : x \text{ can produce } y\} \tag{2.1.1}$$

Production sets are assumed to satisfy some properties. Although the relevance of these properties can change under various circumstances, they constitute a general basis for modeling the production process.

i. Y is non-empty.
ii. Y is closed so the boundary of the set Y is also feasible.
iii. No outputs can be produced with zero inputs. That is $(0, y)$ is not feasible if $y \neq 0$.
iv. Firm has possibility of inaction, i.e. $0 \in Y$
v. Firm can dispose its output without any cost. In other words, firm can produce the same amount of outputs by using more of inputs that she used to. Analytically, given $(x, y) \in Y$, if $(x', y') \leq (x, y)$ then $(x', y') \in Y$ also holds.
vi. The production process is irreversible. That is if $(x, y) \in Y$, $(-x, -y) \notin Y$.
vii. If, when $y \in Y$, $\alpha y \in Y$, for any $\alpha \in (0,1)$, then production technology Y is said to exhibit a non-increasing returns to scale. If, when $y \in Y$, $\alpha y \in Y$, for any $\alpha > 1$, then production technology Y is said to exhibit a non-decreasing returns to scale. If, when $y \in Y$, $\alpha y \in Y$, for any $\alpha \geq 0$, then production technology Y is said to exhibit a constant returns to scale.
viii. Production set Y is convex so that if $y \in Y$ and $y' \in Y$, then $\alpha y + (1-\alpha) y' \in Y$ for $\alpha \in (0,1)$

Production sets can be expressed graphically. Figure 2-1, sketches a production set that satisfies these properties. Production set is the shaded area. The boundary of that area shows the maximum amount of output that can be produced with the corresponding amount of inputs, or the minimum amount of inputs that is required to produce a given amount of outputs.

Alternative and more convenient methods to represent the production possibilities set is input sets. In the definition and description of technical efficiency measures, we will use inputs sets rather than production sets.

Definition 2-3: Input requirement set of a production technology is a set such that

$$L(y) = \{x : (y,x) \in Y\} \tag{2.1.2}$$

describes the set of input vectors that are feasible for each output vector $y \in R_{+}^{M}$ (Kumbhakar and Lovell, 2000).

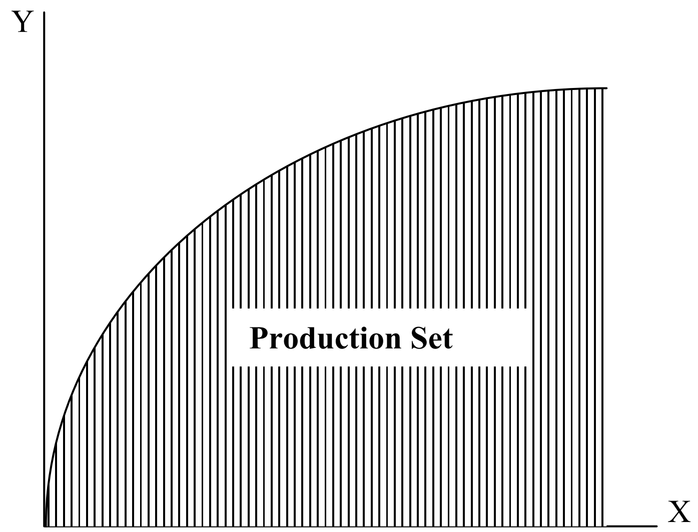


Figure 2-1: Production set

Input requirement set is closely related to the production set, so it satisfies some properties due to the properties of the production set.

i. There is no production with zero inputs so, $0 \notin L(y)$ for $y \geq 0$ and $L(0) = R_{+}^{N}$

ii. Since production set is closed , $L(y)$ is also closed.

iii. $x \in L(y) \Rightarrow \lambda x \in L(y)$ for $\lambda \in (0,1)$ due to the monotonicity of production function.

iv. $L(\lambda y) \subseteq L(y)$ for $\lambda \geq 1$ due to monotonicity of production function.

v. Since inputs and outputs are freely disposable $x' \geq x \in L(y) \Rightarrow x' \in L(y)$ and $y' \geq y \Rightarrow L(y') \subseteq L(y)$.

vi. Since production set is convex, so does the input set.

The definition tells that input requirement set consists of all input vectors with which at least the given output level can be produced. The graphical representation of a regular input set will be something like shown in Figure II.2 below.

The boundary of input requirement set is called as *input isoquants*.

Definition 2-4: Input isoquants of an input requirement set describe the set of input vectors that are capable of producing an output vector *y*, and they are represented with

$$Isoq\ L(y) = \{x : x \in L(y), \lambda x \in L(y), \lambda < 1\} \tag{2.1.3}$$

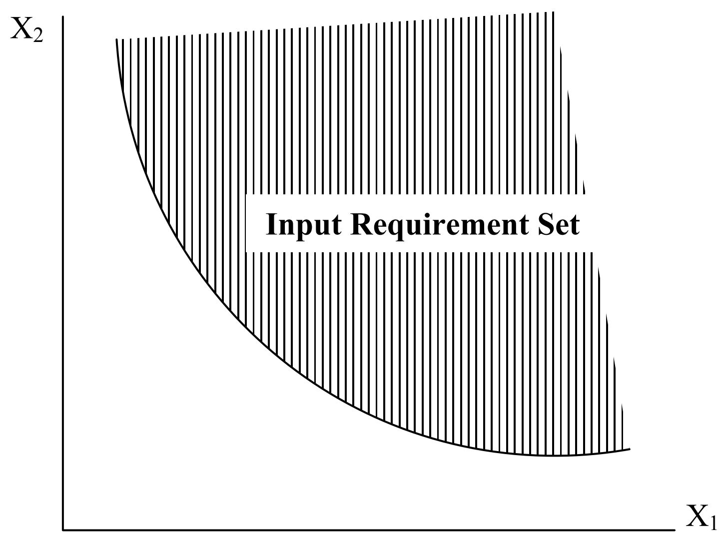


Figure 2-2: Input requirement set

If input isoquants are radially contracted, they will be incapable of producing the output vector y. Figure 2-3 below shows an input isoquant, as mentioned afore, $Isoq\ L(y)$ represents amount of inputs required to produce the output y. However, in the analysis of technical efficiency we will be interested in the *minimal* amount of inputs that are capable of producing y. In fact, these input vectors are a subset of $Isoq\ L(y)$.

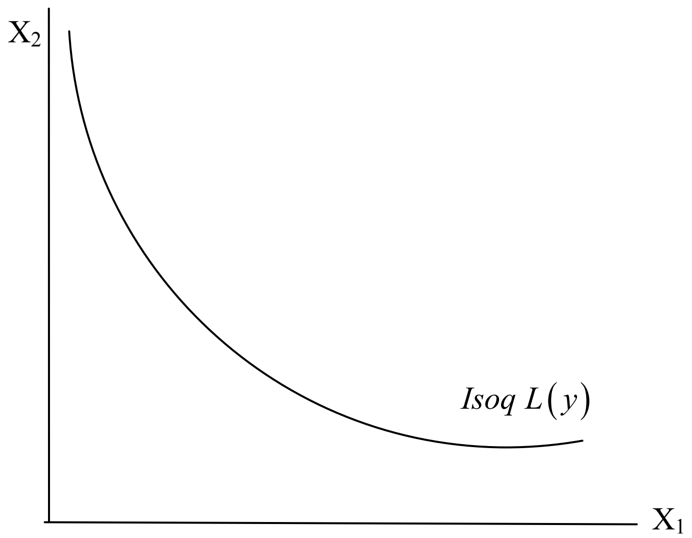


Figure 2-3: Input isoquants

Definition 2-5: Input efficient subsets describe the sets of minimal input requirements that are capable of producing y.

When $Isoq\ L(y)$ satisfies some regularity conditions, specifically a strong version of 'Property *v'*, or under some functional forms such as Cobb-Douglas, $Isoq\,L(y) = Eff\ L(y)$ holds. Fare et al. (1985) show that $Isoq\,L(y) = Eff\ L(y)$ holds if $Isoq\,L(y) \cap Isoq\,L(y') = \varnothing$ for $\forall\, y > y'$. Alternatively, $Isoq\,L(y) = Eff\ L(y)$ holds under the existence of free disposability of inputs. (Fare et al., 1985)

Figure 2-4 depicts the efficient subset of input isoquant. The part of input isoquant above the line from the origin is called *as uneconomic region* of input isoquant. $Eff\ L(y)$ is a more stringent standard against which to measure the efficiency (Kumbhakar and Lovell, 2000).

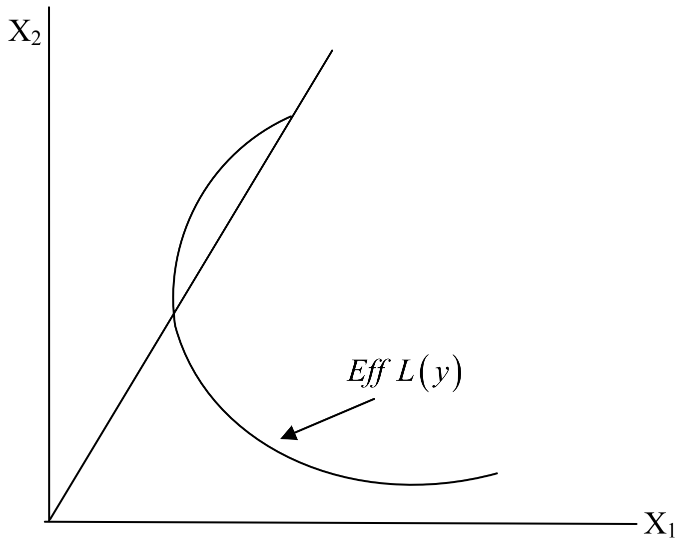


Figure 2-4: Efficient subset of input isoquants

It is possible to make dual definitions to describe the production technology through the output vectors.

Definition 2-6: The output sets of production technology describe the sets of output vectors that are feasible for each input vector $x \in R_+^N$ and it is shown as,

$$P(x) = \{y : (x, y) \in Y\} \tag{2.1.4}$$

Output set also satisfies some properties due to the properties of production set.

i. $P(0) = \{0\}$

ii. $P(x)$ is closed.

iii. $P(x)$ is bounded.

iv. $P(\lambda x) \supseteq P(x)$ for $\lambda \geq 1$ and $y \in P(x) \Rightarrow \lambda y \in P(x)$ for $\lambda \in [0,1]$

A rather stronger version of this property is as follows:

$$x' \geq x \Rightarrow P(x') \supseteq P(x) \text{ and } y \leq y' \in P(x) \Rightarrow y \in P(x)$$

v. $P(x)$ is a convex set

Figure 2-5 illustrates the output set for a regular production technology.

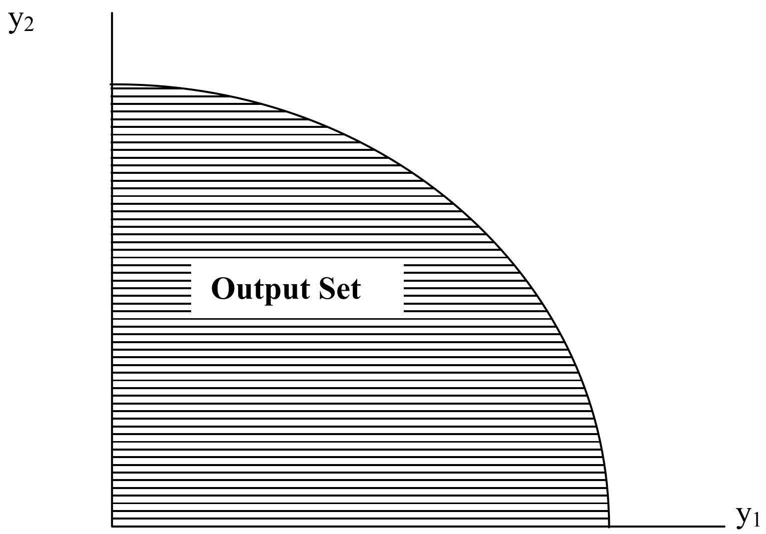


Figure 2-5: Output set

The boundary of output set is called as *output isoquants*, and defined as:

Definition 2-7: The output isoquants describe the sets of all output vectors that can be produced with each input vector and represented as

$$\textit{Isoq}\, P(x) = \{ y : y \in P(x), \lambda y \notin P(x), \lambda > 1 \} \tag{2.1.5}$$

When output isoquant is radially expanded, it cannot be produced with input vector x shows the output isoquant.

A similar argument about the efficient subset can be made about the output isoquants.

Definition 2-8: Output efficient subsets describe the sets of maximum amount of outputs producible given the level of inputs x and it is denoted as

$$Eff\,P(x) = \{y : y \in P(x), y' > y \Rightarrow y' \notin P(x)\} \tag{2.1.6}$$

When efficient subset of output isoquant is contracted in any direction, it is impossible to produce the output level y given the inputs x. As in the case of input isoquants, when output isoquants satisfy certain conditions such as a strong version of "*property vi*" or under certain functional forms such as Cobb-Douglas, $Isoq\,P(x) = Eff\,P(x)$ holds. Fare et al. (1985) show that $Isoq\,P(x) = Eff\,P(x)$ holds if $Isoq\,P(x) \cap Isoq\,P(x') = \varnothing$ for $\forall\, x > x'$. Alternatively, $Isoq\,P(x) = Eff\,P(x)$ holds under the existence of free disposability of outputs (Fare et al., 1985).

Output isoquants and efficient subset of them are depicted in Figure 2-6 and Figure 2-7.

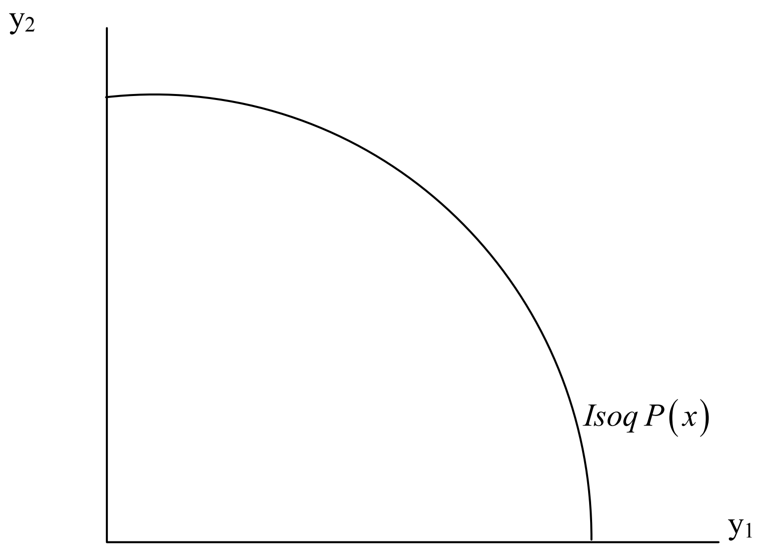


Figure 2-6: Output isoquant

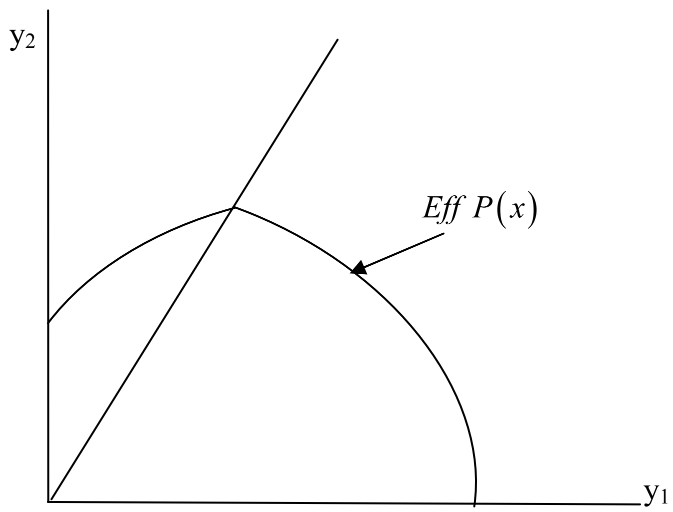


Figure 2-7: Efficient subset of output isoquant

2.1.2.2 Representation of Production Technology with Frontiers

The characterization of production technology in applied work requires more strict assumptions and thus a different representation of production technology. In applied work, it is more convenient to represent the production technology with a function, namely the *production frontier.*

Definition 2-9: A real valued function,

$$f(x) \equiv \max\{y > 0 : x \in L(y)\} \equiv \max\{x > 0 : y \in P(x)\} \qquad (2.1.7)$$

is called a production frontier and it describes the maximum amount of output y, that can be produced given the input vector x (Kumbhakar and Lovell, 2000). Since the frontier represents the maximum amount of output that can be produced with a given amount of inputs, it constitutes a standard against which the efficiency of each individual firm can be measured.

The relationship of production function to the input requirement sets and input isoquants is through the superior and level sets; the level sets precisely correspond to the input isoquants (Jehle, 1991). Due to this relationship $f(x)$ also satisfies some properties.

i. $f(0)=0$.

ii. $f(x)$ is continuous.

iii. $f(x)>0 \Rightarrow \lim_{\lambda\to\infty} f(\lambda x)=+\infty$

iv. $f(\lambda x)>f(x), \lambda\geq 1$

v. $f(x)$ is quasiconcave.

Figure 2-8 shows a production frontier that satisfies these properties. Such a representation of production technology is valid only for one input and one output case. A more general, and in fact the one that we are interested in is one output and two inputs case. This case is more general than it promises as soon as the output can be aggregated, which is generally possible when the values of different products are available. In that case, production technology can be represented by the isoquants that are same as in Figure 2-3.

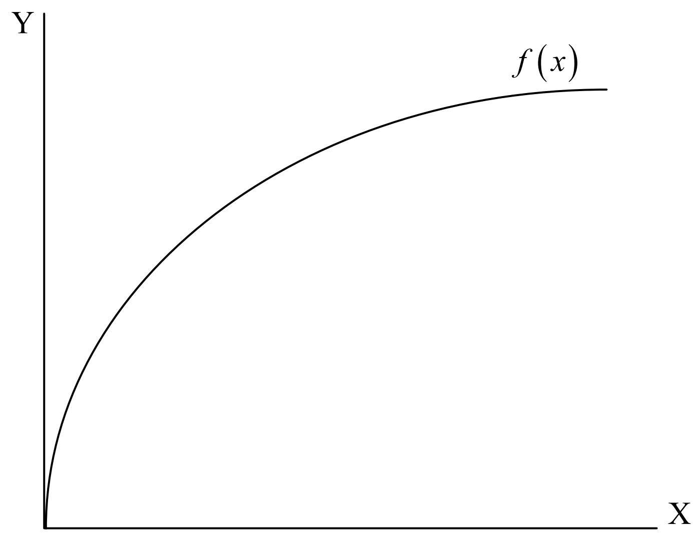


Figure 2-8: Production possibilities set

The efficiency of a firm is not merely related to the input and output quantity. The input and output prices are very important factors that the firm and thus the efficiency measurement analysis should take into account. The input prices are incorporated by the cost frontiers, while the output prices are introduced to the analysis by revenue frontiers. Lastly the profit frontier uses the input and output prices together. All three frontiers constitute a standard against which the efficiency can be measured. The choice about the one to be used depends on the behavioral assumption about the firm. If the firm is assumed as a cost minimizer, then cost frontier will be the appropriate standard, while the revenue frontier will be the suitable one for a revenue maximizer and profit frontier should be used for a profit maximizer. Although a profit maximization assumption seems to be the most general case, data requirements for each assumption should be paid attention in applied studies.

Definition 2-10: Cost frontier is a function that describes the minimum cost of producing output y with inputs x. It is represented in the following way:

$$c(y,w) = \min_x \left\{ w^T x : x \in L(y) \right\} \tag{2.1.8}$$

If there is only one output produced or the outputs can be aggregated, cost frontier can be represented in the following way:

$$c(y,w) = \min_x \left\{ w^T x : y \leq f(x) \right\} \tag{2.1.9}$$

Cost frontier has some properties since it is derived from $L(y)$ and $P(x)$.

i. $c(0,w) = 0$ and $c(y,w) > 0$ for $y \geq 0$

ii. $c(y,\lambda w) = \lambda c(y,w)$ for $\lambda > 0$

iii. $c(y,w') \geq c(y,w)$ when $w' \geq w$

iv. $c(y,w)$ is concave and continuous in w and lower semi-continuous in y.

v. $c(\lambda y,w) \leq c(y,w)$ for $0 \leq \lambda \leq 1$

vi. If Y is convex, then $c(y,w)$ is also convex in y.

A cost frontier that satisfies these properties is depicted in Figure 2-9. It is possible to describe the cost structure of a production technology with level sets of the cost frontier. These level sets are called as input *isocost*.

Definition 2-11: Input isocosts of a cost frontier describe the input combinations that can be afforded with the minimum resources required to produce the output y. It can be represented in the following way.

$$Isoc\ c(y,w) = \{x : w^T x = c(y,w)\} \tag{2.1.10}$$

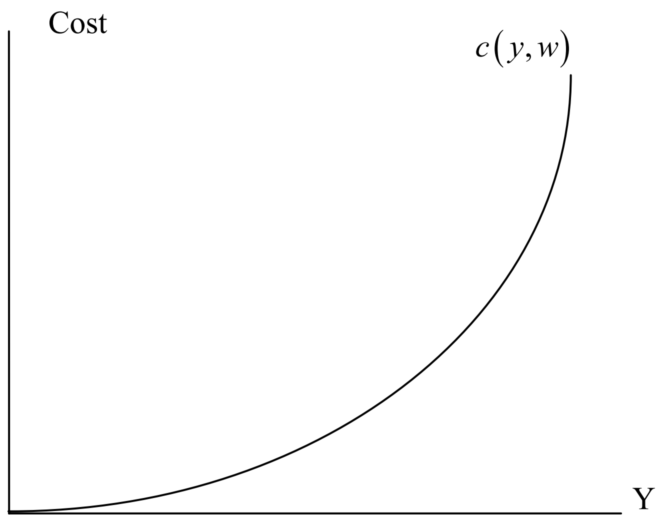


Figure 2-9: Cost frontier

The cost minimization problem of a firm is solved when the firm uses the input combination at which the isocost is tangent to the isoquants at this input combination, x^*. The reason for this can be shown easily by solving the cost minimization problem.[2] Therefore, this optimum input allocation is also a reference point to measure the efficiency.

The approach developed above treats all inputs and thus all cost of production as variable, but it is possible to have cases with fixed and variable costs. The producer may not have the flexibility to change the quantity of some of the inputs. In such cases, since producer cannot make a choice about the fixed costs, it is reasonable to leave them out of the efficiency analysis. If necessary, it is possible

[2] See appendix for the solution of cost minimization problem.

to define a variable cost frontier that takes into account fixed and variable costs separately.

The information about input prices is incorporated into the analysis of production technology by revenue frontier. Revenue frontiers are rarely used in applied work. (Kumbhakar and Lovell, 2000)

Definition 2-12: A revenue frontier is a function such that

$$r(x,p) = \max_y \{p^T y : y \in P(x)\} \qquad (2.1.11)$$

If there is only one output produced or the outputs can be aggregated, revenue frontier can be represented in the following way:

$$r(x,p) = \max_y \{py : y \le f(x)\} = pf(x) \qquad (2.1.12)$$

Revenue frontier also satisfies some properties.

i. $r(0,p) = 0$ and $r(0,p) > 0$ for $x \ge 0$

ii. $r(x,\lambda p) = \lambda r(x,p)$ for $\lambda > 0$

iii. $r(x,p') \ge r(x,p)$ when $p' \ge p$

iv. $r(x,p)$ is convex and continuous in p and upper semi-continuous in x.

v. $r(\lambda x,p) \ge r(x,p)$ for $\lambda \ge 1$

vi. If Y is convex, then $r(x,p)$ is also concave in x.

Figure 2-10 depicts a revenue frontier that satisfies these properties:

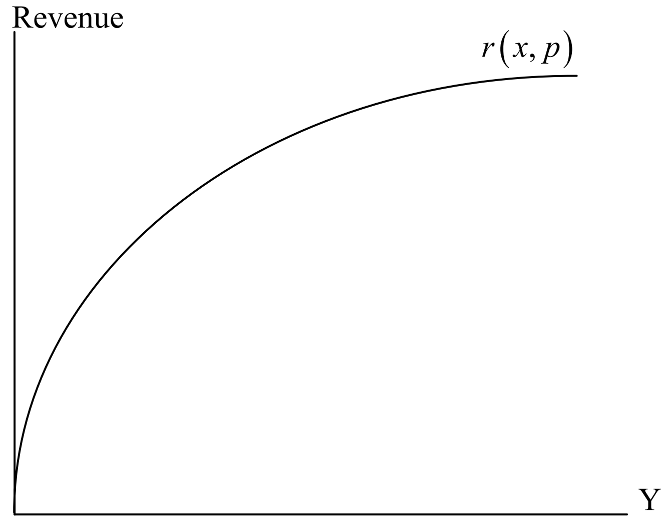


Figure 2-10: Revenue frontier for one output case

The last standard against which the efficiency can be measured is the profit frontier. Profit frontier takes into account both input and output prices.

Definition 2-13: A profit frontier is a function

$$\pi(x,p) = \max_{x,y}\left\{p^T y - w^T x : (x,y) \in Y\right\} \qquad (2.1.13)$$

Profit frontier satisfies the following properties.

i. $\pi(p',w) \geq \pi(p,w)$ for $p' \geq p$

ii. $\pi(p,w') \leq \pi(p',w)$ for $w' \geq w$

iii. $\pi(\lambda p, \lambda w) = \lambda \pi(p,w)$ for $\lambda \geq 0$

iv. $\pi(p,w)$ is a convex function in (p,w).

A profit frontier that satisfies the above properties is dual to Y that satisfies the properties listed for Y (Kumbhakar and Lovell, 2000).

As in the cases of cost and revenue frontiers, we can define a variable profit frontier, which represents the difference between total revenue and variable cost.

Definition 2-14: A variable profit frontier is a function such that

$$v\pi(p,w,z) = \max_{x,y}\left(p^T y - w^T x : (y,x,z) \in Y\right) \qquad (2.1.14)$$

The properties of variable profit frontier are same as profit frontier.

2.1.2.3 Distance Functions

The basic analytical framework to represent the production technology is established above. Thus, the problem concerning the measurement of technical efficiency is to determine the position of each producer relative to the standard against which the efficiency will be measured. This requires the measurement of the distance of each firm's input-output bundle to the production frontier. The analytical tool is called *distance functions* (Shephard, 1953 and 1970; Kumbhakar and Lovell, 2000).

Distance functions rescale the output and input vectors, such that they remain feasible. Although they are originally used in duality theory, they are closely related to the measurement of efficiency. Rescaling can be made in input and output vectors independently, thus we can define a distance functions for each case.

Definition 2-15: An *input distance function* represents the maximum amount by which a producer's input vector can be radially contracted and still remain feasible for the output vector it produces. It is represented as follows (Kumbhakar and Lovell, 2000)

$$D_I\left(y,x\right)=\max\left\{\lambda:\frac{x}{\lambda}\in L\left(y\right)\right\} \qquad (2.1.15)$$

Definition 2-16: An *output distance function* represents the minimum amount by which a producer's output vector can be radially deflated and still remain producible for the input vector given. It is represented as follows (Kumbhakar and Lovell, 2000)

$$D_O\left(y,x\right)=\min\left\{\mu:\frac{y}{\mu}\in P\left(x\right)\right\} \qquad (2.1.16)$$

We can define the cost and revenue frontiers that we described in the previous period by using distance functions in the following way:

$$c\left(y,w\right)=\min_x\left\{w^T x : x\in L\left(y\right)\right\}=\min_x\left\{w^T x : D_I \geq 1\right\} \qquad (2.1.17)$$

$$r\left(x,p\right)=\max_y\left\{p^T y : y\in P\left(x\right)\right\}=\max_y\left\{p^T y : D_O\left(x,y\right)\leq 1\right\} \qquad (2.1.18)$$

Figures II.11-14 depicts the input and output distance functions.

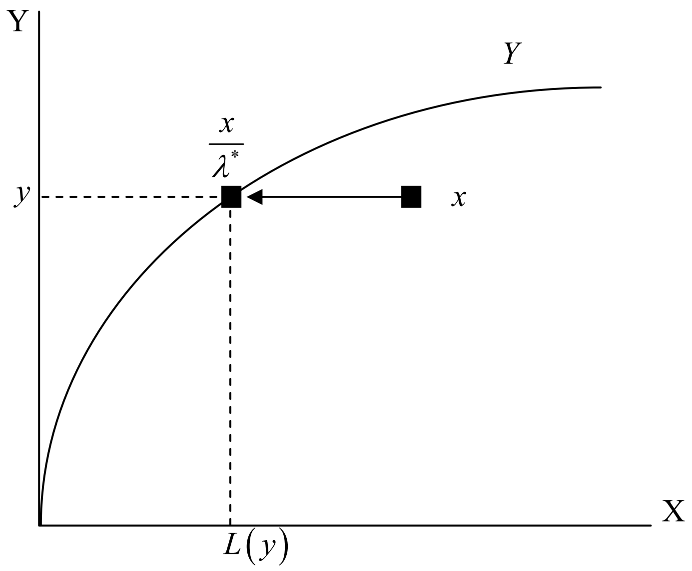


Figure 2-11: Input distance function for one input and one output

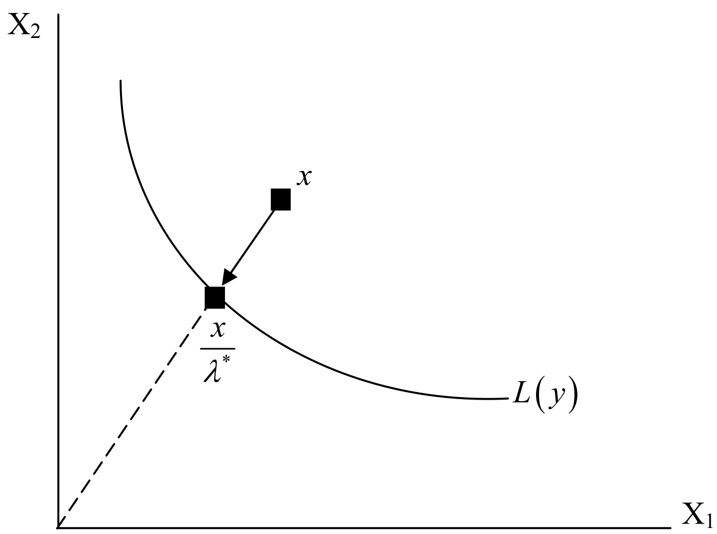


Figure 2-12: Input distance function for two inputs and one output

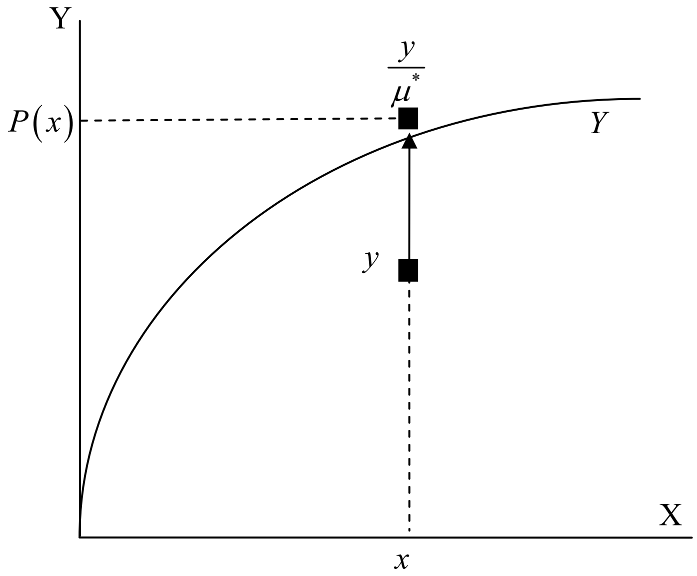


Figure 2-13: Output distance function for one input and one output case

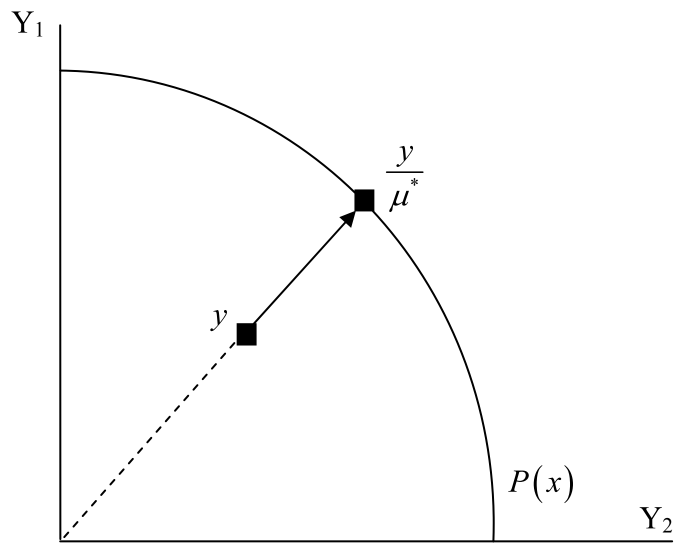


Figure 2-14: Output distance function for two outputs and one input

2.1.3 Efficiency: Definition and Decomposition

Efficiency in production is a concept that relates the production process to the objectives of producers. A producer is said to be efficient if her behavioral objectives are achieved (Fare et. al, 1985). This informal definition brings about two questions: Firstly, “what are the objectives of a producer?” and secondly “under which circumstances are these objectives achieved?”. Obviously, the answers changes from one firm to another, but the analytical framework that is described thus far set some stringent standards for more general cases.

Standards against which the efficiency of a firm can be measured have been revealed in the brief description of the neo-classical production theory. These standards are input and output isoquants, the efficient subset of input and output isoquants, and the point where the isocosts are tangent to input or output isoquants. If the input isoquants are used, we will be measuring *input efficiencies,* while by using output isoquants, we will be measuring *output efficiencies*. The appropriateness of employment of input or output based standards depends on the behavioral assumptions about the firm. If we make a cost minimization assumption, then using the input efficiencies that depend on input prices will be more proper, while under assumption of revenue maximization output based measures are more apposite.

Three different efficiency measures can be defined in accordance with these standards. The efficiency that is measured against isoquants is called as the *technical efficiency*, since input and output isoquants are only a different representation of production technology and they are derived from production frontier directly. Thus, a firm is said to be technically efficient if and only if it is on the appropriate input (output) isoquant given its output (input) vector.

The efficiency measure that is obtained with respect to efficient subsets of input or output isoquants is called as *structural efficiency*. A technically efficient firm is said to be structurally inefficient if it is not on the efficient subset of isoquants. Structural inefficiency exists only if efficient subsets of input and output isoquants are not equal to input and output isoquants, i.e. $Isoq\,P(x) \neq Eff\,P(x)$ or $Isoq\,L(y) \neq Eff\,L(y)$. As mentioned before, this holds if and only if production technology does not allow free disposability of inputs and outputs. If production technology does not allow for disposability, this points out a structural problem and the name structural inefficiency stems from here.

Finally, the position of a firm with respect to the tangency point of isocosts and isoquants defines the *allocative efficiency.* Since the position of tangency point depends on the relative input prices, allocative efficiency is related to the relative prices of inputs and outputs. Therefore, allocative efficiency shows the ability of firm to allocate its sources in an efficient way between inputs to be used or outputs to be produced. Since allocative efficiency is related to the prices, it can also be measured with respect to cost, revenue and profit efficiencies.

2.1.3.1 Input Based Measures of Efficiency

Input based measures of efficiency deserve to be explained in detail since it is used in the empirical analysis.

Figure 2-15 depicts one output and two input case for which free disposability does not hold. Point A denotes the input vector that the firm uses. Assume that firm produces the output vector $\overline{y}$, so that the input isoquant is represented with $L(\overline{y})$. The ray $|OA|$ denotes the path of possible equi-proportionate radial contradictions in input vector x. Point B denotes the point on the isoquant that can be reached with the minimum equi-proportionate radial contradiction of x. The box $C'CC''O$ is drawn to figure out the structural inefficiency. A non-positive orthant with the origin at A is shifted through $|OA|$, until it has only one point as intersection with isoquant, to obtain $C'CC''O$. The intersection of isoquant and $C'CC''O$ is point D. As can be seen the efficient subset is the part of isoquant that lies at the lower right side of point D. $G'G''$ denotes the isocost that is tangent to $L(\overline{y})$. Point E is tangency point between isocost and isoquant.

The ratio $\frac{|OB|}{|OA|}$ is the measure of *input technical efficiency*, since this ratio gives the minimum scalar with which the input vector x should be scaled to obtain a vector located on isoquant. This ratio also gives the cost saved from moving point A to B, since cost of inputs will decrease at the same proportion with the decrease in input.

The ratio $\frac{|OC|}{|OA|}$ is the measure of *input structural efficiency*. It is easy to see that if the inputs could be freely disposed, by disposing some inputs it would have been possible to produce the same level of output at D. However, it is not possible to reach point D with a proportionate radial contraction in inputs. Point C denotes the maximum proportionate contraction in inputs. At C, all excess x_1 is disposed away but we still have excess x_2. Therefore, although C is not obtainable, by not employing some part of x_2, point D, which is on the efficient subset of the isoquant, can be reached.

The input vector that is consistent with input prices on the input isoquant is denoted by point E. Point F denotes the input vector that can be reached with a proportionate radial contraction and has the same cost with the input vector at E. That is, although point F is not obtainable, point E is obtainable with the same cost. Therefore, after a radial contraction, firm can produce $\bar{y}$ by reallocating the inputs from input vector at F to input vector at E by bearing the same cost. Recall that at point C, the firm is technically and structurally efficient. However, firm still faces the allocation problem stated above at point C. The proportionate radial contraction from point C to point F, that is the ratio $\frac{|OF|}{|OC|}$, measures the *input allocative efficiency*.

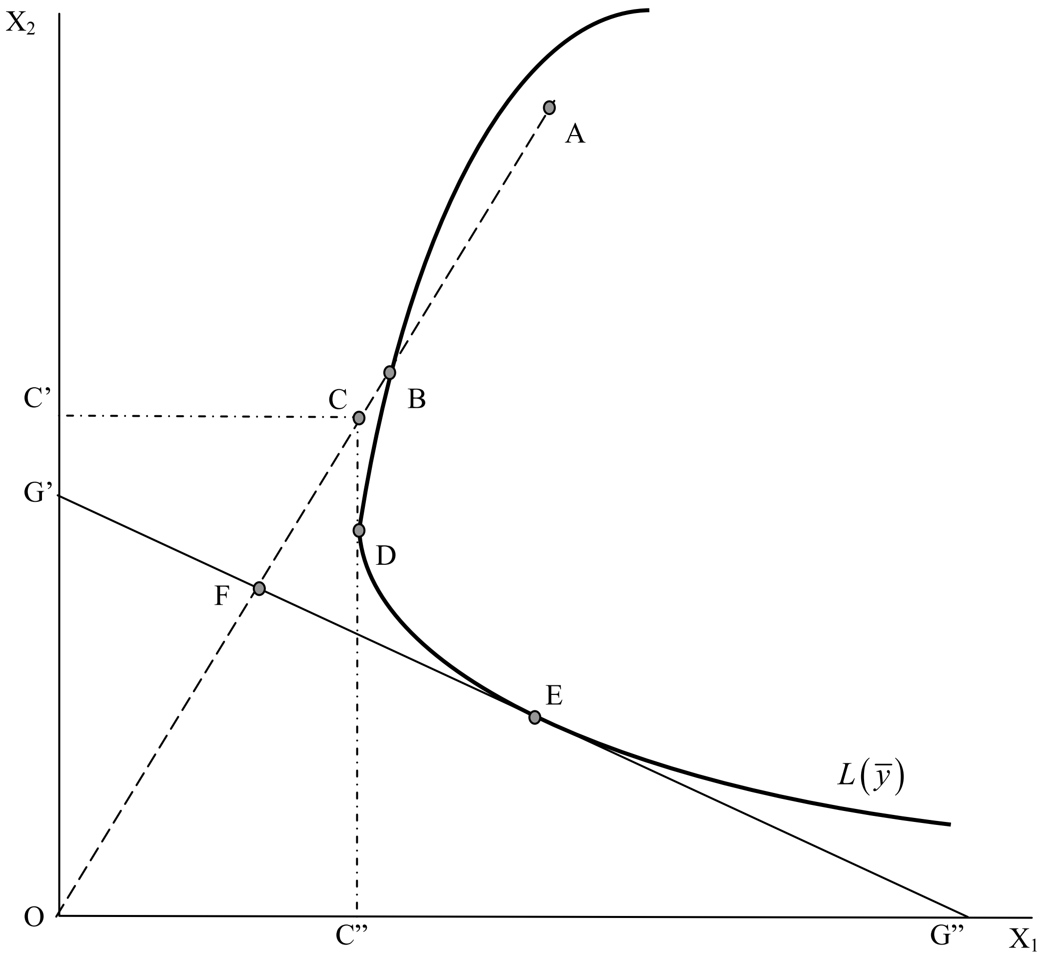


Figure 2-15: Input efficiency measures

The aggregation of these three efficiencies will provide the *input overall efficiency* or *cost efficiency*. Point F represents the most efficient input vector that the firm should employ. The radial contraction from point A to point F is a measure of overall efficiency. This contraction is given with the ratio $\frac{|OF|}{|OA|}$.

Besides, see that:

$$IOE = \frac{|OF|}{|OA|} = \frac{|OF|}{|OC|} \times \frac{|OC|}{|OA|} = ISE \times IAE \tag{2.1.19}$$

That is to say, overall input efficiency can be decomposed into structural and allocative efficiency. To relate the overall efficiency to technical efficiency we need a fifth measure of efficiency. The efficiency measure $\frac{|OC|}{|OB|}$ is attributable to congestion of input x_2, or alternatively it measures the efficiency loss due to the lack of free disposability. This measure is called as *input congestion* measure of efficiency (Fare et. al. 1985).

If we insert input congestion to the decomposition of input overall efficiency, together with input technical efficiency we will come up with the following:

$$IOE = \frac{|OF|}{|OA|} = \frac{|OF|}{|OC|} \times \frac{|OC|}{|OB|} \times \frac{|OB|}{|OA|} = ISE \times IC \times ITE \qquad (2.1.20)$$

In applied work, free disposability is generally assumed to hold. Hence, in what follows, the efficiency measures described above will be illustrated under free disposability assumption.

Figure 2-16 depicts the two inputs, one output case under free disposability. Point A is the input vector that the firm uses to produce $\overline{y}$. $L(\overline{y})$ denotes the input isoquants while $G'G''$ is the input isocost. Point E is the tangency point between them as in the previous case. The ray $|OA|$ denotes the path of possible equi-proportionate radial contradictions in input vector x.

The difference from the previous case is that there is no structural inefficiency and input congestion. The other measures of the efficiency can be defined in the same way. The input technical efficiency is given by $\frac{|OB|}{|OA|}$, while the input allocative efficiency is $\frac{|OF|}{|OB|}$. The input overall efficiency is $\frac{|OF|}{|OA|}$. The decomposition of input overall efficiency is straightforward for this case:

$$IOE = \frac{|OF|}{|OA|} = \frac{|OB|}{|OA|} \times \frac{|OF|}{|OB|} = ITE \times IAE \qquad (2.1.21)$$

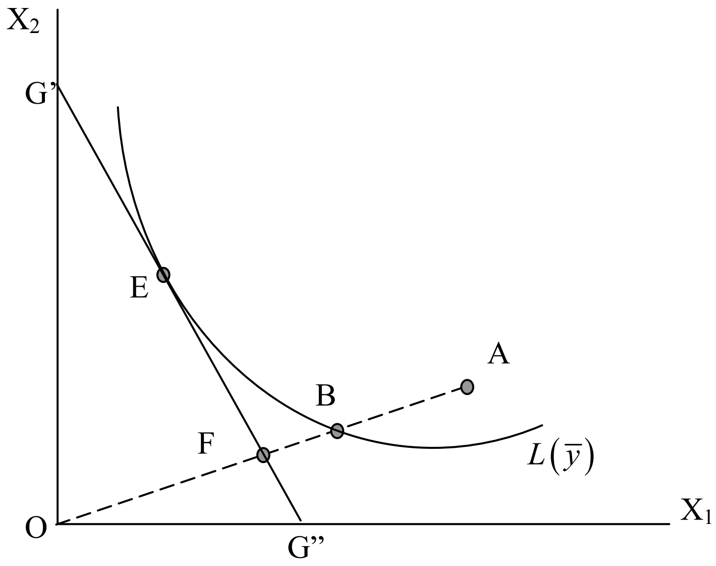


Figure 2-16: Input efficiency measures under free disposability

2.1.3.2 Output Based Measures of Efficiency

The input based measures of efficiency may not be used due to two reasons. Firstly, a cost minimization assumption may not be appropriate given the conditions under which the firm operates. Secondly, since input based measures of efficiency require information about the input prices, they cannot be used when the proper data on input prices are not available. Under these circumstances, it is more appropriate to take the revenue maximizing set of output vectors as reference.

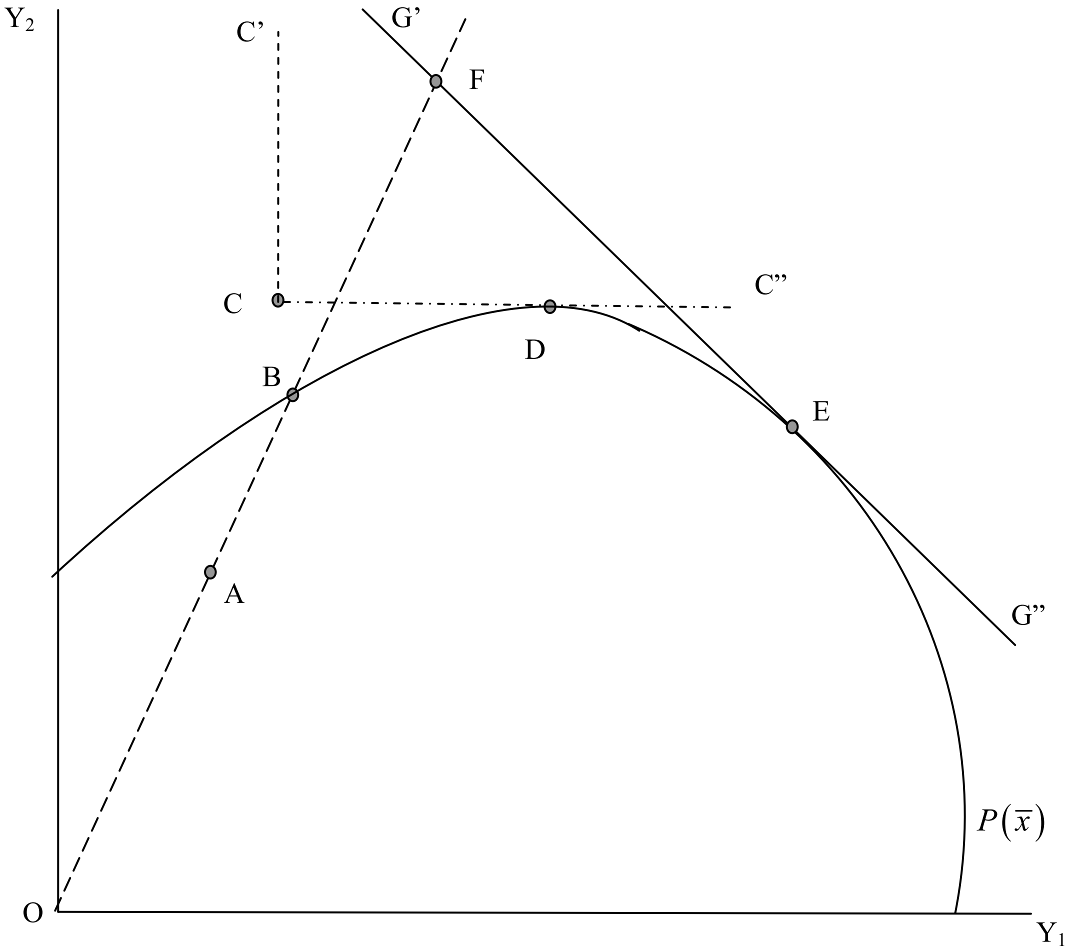
Three measures of efficiency will be defined using the definitions in section 2.1.3. Although the rationale behind these measures is not dependent on the utilization of input or output frontiers, there is an important difference between these two measures. When we measure efficiency with respect to the input frontiers, we are looking at the minimum, attainable (i.e. the output vector is kept constant) radial contraction in inputs. On the other hand, the measurement of efficiency with respect to output yields the maximum attainable (i.e. the input vector is kept constant) radial expansion in output vector. Thus, input and output based efficiency does not imply each other. A firm which minimizes the costs in line with the input prices does not necessarily produce revenue maximizing output vector in line with the output prices, and vice versa.

Output based measures of efficiency will not be analyzed in detail since they are similar to input based case.

Figure 2-17 depicts the two-output case for which free disposability does not hold. Point A denotes the output vector that the firm produces. Assume that firm uses the input vector $\overline{y}$, so that the output isoquant is represented with $P(\overline{x})$. The ray $|OA|$ denotes the path of possible equi-proportionate radial expansion in output vector y. Point B denotes the point on the isoquant that can be reached with the minimum equi-proportionate radial contradiction of x. The set $C'CC''$ is drawn to figure out the structural inefficiency. A nonnegative orthant with the origin at A is shifted through $|OA|$, until it has only one point as intersection with isoquant, to obtain $C'CC''$. The intersection of isoquant and $C'CC''$ is point D. As can be seen the efficient subset is the part of isoquant that lies at the lower right side of point D. $G'G''$ denotes the price plane representing the output prices that is tangent to $L(\overline{y})$. Point E is tangency point between price plane and isoquant.

The ratio $\frac{|OB|}{|OA|}$ is the measure of *output technical efficiency*, since this ratio gives the maximum scalar with which the output vector y should be scaled to obtain a vector located on isoquant. This ratio also gives the revenue increase from moving point A to B, since revenue will increase at the same proportion with the increase in output.

The ratio $\frac{|OC|}{|OA|}$ is the measure of *output structural efficiency*. See that if outputs could be freely disposed, by disposing some outputs it would have been possible to produce the same level of output at D. However, we cannot go to point D with a proportionate radial expansion in outputs. Point C denotes the maximum proportionate expansion in outputs. At C, all excess y_2 is disposed away but we



$P(\overline{x})$

Figure 2-17: Output efficiency measures

still have excess y_1. Consequently, although C is not obtainable, by disposing some y_1, point D, which is on the efficient subset of isoquant, is obtainable.

The output vector that is consistent with output prices on the output isoquant is denoted by point E. Point F denotes the input vector that can be reached with a proportionate radial expansion and yields the same revenue with the output vector at E. That is, although point F is not obtainable, point E is obtainable with the same revenue. Therefore, after a radial expansion, firm can generate the same revenue by reorganizing the production from output vector at F to output vector at E. Recall that at point C, the firm is technically and structurally efficient. However, firm still faces the allocation problem stated above at point C. The proportionate radial contraction from point C to point F, that is the ratio $\frac{|OF|}{|OC|}$, measures the *output allocative efficiency*.

The aggregation of all three efficiencies will give the *output overall efficiency* or *revenue efficiency*. Point F represents the most efficient output vector that the firm should produce. The radial contraction from point A to point F is a measure of overall efficiency. This contraction is given with the ratio $\frac{|OF|}{|OA|}$. Besides, see that:

$$OOE = \frac{|OF|}{|OA|} = \frac{|OF|}{|OC|} \times \frac{|OC|}{|OA|} = OSE \times OAE \tag{2.1.22}$$

That is to say, overall output efficiency can be decomposed into structural and allocative efficiency. To relate it to the overall efficiency to technical efficiency a fifth measure of efficiency is needed. The efficiency measure $\frac{|OC|}{|OB|}$ measures the efficiency loss due to the lack of free disposability. This measure can be represented as OC in line with the input based case (Fare et. al. 1985).

If we insert inefficiency due to lack of disposability to the decomposition of output overall efficiency, together with output technical efficiency we will come up with the following:

$$OOE = \frac{|OF|}{|OA|} = \frac{|OF|}{|OC|} \times \frac{|OC|}{|OB|} \times \frac{|OB|}{|OA|} = OSE \times OC \times OTE \tag{2.1.23}$$

In applied work, free disposability is generally assumed to hold. Therefore, in what follows we will try to illustrate the efficiency measures, which are developed so far, under free disposability assumption.

Figure 2-16 depicts the two inputs, one output case under free disposability. Point A is the input vector that the firm uses to produce $\bar{x}$. $P(\bar{x})$ denotes the input isoquants while $G'G''$ is the input isocost. Point E is the tangency point between them as in the previous case. The ray $|OA|$ denotes the path of possible equi-proportionate radial contradictions in input vector x.

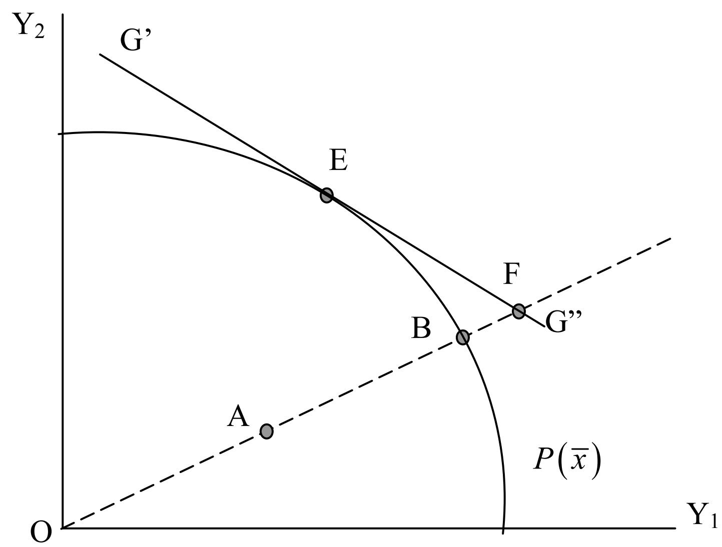


Figure 2-18: Output efficiency measures under free disposability

The difference from the previous case is that there is no structural inefficiency and inefficiency attributable to the lack of free disposability. The other measures of the efficiency can be defined in the same way. The output technical efficiency is given by $\frac{|OB|}{|OA|}$, while the output allocative efficiency is $\frac{|OF|}{|OB|}$. The output overall efficiency is $\frac{|OF|}{|OA|}$. See that decomposition of output overall efficiency is straightforward for this case:

$$OOE = \frac{|OF|}{|OA|} = \frac{|OB|}{|OA|} \times \frac{|OF|}{|OB|} = OTE \times OAE \tag{2.1.24}$$

2.2 Estimation of Efficiency Measures

The analytical framework in the previous part provides the necessary efficiency measures that should be calculated at the firm level. However, it is short in offering any practical techniques to estimate or calculate these measures. In fact, once the theoretical framework was set by Farrell (1957), the techniques for estimation of efficiency did not follow immediately. These techniques evolved following two different paths, named as non-parametric and parametric approaches, towards the end of 1970s.

The application of efficiency measurement requires the estimation or calculation of the distance of each firm (or decision-making unit –DMU) to a frontier. Thus, the problem consists of two steps: First, a frontier should be estimated (or calculated), and then the distance to this frontier should be measured. Thus for the first step, it is necessary to assume that an efficient frontier exists. This hypothetical frontier is estimated or calculated by using the observations. The second assumption is related to the first: Some firms in the sample are on the efficient frontier and they define the efficient frontier. Hence, each firm is compared with the most efficient element of the sample that is on the same radial contraction ray with the compared firm. However, since it is impossible to find a "most efficient firm" on every possible radial contraction ray, we estimate a hypothetical frontier that defines the position of hypothetical most efficient firms against which the positions of actual observations can be estimated (or calculated).

The hypothetical frontier can be estimated or calculated by using various methods, under different assumptions and implications. As mentioned before, these techniques are generally grouped as parametric and non-parametric, according to their assumptions about the functional form of production (or cost) frontier. In parametric methods, functional form is predefined or a-priori imposed, while in non-parametric methods, functional form is not assumed but calculated from the sample observations (Murillo-Zamorano, 2004).

2.2.1 Non-parametric Approaches

The non-parametric method, first developed by Charnes, Cooper and Rhodes (1978) is called as Data Envelopment Analysis (DEA). The aim of the method is to calculate the coefficients for input-output matrix that will in turn define a "*frontier envelopment surface*". Charnes, Cooper and Rhodes (1978) extend the general efficiency definitions of Pareto and Koopmans in the following way (Cooper, Seiford, Zhu, 2004):

Definition 2-17: A DMU is efficient if and only if it cannot use less of any inputs without using more of some other inputs or producing less of some outputs and it cannot produce more of some outputs without using more of some inputs or producing less of some other outputs.

This definition yields a rather simple formulation to measure the efficiency of each DMU. The relative ratio of inputs to outputs for a DMU with respect to all DMUs is used as a measure of relative efficiency of this DMU. Charnes, Cooper and Rhodes (1978) introduce the concept of *virtual output* and *virtual input* to incorporate the multiple output – multiple input cases. Virtual output and input are sum of all outputs and inputs multiplied by some non-negative multipliers, which become the choice variables of the maximization problem.

Assume each of *i* DMU consumes *m* different inputs, to produce *n* different outputs. Let $x_{ij} \geq 0$ denote the inputs *i* consumed and $y_{rj} \geq 0$ denote the output *r* produced by firm *j*. Assume $x_{ij} > 0$ and $y_{rj} > 0$ for some *i* and *r* for all *j*. Then the problem of DEA can be stated as:

$$\max h_0(u,v) = \sum_r u_r y_{r0} / \sum_i v_i x_{i0} \qquad (2.2.1)$$

subject to

$$\sum_r u_r y_{rj} \Big/ \sum_i v_i x_{ij} \leq 1 \text{ for } j = 1,...,n \qquad (2.2.2)$$

$$u_r, v_r \geq 0 \text{ for all i and r.} \qquad (2.2.3)$$

Equation (2.2.2) is normalization constraint for each DMU. However, this problem will have infinite number of solutions. Since for different levels of virtual input, we will have different levels of virtual output. Thus, by imposing $\sum_{i=1}^{m} v_i x_{i0} = 1$ Charnes, Cooper and Rhodes (1978) take a representative solution. The problem becomes maximizing the virtual output given a predetermined level of virtual input. Then the maximization problem will be:

$$\max z = \sum_r \mu_r y_{r0} \tag{2.2.4}$$

subject to:

$$\sum_r \mu_r y_{rj} - \sum_i v_i x_{ij} \leq 1 \text{ for } j = 1,\ldots,n \tag{2.2.5}$$

$$\sum_{i=1}^{m} v_i x_{i0} = 1 \tag{2.2.6}$$

$$\mu_r, v_r \geq 0 \text{ for all } i \text{ and } r. \tag{2.2.7}$$

The solution to the above problem will be vectors M and V, which will consist of μ_rs and v_is and finally z will be the efficiency score.

A dual version of this problem can be stated by considering a peer group of DMUs, which can produce at least the same amount of virtual output that any DMU produce by consuming only a proportion $\theta \leq 1$ of virtual inputs (Murillo-Zamorano, 2004). Thus, dual version can be stated as:

$$\theta^* = \min \theta \tag{2.2.8}$$

subject to

$$\sum_{j=1}^{n} x_{ij} \lambda_j \leq \theta x_{i0} \text{ for } i = 1,..,m \tag{2.2.9}$$

$$\sum_{j=1}^{n} y_{rj} \lambda_j \geq y_{i0} \text{ for } r = 1,\ldots,s \tag{2.2.10}$$

$$\lambda_i \geq 0 \text{ for } j = 1,\ldots,n \tag{2.2.11}$$

This formulation determines the peer group. Those DMUs for which $\theta^* = 1$ constitute the peer group and the efficiency of other DMUs are calculated with respect to those DMUs. Note that we take the minimum θ for each DMU, which is consistent with the equi-proportionate contraction in the other DMUs. However, in order to measure the efficiency of a DMU with respect to another requires that equi-proportionate contraction in inputs to be feasible. Graphically this implies both DMUs to be on the same array drawn from origin to one of the DMUs (see Figure 2-19). In Figure 2-19, A, B, C and D constitutes the peer group. Efficiency of E can be measured with respect to point C. However, no DMU exists against which the efficiency of F can be measured. Therefore, the efficiency of F is measured with respect to a linear combination of B and C.

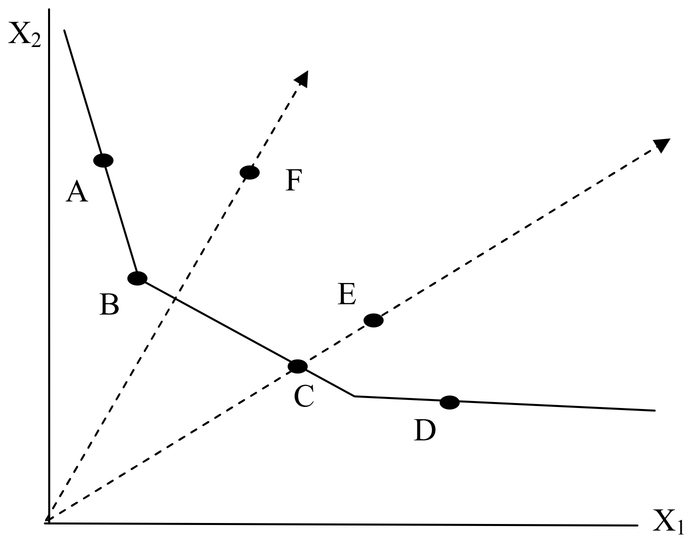


Figure 2-19: Envelopment surface

The linear programming model above yields the peer group. The final objective is to determine the linear combinations of the DMUs in peer group that will minimize the value of θ. Technical efficiency scores will be determined by θ^*.

The above formulations impose following restrictions implicitly:

- Constant returns to scale (CRS)
- Strong disposability of inputs and outputs

- Convexity of the set of feasible input-output combinations

The CRS restriction assumes that all DMUs operate under an optimal scale. However, different types of market power, financial constraints, externalities, etc… generally preclude such cases. Fare, Grosskopf Lovell (1983), Byrnes, Fare and Grosskopf (1984) and Banker, Charnes and Cooper (1984) extended the model of Banker, Charnes and Cooper (1978) to Variable Returns to Scale (VRS) case by adding a convexity constraint, $\sum_{j=1}^{m} \mu_j = 1$. This assures that each DMU is compared to the DMUs that are in the same size with them. Same constraint can be stated as $\sum_{j=1}^{m} \mu_j \leq 1$ for non-increasing returns to scale (NIRS) (Murillo-Zamorano, 2004).

Different scale assumptions have important implications and efficiency scores obtained under different returns to scale assumptions can be used to measure the scale inefficiencies. Consider Figure 2-20:

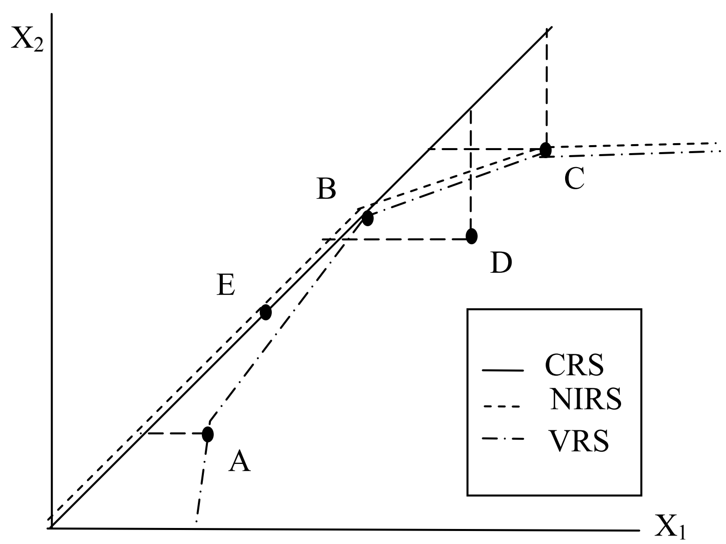


Figure 2-20: CRS, VRS and NIRS envelopment surfaces

As it can be, under different returns to scale assumptions, different envelopment surfaces will be found and the efficiency scores will vary by returns to scale assumption. Under CRS B and E are efficient and A, D and C will be relatively inefficient. Under NIRS, C will also be efficient and efficiency score of D will be higher since it is closer to NIRS envelopment surface. Nothing will change for A. Under VRS, A will also become efficient.

A and C are on the VRS efficient envelopment surface but not on CRS efficient envelopment surface. That means they deviate from the optimal scale. Thus, ratio of efficiency score under CRS to efficiency score under VRS can be used as a measure of scale inefficiency. For DMU D, we can make a decomposition using this ratio.

NIRS can be used to distinguish increasing returns to scale and decreasing returns to scale. The following rules ensue from the analysis above:

- If $TE_{NIRS} = TE_{VRS} = TE_{CRS}$, the DMU operates under CRS
- If $TE_{NIRS} = TE_{VRS} \neq TE_{CRS}$, the DMU operates under CRS
- If $TE_{NIRS} \neq TE_{VRS}$, the DMU operates under CRS

The assumption about strong disposability can be relaxed by incorporating slack variables, which are simply the unused input or unsold output quantity, in the optimization process. After the θ^* is calculated by the previous models, one can solve the following problem for slacks as second step,

$$\max \sum_{i}^{m} s_i^- + \sum_{r}^{s} s_j^+ \tag{2.2.12}$$

subject to

$$\sum_{j=1}^{n} x_{ij}\lambda_j = \theta^* x_{i0} \text{ for } i = 1,...,m; \tag{2.2.13}$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j = \theta^* x_{i0} \text{ for } r = 1,...,s; \tag{2.2.14}$$

$$\lambda_j, s_i^-, s_j^+ \geq 0 \ \forall i, j, r \tag{2.2.15}$$

Here s_i^- and s_j^+ are input and output slacks respectively. Thus after solving for θ^* by multipliers model, we can solve for optimal slacks using this information. (Cooper, Seiford, and Zhu, 2004)

DEA problems can be set both by input and output oriented (Murillo-Zamorano, 2004). Considering virtual input the ratio of virtual input to virtual output, one can set the output-oriented model. Minimization will be appropriate for output-oriented framework. The problem can be stated as

$$\min g_0(u,v) = \sum_i v_i x_{i0} \Big/ \sum_r u_r y_{r0} \tag{2.2.16}$$

subject to

$$\sum_r v_i x_{ij} \Big/ \sum_i u_r y_{rj} \geq 1 \text{ for } j = 1,...,n \tag{2.2.17}$$

$$u_r, v_r \geq 0 \text{ for all i and r.} \tag{2.2.18}$$

Making the necessary transformations, envelopment model will be

$$\min \sum_r v_i x_{i0} \tag{2.2.19}$$

subject to

$$\sum_r v_i x_{ij} - \sum_i u_r y_{rj} \geq 0 \text{ for } j = 1,...,n \tag{2.2.20}$$

$$\sum_{r=1}^{s} \mu_r = 1 \tag{2.2.21}$$

$$\mu_r, v_r \geq 0 \text{ for all i and r.} \tag{2.2.22}$$

Corresponding multiplier model will be

$$\theta^* = \max \theta \tag{2.2.23}$$

subject to

$$\sum_{j=1}^{n} x_{ij} \lambda_j \leq x_{i0} \text{ for } i = 1,..,m \tag{2.2.24}$$

$$\sum_{j=1}^{n} y_{rj} \lambda_j \geq \theta y_{i0} \text{ for } r = 1,...,s \tag{2.2.25}$$

$$\lambda_i \geq 0 \text{ for } j = 1,...,n \tag{2.2.26}$$

Slacks can be incorporated by solving the same problem as in the input oriented case, as second step. (Cooper, Seiford, and Zhu, 2004)

Another shortcoming of the original model of Charnes, Cooper, and Rhodes (1978) is that it does not allow for discrete (or categorical) variables. However, Cooper, Cooper and Rhodes (1978) develops a method to solve this problem by solving a separate DEA for each category group (Murillo-Zamorano, 2004).[3]

The uncontrolled or discretionary variables are also an important weakness of model developed in Charnes, Cooper, and Rhodes (1978). Some variables cannot be controlled directly by DMUs. Maximization of equi-proportionate contraction should be made by omitting these variables to obtain more precise efficiency scores. Banker and Morey (1986) develop a partial analysis of efficiency. Fare, Grosskopf and Lovell (1994) also represent a rather developed model depending on sub-vector optimization (Murillo-Zamorano, 2004).

Recent research has been directed toward the statistical inference in DEA. Grosskopf (1996) gives an extended survey of development in statistical inference in DEA. Grosskopf (1996) represents non-parametric regularity tests and sensitivity analysis. She shows that DEA estimators are maximum likelihood. She indicates the results of statistical inference are valid only asymptotically and asymptotic sampling distributions are available only for univariate DEA models. Another approach for statistical inference is bootstrap analysis. Although Simar and Wilson (1999a, 1999b) show that bootstrap procedure gives inconsistent estimates, Ferrier and Hirscberg (1997) give confidence intervals for the original efficiency levels (Murillo-Zamorano, 2004).

The non-parametric approaches are criticized for not distinguishing between random and systematic deviations from efficient frontier and thus being "*deterministic in nature*". Although Sengupta (2000b), Huang, and Li (2001) developed, non-parametric models that incorporate non-systematic deviations from efficient frontier this problem is still to be resolved (Murillo-Zamorano, 2004).

Another point of criticism is about the robustness of non-parametric approaches. The outliers and the "*stochastic nature of constraints*" affect the results generated by parametric approaches (Sengupta, 2000a). Although there were some attempts to solve this problem by not enveloping outliers in the data, the problem about the robustness of DEA remains to be solved.

The last but not the least criticism about non-parametric methods follows from their ignorance "*about the objectives of the agents.*" Thus, non-parametric methods

[3] The formulation of model can be found in Cooper, Seiford, and Zhu (2004).

are lacking of a “*solid economic theory*”. Sengupta (2000a) attempts to incorporate the economic theory in the DEA.

2.2.2 Parametric Cross Sectional Approaches

The parametric approaches try to estimate the efficiency scores by estimating an efficient frontier. Thus, the difference between parametric and non-parametric approach is that while non-parametric approaches try to calculate the efficiency scores directly without estimating any frontier, the parametric approaches estimates the efficient frontier by estimating the parameters of frontier, and then measures the distance of observed input-output data to the estimated frontier.

The parametric approach depends on the assumptions about the mathematical form of production function. So, the conventional assumption of neoclassical production theory about the shape of production frontier is maintained in parametric approaches. Thus parametric approaches, unlike the non-parametric ones, are subject to any criticisms directed to functional assumptions of the neoclassical production theory. In fact, the criticisms directed to non-parametric approaches for ignoring the economic theory stems from this point. The followers of parametric approach accuse the followers of non-parametric approach with ignoring the conventional production theory, while the followers of parametric approach accuse the others with “torching” the data by making a priori impositions about the functional form. The debate is still going on and it is impossible to give a precise reason to prefer one of the approaches to the other. The parametric approach is generally preferred by economists, while the champions of non-parametric approaches are generally from management and operations research.

Farrell (1957) used a non-parametric approach to calculate the efficiency scores in his original paper. Consideration of efficiency in a stochastic context as deviations from an efficient frontier has appeared in Aigner and Chu (1968), Seitz (1971), Timmer (1971), Afriat (1972) and Richmond (1974) (Kumbhakar and Lovell, 2000). These early models were deterministic in nature. Aigner, Lovell and Schmidt (1977), Meusen and van den Broeck (1977) and Battese and Corra (1977) introduced simultaneously stochastic models to estimate firm level efficiency. Finally, to overcome the restrictions of Stochastic and deterministic models, Van den Broeck, Koop, Osiewalski and Steel (1994) and Koop, Osiewalski and Steel (1994) introduced the Bayesian approach (Murillo-Zamorano, 2004).

One can set a general analytical framework that underlies these three standpoints in parametric approach. If y_i is the output, x_i is input vector, β is parameter vector of production frontier and TE_i is the technical efficiency score, then the following equation will hold

$$y_i = f\left(x_i, \beta\right) TE_i \quad (2.2.27)$$

which can be organized to yield TE_i, in the following way:

$$TE_i = \frac{y_i}{f\left(x_i, \beta\right)} \quad (2.2.28)$$

2.2.2.1 Deterministic Models

Deterministic models will be depicted by modifying Equation (2.2.27) which can be written as

$$y_i = f\left(x_i, \beta\right) \exp\left(-u_i\right) \quad (2.2.29)$$

where

$$TE_i = \exp\left(-u_i\right) \quad (2.2.30)$$

Assuming a Cobb-Douglas form for $f\left(x_i, \beta\right)$ such that

$$f\left(x_i, \beta\right) = \prod_{n=1}^{N} \beta_0 \left(x_{ni}\right)^{\beta_n} \quad (2.2.31)$$

Substituting equation (2.2.31) in equation (2.2.29), and taking the logarithms of both sides will yield a linear regression model:

$$\ln\left(y_i\right) = \beta_0 + \sum_{n=1}^{N} \beta_n x_{ni} - u_i \quad (2.2.32)$$

Since $TE_i \leq 1$ should hold, the restriction on $u_i \geq 0$ is necessary. There are three methods to estimate equation (2.2.32) (Kumbhakar and Lovell, 2000).

Goal Programming Method: The method is originally proposed by Aigner and Chu (1968). They calculate the parameters of equation (2.2.32) by using deterministic optimization techniques (Murillo-Zamorano, 2004). The optimization problem set for that purpose is not much different from the non-parametric approaches:

$$\min \sum_{i}^{I} u_i \tag{2.2.33}$$

subject to

$$\beta_0 + \sum_{n=1}^{N} \beta_n x_{ni} \geq \ln y_i, \quad i = 1,...,I \tag{2.2.34}$$

An alternative method is to minimize the sum of squared deviations such that

$$\min \sum_{i}^{I} u_i^2 \tag{2.2.35}$$

subject to

$$\beta_0 + \sum_{n=1}^{N} \beta_n x_{ni} \geq \ln y_i, \quad i = 1,...,I \tag{2.2.36}$$

Once the parameters are calculated, technical efficiency can be found by

$$u_{i=}\beta_0 + \sum \beta_n x_{ni} - y_i \quad i = 1,...,I \tag{2.2.37}$$

The problem with goal programming is that it requires a complicated statistical inference procedure about the calculated (rather than estimated) parameters and does not allow for hypothesis testing (Murillo-Zamorano, 2004).

Although, Schmidt (1976) has shown that under certain distributional assumptions about u_i, the parameters calculated by solving (2.2.35) and (2.2.36) are maximum likelihood. However, Schmidt (1976) noted that statistical properties of maximum likelihood estimates cannot be obtained in the traditional way since as the range of $\ln y_i$ depends on β, the regularity conditions of maximum likelihood estimation are violated (Kumbhakar and Lovell, 2000).

Greene (1980a) has attempted to link the maximum likelihood estimation to goal programming. He showed that when $u_i \geq 0$ follows a gamma distribution, the maximum likelihood estimates satisfy the regularity conditions. However there is no goal programming model when u_i follows a gamma distribution (Kumbhakar and Lovell, 2000).

As a conclusion, the statistical properties of goal programming model remain ambiguous and statistical inference on these parameters is not possible.

Corrected Ordinary Least Squares (COLS): Gabrielsen (1975) proposed another approach to estimate deterministic frontier by COLS that is a two-step method. In the first step, equation (2.2.32) is estimated by using ordinary least squares (OLS) to obtain parameter vector β. Since $u_i \geq 0$, the estimate of β_0 is biased but consistent. In the second step, biased estimate of β_0 is "corrected" such that the estimated frontier bounds the data from above. For correction, we use the maximum value of estimated residuals, $\hat{u}_i$, such that

$$\ln(y_i) = \hat{\beta}_0 + \max(u_i) + \sum_{n=1}^{N} \beta_n x_{ni} - \hat{u}_i + \max(u_i) \tag{2.2.38}$$

In equation (2.2.38), corrected intercept and residuals are

$$\beta_0^* = \hat{\beta}_0 + \max(u_i) \tag{2.2.39}$$

$$-u_i^* = \hat{u}_i - \max(\hat{u}_i) \tag{2.2.40}$$

Then technical efficiency will be found by

$$TE_i = \exp(-u_i^*) \tag{2.2.41}$$

The problem about COLS is that since only β_0 is corrected, COLS frontier dose not bound the data from above as closely as possible. Since COLS frontier is parallel to the OLS frontier, the structure of frontier is the same as the central tendency (Kumbhakar and Lovell, 2000).

Modified Ordinary Least Squares (MOLS): Afriat (1972) and Richmond (1974) have proposed a different variation of COLS. Instead of correcting $\hat{\beta}_0$ with $\max(\hat{u}_i)$, they proposed to make a modification with $E(\hat{u}_i)$. MOLS is similar to COLS, but it may have two additional drawbacks. First, MOLS may not shift OLS frontier far enough since it is possible that $\hat{u}_i \geq E(\hat{u}_i)$ in which case some firms will have efficiency scores greater than one. Secondly, MOLS may shift OLS frontier so far up that none of the producers may have an efficiency score equal to one (Kumbhakar and Lovell, 2000).

A final shortcoming that concerns all three approaches follows from the specification of efficiency score as u_i. This specification excludes the probability of existence of random deviations from efficient frontier, mostly due to the conditions that cannot be controlled by the firm such as weather. The deterministic approaches attribute all deviation to the inefficiency. Such a restriction may not be acceptable, especially when the production process is highly dependant on factors like climate such as in agriculture. The stochastic models allow for random deviations from efficient frontier.

2.2.2.2 Stochastic Models

Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) introduced simultaneously the idea of composed error to overcome the problems with the deterministic models in the cross-sectional context (Kumbhakar and Lovell, 2000). The idea was rather simple, but its implementation led to the use of complicated econometric procedures. They added a symmetric white noise term to the deterministic model to capture the effects of factors other than technical efficiency on production procedure. Their model for single output can be represented by

$$\ln y_i = \beta_0 + \sum_{n=1}^{N} \beta_n x_{ni} + v_i - u_i \tag{2.2.42}$$

Here v_i is an independently and identically distributed symmetric noise component, while u_i denotes nonnegative technical inefficiency term. An important assumption about v_i is that it is independently distributed from u_i.

OLS cannot be used to estimate (2.2.42), since the composed error term $\varepsilon_i = v_i - u_i$ would be asymmetric and

$$E(\varepsilon_i) = E(v_i) - E(u_i) = 0 - E(u_i) = -E(u_i) \leq 0 \tag{2.2.43}$$

Moreover, even if the bias in OLS is somehow resolved, it is not possible to estimate firm specific efficiency scores (Kumbhakar and Lovell, 2000). OLS can only be used to test the existence of technical inefficiency. Schmidt and Lin (1984) proposed the following test statistic to test the existence of technical inefficiency.

$$(b_1)^{1/2} = m_3 \Big/ (m_2)^{3/2} \tag{2.2.44}$$

Here, m_2 and m_3 are the second and third moments of OLS residuals and $(b_1)^{1/2}$ measures the skewness. Negative values of $(b_1)^{1/2}$ indicates negative skewness in residuals and thus the existence of technical inefficiency. Alternatively, Coelli (1995) proposed the following test statistic that is distributed with $N(0.1)$ asymptotically.

$$b_2 = \left(\frac{m_3}{6m_2^3 / I} \right)^{1/2} \tag{2.2.45}$$

Since OLS yields inconsistent estimate of β_0 and it is impossible to decompose the technical inefficiency from the white noise with OLS, MLE is used to estimate equation (2.2.42).

MLE can be used in two different ways. In the first one parameter vector β and u_i is estimated directly with MLE. In the second method, namely the method of moments, a two-step procedure is followed. In the first step β_n for $n = 1,...,N$ is estimated consistently by using OLS, and in the second step β_0, u_i and v_i is estimated by using MLE. The general framework of this method can be found in Kumbhakar and Lovell (2000).[4]

Estimation of β and u_i by using MLE requires a priori imposition of distributional assumptions about v_i and u_i. The MLE models generally assume a normal distribution with $N(0, \sigma_v^2)$ for v_i. On the other hand, there are different assumptions about distribution of u_i. Half normal (Jondrow et. al. 1982),

[4] The details are given in Greene (1990, 1993, 1997b); for exponential and gamma specifications see Kumbhakar and Lovell (2000) and Murillo-Zamorano, (2004); see Harris (1992) for truncated normal specification; see Olson, Schmidt and Waldman (1980) for half-normal specification.

Exponential (Aigner, Lovell and Schmidt, 1977, and Meeusen and van den Broeck, 1977), Truncated Normal (Stevenson, 1980) and Gamma (Greene, 1980a, and Stevenson 1980, and Greene, 1990) are amongst the most frequently assumed distributions for u_i. Although different assumptions are made in literature, Greene (1990) and Ritter and Simar (1997) suggests that distributional assumption does not affect results very much. For that reason, they offer to use simple distributions.

The formal framework for truncated-normal distribution will be presented since it is used in the empirical analysis of this study.[5]

Normal – Truncated Normal Model: The assumptions of the model can be listed formally as follows:

(i) $v_i \sim$ iid $N\left(0,\sigma_v^2\right)$

(ii) $u_i \sim$ iid $\left|N\left(0,\sigma_u^2\right)\right|$

(iii) v_i and u_i is distributed independently from each other and of regressions.

Density functions for u_i and v_i are given as

$$f\left(u\right)=\frac{2}{\sqrt{2\pi}\sigma_u\Phi\left(-\mu/\sigma_u\right)}\exp\left(-\frac{\left(u-\mu\right)^2}{2\sigma_u^2}\right) \qquad (2.2.46)$$

$$f\left(v\right)=\frac{1}{\sqrt{2\pi}\sigma_v}\exp\left(-\frac{v^2}{2\sigma_v^2}\right) \qquad (2.2.47)$$

where μ is the mode of the normal distribution truncated below zero, $\Phi\left(.\right)$ is standard normal cumulative distribution function.

Under the independence assumption, the joint density function for u_i and $\varepsilon_i = v_i - u_i$ is given as

$$f\left(u,\varepsilon\right)=\frac{2}{2\pi\sigma_u\sigma_v\Phi\left(-\mu/\sigma_u\right)}\exp\left(-\frac{\left(u-\mu\right)^2}{2\sigma_u^2}-\frac{\left(\varepsilon+u\right)^2}{2\sigma_v^2}\right) \qquad (2.2.48)$$

Integrating the right hand side of equation (2.2.48) over u_i yields the marginal density function of ε_i, which will be used in obtaining log-likelihood function

[5] See Kumbhakar and Lovell (2000) for the detailed analysis of the other distributional assumptions.

$$f(\varepsilon)=\int_0^{\infty} f(u,\varepsilon)\,du$$

$$=\frac{2}{\sqrt{2\pi}\sigma\Phi\left(-\mu/\sigma_u\right)}\Phi\left(\frac{\mu}{\sigma\lambda}-\frac{\varepsilon\lambda}{\sigma}\right)\exp\left(-\frac{(\varepsilon+\mu)^2}{2\sigma^2}\right)$$

$$=\frac{a}{\sigma}\phi\left(\frac{\varepsilon+\mu}{\sigma}\right)\Phi\left(\frac{\mu}{\sigma\lambda}-\frac{\varepsilon\lambda}{\sigma}\right) \quad (2.2.49)$$

where $a=\left[\Phi\left(-\mu/\sigma_u\right)\right]^{-1}$, $\sigma=\left(\sigma_u^2+\sigma_v^2\right)^{\frac{1}{2}}$, $\lambda=\frac{\sigma_u}{\sigma_v}$, and $\phi(.)$ and $\Phi(.)$ are the standard normal cumulative density and distribution functions respectively. If $\lambda\to\infty$, $\sigma_v\to 0$ or $\sigma_u\to\infty$ which means that u_i dominates v_i and our model is not different from deterministic models, in which symmetric error term is excluded. If $\lambda\to 0$, $\sigma_v\to\infty$ or $\sigma_u\to 0$, which means that v_i dominates u_i and our model is not different from OLS model, in which technical efficiency term is excluded. If $\mu=0$, distribution of u_i collapses to a half normal.

Mean and variance of ε are as follows

$$E(\varepsilon)=-E(u)=-\frac{\mu a}{2}-\frac{\sigma_u a}{\sqrt{2\pi}}\exp\left(-\frac{\mu^2}{2\sigma_u}\right) \quad (2.2.50)$$

$$V(\varepsilon)=\mu^2\frac{a}{2}\left(1-\frac{a}{2}\right)+\frac{a}{2}\left(\frac{\pi-a}{\pi}\right)\sigma_u^2+\sigma_v^2 \quad (2.2.51)$$

The log-likelihood function will be

$$\ln L=\text{constant}+I\ln(a)+\sum_i\Phi\left(\frac{\mu}{\sigma\lambda}-\frac{\varepsilon_i\lambda}{\sigma}\right)-\frac{1}{2}\sum_i\frac{(\varepsilon_i+\mu)^2}{\sigma} \quad (2.2.52)$$

By maximizing $\ln L$ with respect to the all parameters, one can obtain ML estimates of all parameters.

The conditional distribution of u with respect to ε is

$$f(u|\varepsilon)=\frac{f(u,\varepsilon)}{f(\varepsilon)}=\frac{1}{\sqrt{2\pi}\left[1-\Phi\left(-\tilde{\mu}/\sigma_*\right)\right]}\exp\left(-\frac{(u-\tilde{\mu})^2}{2\sigma_*}\right) \quad (2.2.53)$$

where, $\tilde{\mu}_i = \left(-\sigma_u^2 \varepsilon_i + \mu \sigma_v^2\right) \big/ \sigma^2$ and $\sigma_*^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$. Equation (2.2.53) tells that $\left(u \middle| \varepsilon\right)$ is distributed as $\left| N\left(\tilde{\mu}, \sigma_*^2\right)\right|$. The mean or the median of $f\left(u \middle| \varepsilon\right)$ can be used to estimate technical efficiency.

$$E\left(u_i \middle| \varepsilon_i\right) = \sigma_* \left[\frac{\tilde{\mu}_i}{\sigma_*} + \frac{\phi\left(\tilde{\mu}_i / \sigma_*\right)}{1 - \Phi\left(-\tilde{\mu}_i / \sigma_*\right)}\right] \tag{2.2.54}$$

$$M\left(u \middle| \varepsilon_i\right) = \begin{cases} \tilde{\mu}_i & if\ \tilde{\mu}_i \geq 0 \\ 0 & otherwise \end{cases} \tag{2.2.55}$$

Jondrow, Lovell, Materov and Schmidt (1982) proposed the following formulation to calculate the technical efficiency:

$$TE_i = \exp\left(-\hat{u}_i\right) \tag{2.2.56}$$

where $\hat{u}_i$ is either $E\left(u_i \middle| \varepsilon_i\right)$ or $M\left(u \middle| \varepsilon_i\right)$. An alternative point estimator proposed by Battese and Coelli (1988) is

$$TE_i = E\left(\exp\left(-u_i\right) \middle| \varepsilon_i\right) = \left[\frac{1 - \Phi\left(\sigma_* - \tilde{\mu}_{*i} / \sigma_*\right)}{1 - \Phi\left(-\tilde{\mu}_{*i} / \sigma_*\right)}\right] \exp\left(-\tilde{\mu}_{*i} + \frac{\sigma_*^2}{2}\right) \tag{2.2.57}$$

Both point estimators are unbiased but also inconsistent since

$$p \lim E\left(u_i \middle| \varepsilon_i\right) - u_i \neq 0 \tag{2.2.58}$$

which implies that variation associated with $\left(u_i \middle| \varepsilon_i\right)$ is independent of u_i (Kumbhakar and Lovell, 2000 and Murillo-Zamorano, 2004). Nevertheless, this seems to be the best that can be obtained by cross-section data.

It is possible to obtain confidence intervals for these point estimators since density of $\left(u_i \middle| \varepsilon_i\right)$ is known to be $\left| N\left(\tilde{\mu}, \sigma_*^2\right)\right|$. $(1-\alpha)100\%$ confidence interval $\left(L_i, U_i\right)$ for technical efficiency scores calculated by (2.2.57) would be

$$L_i = \exp\left(-\tilde{\mu}_i - z_L \sigma_*\right)$$

$$U_i = \exp\left(-\tilde{\mu}_i - z_U \sigma_*\right) \tag{2.2.59}$$

where,

$$P\left(Z > z_L\right) = \frac{\alpha}{2}\left[1 - \Phi\left(-\frac{\tilde{\mu}_i}{\sigma_*}\right)\right]$$

$$P(Z > z_U) = \left(1-\frac{\alpha}{2}\right)\left[1-\Phi\left(-\frac{\tilde{\mu}_i}{\sigma_*}\right)\right]$$
$$Z \sim N(0,1) \tag{2.2.60}$$

Then, z_L and z_U can be found by using the inverse of cumulative normal distribution function.

2.2.3 Parametric Panel Data Models

Many problems mentioned about the cross-sectional models can be overcome with the availability of panel data. More information can be obtained about the firms since the same firm is observed more than once. Thus, panel data models allow relaxing some of the restrictive assumptions necessary in cross-sectional models. To be more specific, following problems prevalent in cross-sectional models can be avoided with having access to panel data (Schmidt and Sickles, 1984).

i. MLE requires strong distributional assumptions and robustness to those assumptions is not well documented.
ii. MLE requires that technical efficiency term to be independent of regressors, which does not make much sense since technical efficiency is likely to be correlated with inputs used.
iii. Firm specific efficiency scores cannot be estimated consistently.

Panel data models can incorporate time varying or time-invariant technical efficiency. The method that will be used in the empirical analysis will depend on a time-varying model. A special emphasis will be put on model specifications of time-invariant models rather than methods to estimate them. The focus will be on the details of various model specifications with time variables and estimation methods for time-varying models.

2.2.3.1 Time-Invariant Models

The general model for time-invariant is as follows:

$$\ln y_{it} = \beta_0 + \sum_{n=1}^{N} \beta_n x_{nit} + v_{it} - u_i \tag{2.2.61}$$

where v_i is the symmetric noise term and u_i is the technical efficiency term. Subscript t denotes time and $t = 1,...,T$. Parameters of this model can be estimated by fixed effects, random effects or maximum likelihood models.

In fixed effects model, u_i is assumed to be fixed rather than being random, and so they are like producer specific intercept terms. The model for fixed effects model is thus

$$\ln y_{it} = \beta_{0i} + \sum_{n=1}^{N} \beta_n x_{nit} + v_{it} \quad (2.2.62)$$

This model can be estimated by using a within transformation. When all data is expressed in terms of deviations from producer means intercepts can be recovered as means of producer residuals. Once the parameters are estimated, $\hat{u}_i$ can be recovered by

$$\hat{u}_i = \max\left(\hat{\beta}_{0i}\right) - \hat{\beta}_{0i} \quad (2.2.63)$$

and thus,

$$TE_i = \exp\left(-\hat{u}_i\right) \quad (2.2.64)$$

Estimates of β_n are consistent as $N \to \infty$ or $T \to \infty$. Estimates of β_0 are consistent as $T \to \infty$. Estimates of u_i are consistent when both $N \to \infty$ and $T \to \infty$. Note that consistency does not require v_{it} to be distributed normally. In finite samples (i.e. when T is small), the max operator in (2.2.63) induces an upward bias (Kim and Schmidt, 2000).

Fixed effect model has a serious drawback. The $\hat{u}_i$ estimated by fixed effects model captures the effect of any phenomena that vary across producers but not in time such as regularity environment (Kumbhakar and Lovell, 2000).

Random Effects Model: For random effects model we assume that u_i is distributed randomly with constant mean and variance and uncorrelated with regressors and v_{it}. The model for random effects model can be written as

$$\ln y_{it} = \left[\beta_0 - E(u_i)\right] + \sum_{n=1}^{N} \beta_n x_{nit} + v_{it} - \left[u_i - E(u_i)\right]$$
$$= \beta_0^* + \sum_{n=1}^{N} \beta_n x_{nit} + v_{it} - u_i^* \qquad (2.2.65)$$

This model can be estimated by standard two-step generalized least squares (GLS) method in the panel data literature (Kumbhakar and Lovell, 2000). OLS is used to obtain the consistent estimates of all parameters, including the variances. Then using feasible GLS, β_0^* and β_n is re-estimated. Then, $\hat{u}_i^*$ is estimated by means of either

$$\hat{u}_i^* = \frac{1}{T}\sum_t \left(\ln y_{it} - \beta_0^* - \sum_n \hat{\beta}_n \ln x_{nit} \right) \qquad (2.2.66)$$

or,

$$\hat{u}_i^* = \left[\frac{\hat{\sigma}_u^2}{T\hat{\sigma}_u^2 + \hat{\sigma}_v^2} \right] \sum_t \left(\ln y_{it} - \beta_0^* - \sum_n \hat{\beta}_n \ln x_{nit} \right) \qquad (2.2.67)$$

then

$$\hat{u}_i = \max\left(\hat{u}_i^*\right) - \hat{u}_i^* \qquad (2.2.68)$$

both for (2.2.66) and (2.2.67). Both estimators are consistent as $T \to \infty$ and $I \to \infty$. The estimator in (2.2.67) is also best linear unbiased estimator.

Although there is conflicting evidence in the literature, these two methods generate similar results (Kumbhakar and Lovell, 2000).[6]

2.2.3.2 Time Varying Models

The time varying models have been introduced to model by Cornwell, Schmidt and Sickles (1990). The model can be stated as follows

$$\ln y_{it} = \beta_{0t} + \sum_n \beta_n \ln x_{nit} + v_{it} - u_{it}$$
$$= \beta_{it} + \sum_n \beta_n \ln x_{nit} + v_{it} \qquad (2.2.69)$$

If this model is estimated with the conventional panel data methods, one has to estimate $I \times T$ intercepts, N slope parameters, and σ_v^2, which is not possible.

[6] MLE is skipped since it will be discussed in time-varying framework. For MLE procedure in time-invariant framework sees Kumbhakar and Lovell (2000).

So, β_{it} is specified as a function of time in the literature. Cornwell, Schmidt and Sickles (1990) proposed the following specification:

$$\beta_{it} = \Omega_{i1} + \Omega_{i2}t + \Omega_{it}t^2 \qquad (2.2.70)$$

where Ω_{ij} s are scalar parameters that determine the relationship between time and efficiency. By using this specification and several estimation strategies of panel data literature one can estimate (2.2.69).

We will skip these methods[7], since they are similar to time-invariaying models.[8] (Kumbhakar and Lovell, 2000)

Battese and Coelli (1992) makes the following specifications:

$$u_{it} = u_i.\beta(t) \qquad (2.2.71)$$

and

$$\beta(t) = \exp(\gamma(t-T)) \qquad (2.2.72)$$

The distributional assumptions are as follows

i. $v_{it} \sim N(0, \sigma_v^2)$

ii. $u_i \sim \left|N(0, \sigma_u^2)\right|$

iii. v_{it} and u_{it} are distributed identically and independently from each other and regressors.

Under these assumptions, it can be shown that

$$(u_i | \varepsilon_i) \sim \left|N(\hat{\mu}_i, \hat{\sigma}_i^2)\right| \qquad (2.2.73)$$

where

$$\varepsilon_i = \mathbf{v}_i - \beta(t)u_i \qquad (2.2.74)$$

[7] If independence and distributional assumptions are feasible, then MLE can be used to estimate the model in (2.2.69).

[8] The details of these strategies can be found in Cornwell, Schmidt and Sickles (1990). General description is available in Kumbhakar and Lovell (2000). More flexible specifications for β_{it} can be found in Lee and Schmidt (1993) and Baltagi and Griffin (1988).

$$\hat{\mu}_i = \frac{\mu\sigma_v^2 - \sigma_u^2 \sum_t \varepsilon_i \beta(t)}{\sigma_v^2 + \sigma_u^2 \sum_t \beta^2(t)} \tag{2.2.75}$$

$$\hat{\sigma}_i = \frac{\sigma_u^2 \sigma_v^2}{\sigma_v^2 + \sigma_u^2 \sum_t \beta^2(t)} \tag{2.2.76}$$

with

$$\varepsilon_i = [\varepsilon_{i1}\, \varepsilon_{i2} \ldots \varepsilon_{iT}]' \tag{2.2.77}$$

$$\mathbf{v}_i = [v_{i1}\, v_{i2} \ldots v_{iT}]' \tag{2.2.78}$$

Note that $\beta(t) \geq 0$ for all $t = 1, \ldots T$. With these specifications, one has to estimate only one parameter, namely γ, for time varying component. Besides, the meaning of γ is important in evaluating the progress of firms over time. If $\gamma > 0$, $\beta(t)$ decreases at an increasing rate that implies deterioration in technical efficiency component u_{it} and which in turn implies an increase in technical efficiency, over time. When $\gamma < 0$, $\beta(t)$ increases at a increasing rate which entails rising u_{it}'s, and thus a diminution in technical efficiency. If $\gamma = 0$, we have the time invariant model (Battese and Coelli, 1992).

From these equations, the log-likelihood function can be found by using the same method used in cross-sectional MLE models given in equations (2.2.46) to (2.2.52). The details can be found in Battese and Coelli (1992). The minimum mean squared error predictor of technical efficiency is given by

$$E\left[\exp(u_{it}) \middle| E_i\right] = \left[\frac{1 - \Phi\left(\beta(t)\hat{\sigma}_i - \frac{\hat{\mu}_i}{\hat{\sigma}_i}\right)}{1 - \Phi\left(-\frac{\hat{\mu}_i}{\hat{\sigma}_i}\right)}\right] \exp\left(\beta(t)\hat{\mu}_i + \frac{1}{2}\left(\beta(t)\hat{\sigma}_i\right)^2\right) \tag{2.2.79}$$

where all parameters are as defined afore.

Coelli (1996) gives a general sketch of model and a detailed description of its application.

2.2.4 Other Models and Approaches

2.2.4.1 Bayesian Models

To overcome the criticisms concerning the a priori imposition of sampling distribution of technical efficiency term u, van den Broeck, Koop, Osiewalski and Steel (1994) and Koop, Osiewalski and Steel (1994) has first introduced the Bayesian analysis of the cross-sectional composed error term. The following quotation is frequently used in literature to define the rationale behind the Bayesian Models (Murillo-Zamorano, 2004), (Kalirajan and Shand, 1999):

> [Bayesian models]… treat uncertainty concerning which sampling model to use, by mixing over a number of competing inefficiency distributions proposed in literature with posterior model probabilities as weights.

In Bayesian models, posterior distribution of the parameter vector θ, namely $p(\theta|y)$ is found by Bayes Law. In Bayesian models parameter vector consists of intercept and slope terms, variance of symmetric noise term and residuals and some other parameters depending on the model estimated. By specifying a prior density for the parameter vector θ, namely, $p(\theta)$ and determining the likelihood of observing y given θ, namely $p(y|\theta)$, one can find $p(y|\theta)$ by the following formulation:

$$p(\theta|y) \propto p(\theta)\, p(y|\theta) \tag{2.2.80}$$

The difference of Bayesian Models from the classical models is that, while classical models treat the parameters as fixed, Bayesian Models treat them as random. In classical models intercept and slope terms and variance of symmetric noise term is considered as fixed parameters, while the residuals are treated as random. The inference, then, depends on the distribution of u_i conditional on ε_i, which is in some sense a posterior distribution (Kim and Schmidt, 2000).

$p(y|\theta)$ is the same as the likelihood of classical MLE models when v_{it} as identically and independently distributed as normal. When θ is assigned a prior distribution, the marginal posterior distributions of parameters can be found analytically.

Koop, Osiewalski and Steel (1997) derived Bayesian analogues to classical fixed and random effects models. The Bayesian fixed effects models are characterized by marginal prior independence between the individual effects, assumed to be constant over time but not linked across firms. The random effects models, on the other hand, assume prior links between individual effects, in such a way that their means can be functionally related to certain firm characteristics or alternatively be drawn from a common distribution (Murillo-Zamorano, 2000).

Kim and Schmidt (2000) gives a detailed survey of Bayesian models, as well as a comparison of these models with conventional methods.

2.2.4.2 Duality Theory and Multiple-Output Models

As described in section 2.1.3.1, a more convenient way to measure the efficiency is using the cost structure of production. By using the cost structure, one can model the multiple-output production processes, quasi-fixed inputs and different behavioral assumptions. However, estimation of cost frontiers requires information of input prices as well as input and output provisions. When the data on input prices are incorporated to the efficiency measurement analysis, one can decompose efficiency into allocative and technical components.

Estimation of cost frontier to measure the efficiency is meaningful only if the duality between cost functions and production functions is supplied. When production is modeled with a Cobb-Douglas production function, the duality is easy to explore since Cobb-Douglas production functions are self-dual. Schmidt and Lovell (1979) shows that the dual cost frontier representation of a Cobb-Douglas production frontier in equation (2.2.42) is as follows:

$$\ln C = \beta_0 + \frac{1}{r}\ln Y + \sum_{n=1}^{N}\frac{\beta_n}{r}\ln\left(w_n\right) - \frac{v-u}{r} \tag{2.2.81}$$

where

$$r = \sum_{n=1}^{N}\beta_n \tag{2.2.82}$$

Here, u/r measures the cost of technical efficiency. Under allocative efficiency, however, u/r measures the cost of both technical and allocative efficiency.

Schmidt and Lovell (1979) proposes first order conditions of cost minimization problem can be used to decompose the allocative inefficiency.

$$\ln\left(\frac{x_n}{x_1}\right) = \ln\left(\frac{\beta_n}{\beta_{11}}\right) - \ln\left(\frac{w_n}{w_1}\right) + \zeta_n \text{ for } n = 2,...,N \tag{2.2.83}$$

Here ζ_n is the measure of allocative inefficiency and it represents the deviation from the first order conditions. By using (2.2.81) and (2.2.83) input demand functions and the following analogous of (2.2.81) for total can be obtained:

$$\ln C = \beta_0 + \frac{1}{r}\ln y + \sum_{n=1}^{N}\frac{\beta_n}{r}\ln(w_n) - \frac{v-u}{r} + (E - \ln r) \tag{2.2.84}$$

where

$$E = \sum_{m=2}^{N}\frac{\beta_m}{r}w_m + \ln\left[\beta_1 + \sum_{m=2}^{N}\beta_m \exp(-\zeta_m)\right] \tag{2.2.85}$$

Model in (2.2.84) can be estimated by using MLE techniques. However, estimation of (2.2.84) by MLE will not yield the decomposition for allocative efficiency. To tract allocative efficiency equations (2.2.81) and (2.2.83) can be estimated as a system.

Although Cobb-Douglas from yields a simple framework, Christensen, Jorgenson and Lau (1971) points out that Cobb-Douglas form cannot incorporate multiple-output framework without violating the curvature properties in output space. Besides, the complexity of production structure, which cannot be modeled by Cobb-Douglas form, will show up in error term that will bring about a bias in estimated efficiency scores (Kumbhakar and Lovell, 2000). Thus, the *Transcendental Logarithmic* (or shortly *translog*) cost function proposed by Christensen and Greene (1976) and adapted to frontier framework by Greene (1980a, 1980b) supply a more flexible framework for the estimation of cost frontiers. The translog model can be written as

$$\ln C_i = \beta_0 + \sum_m \alpha_m \ln y_{mi} + \sum_n \beta_n w_{ni} + \frac{1}{2}\sum_m\sum_j \alpha_{mj}\ln y_{mi}\ln y_{ji} + \frac{1}{2}\sum_n\sum_k \beta_{nk}\ln w_{ni}\ln w_{ki} + \frac{1}{2}\sum_n\sum_m \gamma_{nm}\ln w_{ni}\ln y_{mi} \tag{2.2.86}$$

$$S_{ni} = \beta_n + \sum_k \beta_{nk} \ln w_{ki} + \sum_m \gamma_{nm} \ln y_{mi}, \text{ for } n = 1,\ldots,N \tag{2.2.87}$$

The above system can be used in estimation of cost frontiers by deleting the first equation in (2.2.87) and adding stochastic terms. Then the system to be estimated will be:

$$\begin{aligned} \ln C_i &= \ln c\left(y_i, w_i; \beta\right) + v_i + u_i \\ S_{ni} &= S_{ni}\left(y_i, w_i; \beta\right) + \zeta_{ni} \text{ for } n = 2,\ldots,N \end{aligned} \tag{2.2.88}$$

Here u_i captures the effect of technical and allocative inefficiency together, while ζ_{ni} captures the deviation from first order conditions. Thus, u_i and ζ_{ni} are expected to be correlated. Greene (1980b) points out the problems that this correlation brings about in estimation process. Kumbhakar (1991) offers to specify ζ_{ni} as related to allocative efficiency, as a solution. Then MLE techniques can be used to estimate the system. Kumbhakar and Lovell (2000) notes that "… a fully satisfactory econometric specification remains to be developed."

Extension of multiple output case to panel data offers the best opportunity to decompose technical and allocative efficiency (Kumbhakar and Lovell, 2000). The Cobb-Douglas form of the cost frontier model can be slightly rearranged to incorporate panel data in the following way:

$$\begin{aligned} &\ln y_{it} = \beta_0 + \sum_n \beta_n \ln x_{nit} + v_{it} - u_i \\ &\ln x_{1it} - \ln x_{nit} + \ln\left(\frac{\beta_n}{\beta_1}\right) = \ln\left(\frac{w_{nit}}{w1it}\right) + \zeta_{ni} + \xi_{nit} \text{ for } n = 2,\ldots,N \end{aligned} \tag{2.2.89}$$

Solving equation (2.2.89) for inputs will yield

$$\begin{aligned} \ln x_{kit} = \alpha_k &+ \sum_{n>1}\left(\frac{\beta_n}{r} - \delta_{nk}\right)\zeta_{ki} + \frac{1}{r}\ln y_{it} + \sum_{n>1}\left(\frac{\beta_n}{r}\right)\ln\left(\frac{w_{nit}}{w_{kit}}\right) \\ &+ \sum_{n>1}\left(\frac{\beta_n}{r} - \delta_{nk}\right)\xi_{nit} + \frac{u_i - v_i}{r} \qquad \text{for } k = 1,2,\ldots,N \end{aligned} \tag{2.2.90}$$

where

$$\alpha_k = \ln \beta_k - \frac{1}{r}\left[\beta_0 + \sum_n \beta_n \ln \beta_n\right] \tag{2.2.91}$$

$$\delta_{nk} = \begin{cases} 1 \text{ if } k = n \\ 0 \text{ otherwise} \end{cases} \tag{2.2.92}$$

The fixed effects version of this model can be estimated by applying non-linear seemingly unrelated regressions (SUR) following a within transformation to eliminate time invariant terms α_k, ζ_{ki} and u_i. After estimates of β_k s are estimated with nonlinear SUR, ζ_{ni} and u_i can be obtained.

The random effects model can be estimated by using MLE methods used in previously described models. Details for estimation can be found in Kumbhakar and Lovell (2000).

2.2.5 Explaining Technical Inefficiency

Estimation of technical inefficiency does not have much policy implications by itself. The methods explained until now tries to find out the relation between input utilization of firms and their output. However, they do not give any explanation about the reasons of inefficiency. The explanation of the inefficiency by quantitative methods has been an important area of research. The general idea behind the applied work about the explanation of inefficiency is related to the existence of firm specific exogenous variables that are assumed to affect the efficiency of the firm. The early work on efficiency analysis has incorporated such variables by running a second step regression. In this second step, efficiency scores are regressed on these exogenous variables by using OLS. However, this approach turns out to be problematic since when estimating the efficiency scores one assumes identically distributed u (Battese and Coelli, 1995).

Battese and Coelli (1995) develops a single step approach that will not contradict with the identical distribution of u while explaining the technical inefficiency effects. Battese and Coelli (1995) modify the model developed in Battese and Coelli (1992) by making the following assumption:

$$u_{it} = \sum_{i=1}^{k} \delta_i z_{it} + w_{it} \tag{2.2.93}$$

where columns of matrix z_{it}s are exogenous variables, δ_is are parameters to be estimated and w_{it} is identically and independently distributed as $N\left(0,\sigma_w\right)$. To be compatible with the model of Battese and Coelli (1992) we need to impose the following condition on u_{it}:

$$u_{it} = \sum_{i=1}^{k} \delta_i z_{it} + w_{it} \geq 0 \qquad (2.2.94)$$

which in turn implies

$$w_{it} \geq -\sum_{i=1}^{k} \delta_i z_{it} \qquad (2.2.95)$$

and this implies

$$u_{it} \sim \left| N\left(-\sum_{i=1}^{k} \delta_i z_{it}, \sigma_w \right) \right| \qquad (2.2.96)$$

The parameters of the model defined by equations (2.2.69), (2.2.71), (2.2.72) and (2.2.93)-(2.2.96) can be estimated by using maximum likelihood techniques (Battese and Coelli, 1995). The δ coefficients show the marginal effect of exogenous variables on technical efficiency.

Battese and Broca (1997) further enhanced the above model by introducing the interactions of inputs and exogenous variables into the analysis by formulating u_{it} as

$$u_{it} = \sum_{i=1}^{k} \delta_i z_{it} + \sum_{j}^{m} \sum_{i}^{k} \theta_{ij} z_{it} x_{jt} + w_{it} \qquad (2.2.97)$$

According to this specification efficiency effect is a function of input levels as well as the exogenous variables. Thus, shifts in frontier for firms depend on the level of input utilization. In other words, the shift in frontier due to exogenous variables is not neutral to input levels (Battese and Broca, 1997). Both models are estimated by using maximum likelihood methods. Details for the estimation process can be found in Battese and Coelli (1993).

CHAPTER 3

EFFICIENCY IN TURKISH AGRICULTURE

Literature on structure of agricultural production in Turkey focuses on productivity of labor and yield of land rather than efficiency. There is an extensive literature that uses different partial efficiency measures to analyze the state of efficiency in Turkish Agriculture. A few work uses partial efficiency measures by acknowledging the difference between partial and technical efficiency measures such as Zaim and Çakmak (1998), Çakmak (2004), Kepenek and Yentürk (2001) Lundell *et. al.* (2004) while most of the others do not mention any difference at all, such as Özkan *et. al.* (2004) and Uzunlu, *et. al.* (1999). Some authors use extensive statistical methods to analyze partial efficiency such as Toksoy and Ayyıldız (2004) or employ simple econometric methods to obtain partial efficiency measures such as Akçay and Esengün (1999). Rare quantitative work that follows recently developed methods in efficiency measurement literature use aggregate data such as Akder *et. al.* (2000) and Syed and Sari (1998 and 2002) and. In short, the difference between efficiency and productivity is generally ignored in the literature. Yields calculated by various methods are considered as measures of efficiency. Although one can make partial efficiency analysis and comparisons by using yields, a complete picture about the efficiency posture of households cannot be accessed merely by depending on information about yields since these measures do not give any information about relative ability of producers to utilize inputs. Productivity of an input is generally calculated by dividing the output level to input usage level. That is to say, the effect of employment levels of other inputs on production is embedded in the productivity figures of the input under analysis. Thus partial efficiency measure of an input depends on the employment other inputs implying that efficiency of all inputs is embedded in a single figure. Thus, it is meaningless to draw lessons about the input under analysis from partial efficiency measures. Besides, shape of production function is determined by the parameters that determine the effects of inputs on output. These parameters are affected by several conditions that are out of the control of decision maker. Thus, it is hard to claim that partial efficiency measures constitute a reference to compare the ability of producers to utilize the inputs.

To sum up, partial efficiency analysis cannot yield benchmarks for efficiency of producers' decisions or employment of inputs. It only gives a very obscure picture of general structure of production. In this chapter, we will attempt to figure out the general conditions under which Turkish agricultural sector operate, by using extensive descriptive, quantitative and analytical tools. A detailed analysis of data that will be used to estimate the efficient frontier will be given in Section 3.1. Then, methods described in Chapter 2 will be applied in Section 2.3.2. After an extensive analysis of findings, we will conclude.

3.1 Data Sources and Characteristics

The data set used in this study is unique. It is obtained through an extensive farm household survey conducted in 2002 and 2004 to evaluate the impact of the agricultural reform program.

3.1.1 Data: Source and Processing

The data set used for estimation is based on Quantitative Household Survey commissioned by the Treasury and implemented by the GG et al. (2002 and 2004) to observe the effects of Agriculture Reform Implementation Program (ARIP). ARIP is an extended reform program that aims to reorganize the structure of agricultural production in Turkey by replacing input and output based subsidy programs with Direct Income Support (DIS) program. The major aim of the survey is to collect information about the effects of the DIS program on the structure of production and composition of consumption and the income of the farmers.

The questions in the survey span various topics about the rural life. Approximately 2700 variables are obtained from the survey results. Originally, 5508 households are participated in survey. The survey is conducted for the years 2002 and 2004. 1388 of households are replaced by the nearest neighbor in 2004. These households are eliminated from the sample in our analysis. Thus, production section of the questionnaire for 4120 farm households is used for 2002 and 2004. The data are classified using the NUTS-II definition for the regional differentiation of the efficiency analysis. The list of NUTS-II regions and the provinces they include can be found in Table A-1 of the appendix.

Several adjustments were necessary to adapt such an extensive data set to the frontier analysis framework. First of all, selection of the sample is likely to bring a bias. Since the survey aimed to analyze the effects of the reform program on major crop producers[9], sampled households were not distributed evenly among regions. The regions that are more likely to be affected by DIS program have a greater weight in sample selection. Of course, this is not a serious problem as soon as each region has enough observations to make statistical inference. All regions but İstanbul (with 18 observations only) had enough observations. Thus, İstanbul has been excluded from the analysis.

Frontier analysis method requires output and input quantities. Total revenue from crop and livestock production is used as dependant variable. Labor expressed as days worked is used as labor data. Land data consists of total dry and irrigated land used for field crops, dry and irrigated land used as orchards and fallow land in hectares. Livestock data is in Bovine Unit defined by ministry of Agriculture and Rural Affairs, and consists of the number of animals that the households own. Expenditures on seed, fertilizers, pesticides, irrigation, diesel, electricity, animal feed and other operational costs are also included as explanatory variables.

The inefficiency effects are estimated using six groups of variables. The first group is composed of five variables related to land. The share of irrigated land, orchards, fallow, rented land and land taken for sharecropping in total land is included in this group of variables. The second group consists of four dummy variables that are related to agricultural production. Number of households producing field crops (cereals, oilseeds and tubers), industrial crops, vegetables, and fruits are included in this group. The third group of variables is related to basic

[9] These crops are wheat, barley, sugar beet, tobacco, hazelnuts, cotton and sunflower.

characteristics of households and contains six dummy variables for DIS receiving status, credit access, technical support receiving status, affiliation with agricultural sales cooperatives and education level. The fourth group of variables consists of five dummies for farm size. The last group of variables consists of dummies for the regions.

A detailed list of all variables can be found in Table 3-1. All values are in 2002 prices[10]. 1062 observations had zero revenue from agricultural production in one of the two periods. These observations are excluded from the analysis, since zero revenue from agricultural production would imply that the market orientation of these households would be highly restricted. A further 44 observations which had positive revenues but did not made any production has also been eliminated.

The two questionnaires are different in terms of their questions on the use of labor. In 2002, farmers were asked for the hours spent for specific agricultural activities. However, in 2004, farmers were asked only for the number of agricultural workers hired and money paid to these workers. Thus, it was not possible to find the unpaid labor used in agricultural activities for 2004. To overcome this problem, labor use per hectare for 2002 is used to estimate the same figure for 2004. This excludes any effect of introduction of labor saving technologies on efficiency. However, given the short span of time, this will not introduce any bias in the data set. All observations that used zero labor (hence, zero land used in 2004) are excluded from the analysis. Thus, any farms that engage only in livestock production are more likely to be excluded.

Original data set includes information about the ownership, use and irrigation possibilities of the cultivated land. Land used for the field crops, orchards and fallow are incorporated in the land variable.

The theoretical framework developed in Chapter 2 is based on input quantities rather than the money spent on them. However, the original data set does not provide much information about the quantities of seed, fertilizers, pesticides, irrigation, diesel, electricity, animal feed. Using these figures incorporates the

[10] The nominal value of outputs is reported in the original data set. To obtain the real values, output values and subsidies of 2004 are divided by 1.49 which is the ratio of average of agricultural PPI for years 2004 and 2002. The other nominal variables are discounted according to prices reported by SIS (2005b). The items of which prices are not reported by SIS are discounted with the average of discount rates of the other items.

information about input prices by ignoring the differences in prices paid by the households. However, the price formation of these inputs allows including them as expenditures. Prices of these items are not likely to vary a lot through out the country since there is no price discrimination in diesel, electricity, fertilizers, animal feed and pesticides, apart from the transportation costs.

Besides the markets of these inputs are integrated enough to assume a small deviation among regions in the prices of these items. Thus, using money spent on these items as a proxy for the quantities turns out to be reasonable as soon as this fact is taken into consideration in the interpretation of the estimation results. The coefficients of these variables in the estimated frontier denote how much revenue is generated when the money spent on the related item is increased by one unit. There are many examples in literature where money spent on inputs is used instead of quantities. Karagiannis *et. al.* (2004) uses average prices to transform the monetary figures to quantity figures. This is not much different from using money spent on inputs, since dividing this figure by a constant for all households will not change the estimation results. To count a few Batesse, Rao and O'Donnell (2004), Batesse and Coelli (1995), Chavas, Petrie and Roth (2005) use directly money spent on inputs instead of quantity in the estimation of frontier.

Table 3-1: List of variables

Abbreviation	Variable	Unit	Explanation
Lab	Labor	Days	Days worked for agricultural production
Lvst	Livestock	Bovine Unit	Total number of bovine and ovine owned
Land	Land	Hectares	Total land used
Seed	Seed	YTL	Total money spent on Seed
Fert	Fertilizer	YTL	Total money spent on Fertilizer
Pest	Pesticides	YTL	Total money spent on Pesticides
Water	Water	YTL	Total money spent on Water
Dies	Diesel	YTL	Total money spent on Diesel
Elec	Electricity	YTL	Total money spent on Electricity
Other	Other	YTL	Total money spent on Other
Feed	Feed	YTL	Total money spent on Feed
irr	Irrigated land	Percentage	Percentage of irrigated land in total land owned
orch	Orchards	Percentage	Percentage of orchards in total land owned
fallow	Fallow	Percentage	Percentage of fallow land in total land owned
dis	DIS	Dummy (0-1)	DIS receiving status (=1 if HH receives DIS)
cred	Credit	Dummy (0-1)	Credit receiving status (=1 if HH receives Credit)
tech	Technical Support	Dummy (0-1)	Technical Support receiving status (=1 if HH receives technical support)
ASC	Agr. Sales Coop. Uni.	Dummy (0-1)	Affiliation with Agricultural Sales Cooperatives (=1 if any member of the household is affiliated with ASCU)
crop	Cereals	Dummy (0-1)	Cereals production status (=1 if cereal producer)
ind	Industrial Crops	Dummy (0-1)	Industrial crops production status (=1 if ind. crop producer)
vege	Vegetables	Dummy (0-1)	Vegetables production status (=1 if vegetable producer)
frut	Fruits	Dummy (0-1)	Fruits production status (=1 if fruit producer)
Rent	Rent	Dummy (0-1)	Land renting Status (=1 if HH rents land)
shrcropr	Sharecropping	Dummy (0-1)	Sharecropping Status (=1 if HH is sharecropper)

Table 3-1 (continued): List of variables

Abbreviation	Variable	Unit	Explanation
reg2	Region 2	Dummy (0-1)	Region Dummy (=1 if HH is in West Marmara)
reg3	Region 3	Dummy (0-1)	Region Dummy (=1 if HH is in Aegean)
reg4	Region 4	Dummy (0-1)	Region Dummy (=1 if HH is in East Marmara)
reg5	Region 5	Dummy (0-1)	Region Dummy (=1 if HH is in West Anatolia)
reg6	Region 6	Dummy (0-1)	Region Dummy (=1 if HH is in Mediterranean)
reg7	Region 7	Dummy (0-1)	Region Dummy (=1 if HH is in Central Anatolia)
reg8	Region 8	Dummy (0-1)	Region Dummy (=1 if HH is in West Black Sea)
reg9	Region 9	Dummy (0-1)	Region Dummy (=1 if HH is in East Black Sea)
reg10	Region 10	Dummy (0-1)	Region Dummy (=1 if HH is in Northeast Anatolia)
reg11	Region 11	Dummy (0-1)	Region Dummy (=1 if HH is in Central East Anatolia)
hhe1	Education 1	Dummy (0-1)	Education Dummy (=1 if head of HH is illiterate)
hhe2	Education 2	Dummy (0-1)	Education Dummy (=1 if head of HH is literate or has primary school diploma)
siz1	Size 1	Dummy (0-1)	Size Dummy (=1 if HH owns 2-5 Hectares of land)
siz2	Size 2	Dummy (0-1)	Size Dummy (=1 if HH owns 5-10 Hectares of land)
siz3	Size 3	Dummy (0-1)	Size Dummy (=1 if HH owns 1-2 Hectares of land)
siz4	Size 4	Dummy (0-1)	Size Dummy (=1 if HH owns20-50 Hectares of land)
siz5	Size 5	Dummy (0-1)	Size Dummy (=1 if HH owns more than 50 Hectares of land)
t	Time	Dummy(0-1)	Time Dummy (=1 in 2004)

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

3.1.2 Descriptive Findings

In this section, the characteristics of the key variables that are used in estimation will be depicted. Besides, a comparison of these statistics with the Agricultural Structure and Production Report (SIS, 2003, 2004 and 2005a) results will be made to give an idea about the representativeness of the sample.

The means of inputs are depicted in Table 3-2. Standard deviations can be found in Table A-2 of the Appendix. The changes in values of the variables provide the effects of the agricultural reform that started to be implemented in 2001.

Average of agricultural revenue is high in Western coastline and Southern parts of the country, while it is below Turkish average in Central, North and Eastern regions in both periods, as expected. There is a significant 32 percent increase in real value of revenues, for the whole sample. Increase in agricultural output is also higher in West Coast regions, with an exception of Northeast Anatolia where the increase is nearly 90 percent and Southeast Anatolia where there was a small increase in real value of revenues about 0.2 percent. The former is likely to be due to increase in livestock production. Revenue from livestock production has increased by 209 percent in North East Anatolia from 2002 to 2004. Comparison of data obtained from G.G. *et. al.* (2003 and 2005) with 2002 and 2003 Agricultural Structure and Production (SIS, 2003, 2004 and 2005a) Reports reveals the fact that distribution of income among regions does not differ considerably. Although it is impossible to make one to one comparison due to the differences in the structures of two data sets, one can check the central tendencies in both data sets to see if there is a significant inconsistency. For this purpose, we have compared ratio of value of output per labor of regions to that of Turkey for both data sets. Per capita figures are used to avoid the effects of differences in the number of households selected from each region. These figures are calculated for the region r by the following formula:

$$\omega_r^{ARIP} = \frac{\sum_t \left(\overline{rev_{rt}}\right)}{2} \Bigg/ \frac{\sum_t \left(rev_{\Sigma t}\right)}{2} \text{ and } \omega_r^{SIS} = \frac{\sum_t \left(\overline{y_{rt}}\right)}{2} \Bigg/ \frac{\sum_t \left(\overline{y_{\Sigma t}}\right)}{2} \qquad (3.2.1)$$

Table 3-2: Means of input variables used in analysis

	Regions	Numb. Of HHs	agr_inc YTL	sub YTL	lab Days	lvst CBU	land Ha.	seed YTL	fert YTL	pest YTL	water YTL	dies YTL	elec YTL	other YTL	feed YTL	TOC YTL
2002	West Marmara	365	6940	666	72.16	2.70	11.63	312	997	206	48	1118	55	1085	1054	4875
	Aegean	505	5232	312	144.33	1.45	7.48	172	531	322	188	922	108	745	497	3484
	East Marmara	272	5004	501	97.37	2.66	10.79	269	747	236	143	1231	123	841	564	4155
	West Anatolia	179	4363	1049	107.57	1.31	19.31	442	1180	184	408	1765	224	767	499	5469
	Mediterranean	357	6201	418	133.01	1.17	10.94	1063	1472	759	273	1214	58	721	418	5978
	Central Anatolia	238	4155	964	43.66	2.33	24.84	193	1348	149	67	1642	62	749	319	4531
	West Black Sea	363	2937	316	97.58	2.22	6.85	236	479	176	51	705	20	510	276	2455
	East Black Sea	336	2105	155	73.54	1.15	4.50	25	329	53	4	56	13	100	227	806
	Northeast Anatolia	75	2763	650	48.03	4.16	20.31	222	334	1006	86	903	13	762	252	3578
	Central East Anatolia	94	3307	834	87.17	3.03	15.12	104	314	59	26	386	25	650	346	1910
	Southeast Anatolia	230	5318	689	87.25	1.06	15.95	408	807	275	133	658	163	809	205	3459
	Turkey	3014	4656	516	97.82	1.88	11.56	329	802	288	132	955	78	696	457	3738
2004	West Marmara	365	8024	864	70.74	2.95	10.62	152	1962	352	75	1064	44	950	1186	5785
	Aegean	505	6392	498	137.15	1.70	6.83	173	869	512	374	974	134	1227	636	4900
	East Marmara	272	9112	863	84.10	2.14	9.84	149	1425	571	248	1012	33	929	760	5127
	West Anatolia	179	6572	1477	109.23	2.69	20.88	570	1640	295	679	1953	615	1429	747	7930
	Mediterranean	357	8799	654	126.69	1.30	11.07	717	1917	746	425	870	117	1318	344	6454
	Central Anatolia	238	5982	1391	40.15	2.50	20.56	205	1720	319	267	1424	60	932	362	5290
	West Black Sea	363	3721	446	88.48	1.95	5.76	69	675	232	114	636	18	331	250	2325
	East Black Sea	336	2805	241	75.41	0.86	2.35	13	385	27	35	35	1	147	119	762
	Northeast Anatolia	75	5246	983	44.35	3.84	20.47	216	766	59	428	581	76	888	608	3622
	Central East Anatolia	94	3710	799	102.29	4.03	12.05	38	469	247	0	351	3	167	286	1561
	Southeast Anatolia	230	5330	1310	76.88	1.65	15.23	249	1484	321	171	509	200	679	314	3927
	Turkey	3014	6184	771	93.02	2.02	10.50	231	1243	376	247	860	106	854	524	4441

Source: Author’s calculations from G.G. *et. al.* (2003 and 2005)

where $\overline{rev_{rt}}$ is agricultural revenue per household for region r at time t, $rev_{\Sigma t}$ is the agricultural revenue per household for the whole sample at time t, $\overline{y_{rt}}$ is average of value of total output for region r at time t, and $\overline{y_{\Sigma t}}$ is average of value of total output for Turkey. **Figure 3-1** depicts that these ratios are quite close to each other. The correlation coefficient is more than 0.87.

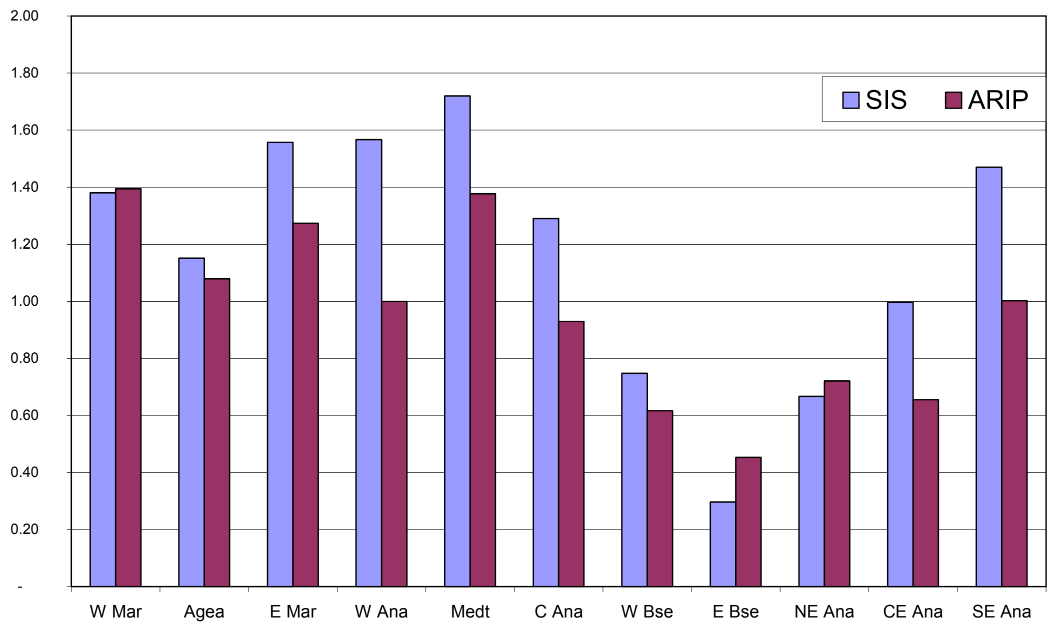


Figure 3-1: Comparison of agricultural revenue with SIS output data

Source: Author's calculations from G.G. *et. al.* (2003 and 2005) and Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a)

Labor is used extensively in Western and Southern coastlines of the country, especially in Aegean and Mediterranean regions. This can be explained by various reasons such as longer harvesting seasons, higher value for the outputs which in turn allows households to hire more of seasonal workers. The decline in labor usage is highest in East Marmara, Southeast Anatolia and Central Anatolia.

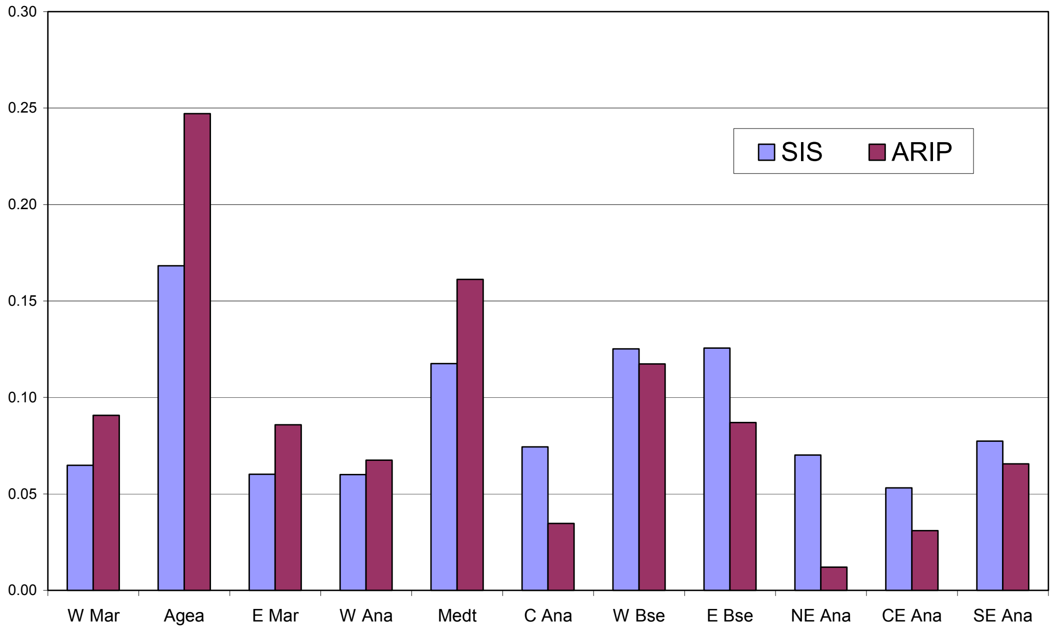


Figure 3-2: Comparison of labor usage with SIS labor data

Source: Author's calculations from G.G. *et. al.* (2003 and 2005) and Agricultural Structure and Production reports (SIS, 2003, 2004 and 2005a)

Labor use has decreased around 5 percent in the average. The decline in land use can be seen as a source of decline in land data since the labor use in 2004 are calculated from the land data. However, the decline in land use is nearly two times higher than the decline in labor use. Labor figures for 2004 are obtained by multiplying the cultivated area in 2004 with labor use per hectare of 2002 for each product. Then, the difference between land and labor use is due to a shift of production from land intensive products (such as sugar bets) to labor-intensive products. Figures for the production quantities confirm this. Details of production quantities for the whole sample can be found in Table A-4.

Comparison of total employment with average days worked for agricultural production depicts that there is no significant difference between our G.G. *et. al.* (2003 and 2005) based calculations and Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a). **Figure 3-2** depicts that variation of labor usage vary in the same direction in both data sets. The correlation coefficient is 0.84.

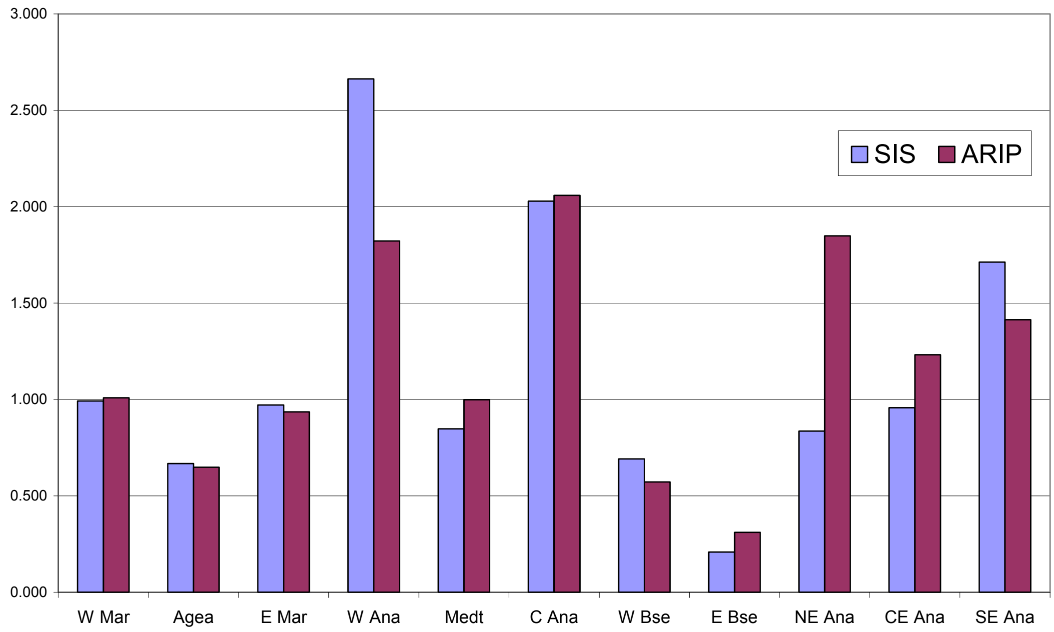


Figure 3-3: Comparison of land usage with SIS data

Source: Author's calculations from G.G. *et. al.* (2003 and 2005) and Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a)

Land use is relatively high in West, Central and Central East Anatolia where cereal production composes a relatively higher part of agricultural production and there is an abundance of land due to geographical properties of these regions. The decline in land figures is highest in East and West Black Sea, Central East and Central Anatolia. This is something expected in the context of structural adjustment process of ARIP.

Comparison of land figures obtained from G.G. *et. al.* (2003 and 2005) with Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a) reveals that two series are highly correlated. The exception is North East and West Anatolia. The correlation coefficient between these two series is 0.78.

There is an increase in the average number of livestock. We have used weights calculated by Ministry of Agriculture and Rural Affairs for culture cows, crossbred cows, domestic cows, culture cattle, crossbred cattle, domestic cattle, sheep and goat to obtain the total number of animals in Bovine unit. According to G.G. *et. al.* (2003 and 2005) data, the average number of livestock holdings has increased about 7.5 percent. However, Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a) designate that number of livestock is increased only with a moderate amount of 0.42 percent. A close analysis of G.G. et al. (2003 and 2005) data shows that the increase is mostly due to West, Central East and Southeast Anatolia regions and besides, breeding for diary products has increased notably from 2002 to 2004 while there has been a decline in the number of bovine that is raised for slaughter. There seems to be a tremendous increase in average number of ovine. A thorough analysis of livestock data results in the conclusion that the increase in animal numbers is mostly due to the increase in ovine raised for milk. The change in all groups of livestock is mainly due to the change in number of households engaged in livestock production. The average livestock holdings of households that are engaged in livestock production did not change radically Table 3-3 gives detailed information on livestock ownership.

Table 3-3: Details for livestock ownership (values in bovine unit)

	Year	Culture Cows	Cross Cows	Dom. Cows	Culture Cattle	Cross Cattle	Dom. Cattle	Sheep (Milk)	Sheep (Slaug.)	Goat
Average (all)	2002	0.28	0.36	0.45	0.14	0.15	0.18	0.05	0.01	0.01
	2004	0.33	0.27	0.53	0.10	0.09	0.13	0.34	0.03	0.06
Total Number	2002	1136	1490	1862	569	629	756	214	32	32
	2004	1341	1125	2204	432	365	538	1388	139	234
% Share in Total	2004	17.27	14.49	28.38	5.56	4.69	6.93	17.87	1.79	3.02
	2002	16.91	22.17	27.70	8.47	9.35	11.25	3.19	0.48	0.48
# of HH engaged	2002	307	610	1440	135	224	520	75	24	9
	2004	379	552	1695	130	135	287	488	136	153
Average (engaged)	2002	3.70	2.44	1.29	4.21	2.81	1.45	2.86	1.35	3.55
	2004	3.54	2.04	1.30	3.32	2.70	1.87	2.84	1.02	1.53

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

Comparison of G.G. *et. al.* (2003 and 2005) data with Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a), by using the weights that are described before depicts the fact that central tendencies in livestock variables of both data sets are parallel. To make the comparison we have looked at the ratio calculated according to equation (3.2.1) by using per capita livestock numbers instead of per capita revenue and output value. Figure 3-4 depicts that the highest difference between two data sources is in Central East and Southeast Anatolia regions. However, the movements of figures are generally in the same direction. Correlation coefficient is quite high for livestock with 0.89. The situation in livestock ownership is also supported by the milk production figures. Milk production has increased drastically from 2002 to 2004.

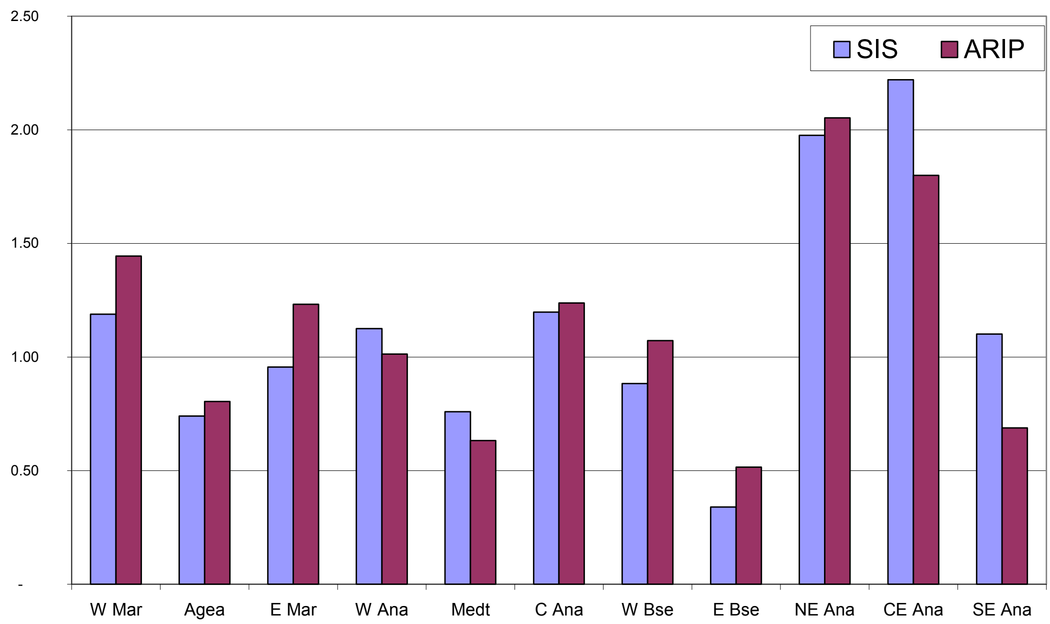


Figure 3-4: Comparison of livestock with SIS data

Source: Author's calculations from G.G. *et. al.* (2003 and 2005) and Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a)

Total operational costs (TOC), which is the sum of all money spent on inputs, is also reported in Table 3-2, although it is not used in estimation. TOC is relatively higher in Central and Western regions of country while it is low in Northern and Eastern regions. Average TOC value for Mediterranean is 60 percent more than the sample average while it is nearly 80 percent less than the sample average in East Black Sea. TOC greatly varies among regions. This is expected due to different production structures in different regions brought about by variety in geographical and climatic conditions. Fertilizers, diesel and animal feed turns out to be the most important components of TOC together with the "other costs" which mainly includes money spent on fodder. Expenditures on electricity and water, on the other hand, are not significant. Although the households that are engaged only in livestock production are likely to be excluded, animal feed has a significant share in total costs. Thus, it can be concluded that livestock production is generally made together with crop production. The average livestock of households that did not used any land in production is 0.94 and 1.47 respectively for 2002 and 2004 which proves the fact that agricultural production based on merely livestock production is not very prevalent.

TOC has increased 19 percent in real terms from 2002 to 2004, for the whole sample. The increase is significant in pesticide, fertilizer, water, electricity and other costs. Only seed and diesel spending has declined with 30 percent and 10 percent respectively.

Money spent on seeds is highest in Central and South parts of the country. However, it has declined drastically, in real terms, with an average of 30 percent. The decline is highest in West and East Marmara, Mediterranean and Central East Anatolia. Money spend on seeds has increased extensively in real terms in West Anatolia.

The use of fertilizer is highest in Western and Southern parts of Turkey. It decreases towards Northern and Eastern parts of country. Increase in money spent on fertilizers is highest in Northeast Anatolia, East and West Marmara. The increase was modest in Central Anatolia and Mediterranean regions with 20 percent-30 percent. This can be explained by high level of fertilizer spending in 2002.

Pesticide usage is also highest in Western and Southern parts of country. The increase in money spent on pesticides is highest in Central East Anatolia, East Marmara and Central Anatolia while there was a significant fall in Northeast and East Black Sea regions.

Animal feed usage is also higher in Western and Southern parts of the country. Increase in animal feed is higher in Northeast Anatolia and Western parts of the country, while it has declined in Mediterranean, East Black Sea and Southeast Anatolia.

There is a 10 percent fall in average diesel usage that can be explained by high prices. Money spent on diesel has increased only in Aegean and West Anatolia. This can be interpreted as a sign of intensification of machinery usage. Diesel is used more in the Western parts of the country and this is compatible with high mechanization in these regions.

There exists high variation in the use of electricity among regions. West Anatolia, Aegean and South East Anatolia turn out to be the most electricity consuming regions. Change in the area of irrigated land explains the change in electricity usage, which verifies the fact that electricity is used mainly for irrigation. These regions are rather semi-arid and irrigation from wells by drilling is prevalent in these regions. Increase is higher in West Anatolia, Mediterranean and Northeast Anatolia.

A few concluding remarks are needed for the descriptive statistics of data used to estimate the efficiency scores. First, per capita revenue is higher in Western and Southern parts of the country and this is consistent with the persistent conviction in the literature.

Secondly, there is a considerable divergence among regions in usage of modern inputs such as fertilizers, electricity, animal feed and pesticides. Variety in geographical, environmental, climatic and infrastructural differences among regions can be the underlying reason of high deviation. This is some how important since it is the sign of segmented structure of agricultural production throughout the country (Çakmak, *et. al.*, 2004). Farmers choose their input mix by acknowledging these factors. The comparison of ratio of standard deviation to average of variables between and within the regions supports this assertion. The between deviation is 2 to 4 times higher than the within deviation. Thus, farmers who produce under similar conditions uses similar input mix. For details, see Table A-3 in Appendix.

DIS and other support payments received by households demonstrate the effects of supporting agriculture according to the land holdings of households. The regions with small land holdings are also at the bottom of DIS distribution albeit their low agricultural revenue. Thus, Central West regions where there is abundance in land, received more payments, in both periods. The success of new support programs can be questioned based on the fact that agricultural supports distributed in these programs cannot reach farmers with lower income. Although sustaining income equality is not among the aims of these programs, the critic is valid as soon as these programs intend to support the producers. Making payments according to land holdings may fail to support small farmers. This can be a serious problem in regions where a weighty part of agricultural production is made by small farmers. The amount of total support payments have increased around 50 percent during the period. The underlying reason for this increase is due to the delayed payments of the DIS payments, the implementation of the alternative crop payments especially for tobacco and the introduction of diesel support in 2004. The money received by households through these new support programs add up to 24 percent of the total support received in 2004. Thus, only 13 percent of increase in subsidies is due to increase in DIS payments, while 36 percent of it comes from the new support programs.

The mean values of selected factors that affect the production structure are given in Table 3-4 and Table 3-5. Standard deviations for these variables can be found in Table A-5 of Appendix. The average share of irrigated land in total land owned is about 21 percent in both years and this is compatible with the Turkish average according to 2001 agricultural census held by SIS (Çakmak and Akder, 2005). This figure takes the highest value in Aegean, Mediterranean and Northeast Anatolia. There has been a 0.23 percent decline in total share of irrigated land from 2002 to 2004. The fall in share of irrigated land is higher in West and Central Anatolia, and East Black Sea. Average share of orchards in total used land is about 16 percent in 2002 and 22 percent in 2004. Agricultural census held by SIS in

2001 and 2004 shows that the orchards constitute around 10 percent of total used land (Çakmak and Akder, 2005). Orchards are more prevalent in Northern and Western parts of the country. Share of orchards has increased around 5 percent in average. This increase is also significant in the regions where orchards are prevalent. The comparison of orchard shares obtained from G.G. *et. al.* (2003 and 2005) data with Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a) shows that series in two data sets is highly correlated, with a correlation coefficient of 0.94.

The average share of fallow land is about 8 percent in both years. Fallow land is relatively high in Central, Eastern and Northern parts of the country with shares changing between 13 percent and 20 percent. There has been a slight fall in share

Table 3-4: Mean values for characteristics of land usage

	Region	Numb.	irr %	orch %	fallow %	rent %	shrcropr %
2002	West Marmara	365	10.00	9.45	2.15	10.72	1.33
	Aegean	505	36.36	13.17	5.02	12.51	2.64
	East Marmara	272	18.71	31.71	8.26	6.06	1.78
	West Anatolia	179	21.73	0.04	19.37	9.78	3.56
	Mediterranean	357	38.80	3.35	5.39	9.93	1.11
	Central Anatolia	238	9.56	0.11	20.09	9.59	3.17
	West Black Sea	363	21.04	14.63	11.36	4.93	1.75
	East Black Sea	336	0.47	66.72	1.07	0.46	2.10
	Northeast Anatolia	75	29.71	0.00	17.40	11.45	0.67
	Central East Anatolia	94	32.17	2.74	13.10	9.39	0.95
	Southeast Anatolia	230	21.02	1.78	7.10	6.14	2.81
	Turkey	3014	21.57	16.04	8.09	8.14	2.06
2004	West Marmara	365	9.85	11.51	1.87	7.99	0.83
	Aegean	505	38.30	22.62	2.82	13.95	1.94
	East Marmara	272	21.10	39.40	9.36	5.17	0.26
	West Anatolia	179	19.77	0.08	19.67	9.83	1.80
	Mediterranean	357	37.86	4.82	3.37	11.45	0.89
	Central Anatolia	238	6.24	0.12	20.02	11.23	1.26
	West Black Sea	363	18.00	13.80	7.48	6.17	1.34
	East Black Sea	336	1.24	84.62	0.74	1.24	0.79
	Northeast Anatolia	75	31.60	4.01	11.61	15.11	1.11
	Central East Anatolia	94	32.51	3.70	15.78	7.04	0.00
	Southeast Anatolia	230	20.70	3.64	8.92	6.75	1.63
	Turkey	3014	21.35	20.91	7.14	8.59	1.16

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

Table 3-5: Mean values for some factors that characterize the production structure

	Region	crop Count	ind Count	vege Count	frui Count	dis Count	cred Count	tech Count	ASC Count	hhe1 Count	hhe2 Count	hhe3 Count	siz0 Count	siz1 Count	siz2 Count	siz3 Count	siz4 Count	siz5 Count
2002	West Marmara	317	280	52	27	248	50	28	145	41	303	21	45	82	101	81	47	9
	Aegean	303	364	58	150	298	111	21	102	63	425	17	94	155	153	73	24	6
	East Marmara	182	90	56	145	162	37	22	85	59	201	12	48	69	79	42	24	10
	West Anatolia	172	65	36	5	119	11	9	3	27	139	13	7	18	35	58	48	13
	Mediterranean	326	107	78	53	157	38	25	58	48	275	34	64	109	82	56	35	11
	Central Anatolia	237	64	21	5	170	14	15	5	46	179	13	2	23	50	67	66	30
	West Black Sea	331	146	109	91	201	44	8	28	77	278	8	50	132	106	56	18	1
	East Black Sea	80	124	15	236	168	22	9	70	72	231	33	178	108	36	8	2	4
	Northeast Anatolia	73	17	8	1	35	1	4	0	14	58	3	7	7	12	22	21	6
	Central East Anatolia	88	29	4	9	37	2	5	0	26	62	6	11	18	15	25	18	7
	Southeast Anatolia	206	80	20	18	135	6	2	5	63	160	7	21	45	54	63	30	17
	Turkey	2315	1366	457	740	1730	336	148	501	536	2311	167	527	766	723	551	333	114
2004	West Marmara	317	278	69	49	292	92	14	144	38	304	23	47	94	101	75	40	8
	Aegean	351	349	91	153	386	148	26	79	47	437	21	94	163	155	65	25	3
	East Marmara	189	88	86	160	219	55	14	77	39	220	13	53	75	69	43	23	9
	West Anatolia	178	52	30	12	163	54	7	3	31	137	11	3	20	35	62	43	16
	Mediterranean	327	89	79	53	229	52	15	45	61	258	38	71	104	74	55	39	14
	Central Anatolia	238	50	17	7	205	20	0	0	51	171	16	4	30	43	72	69	20
	West Black Sea	338	125	224	104	267	32	1	3	66	285	12	78	139	89	42	13	2
	East Black Sea	135	130	46	190	251	21	1	47	67	228	41	192	111	26	6	1	0
	Northeast Anatolia	69	22	16	7	57	1	4	0	9	59	7	5	10	15	19	20	6
	Central East Anatolia	82	25	9	12	57	2	0	6	28	62	4	16	22	14	27	11	4
	Southeast Anatolia	212	84	29	22	170	10	2	4	105	117	8	20	58	55	50	32	15
	Turkey	2436	1292	696	769	2296	487	84	408	542	2278	194	583	826	676	516	316	97

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

of fallow land from 2002 to 2004. The fall was significant in North East and East Black Sea regions. There was an increase in the share of fallow land in East Marmara and Central Anatolia. The share of fallow land is around 19 percent according to Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a). However, correlation coefficient between G.G. *et. al.* (2003 and 2005) data and Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a) data is found to be 0.98.

Average share of rented land to total land used is about 8 percent, both in 2002 and 2004. This figure is higher in western and central parts of the country. Only significant change from 2002 to 2004 is in Northeast Anatolia and West Marmara with a 4 percent increase and 3 percent decrease, respectively. Share of land taken for sharecropping in total land used is quite low with 2 percent and 1 percent in 2002 and 2004. Percentage share of households that rented land or took land for sharecropping for each region is depicted in Table 3-6. An important part of the households rent land. Land renting is more prevalent in western and southern parts of the country. Percentage share of households who rent land has increased considerably in Northeast Anatolia while there was a significant fall in West Marmara. Sharecropping is higher in central parts of the country. However, there is a significant fall in number of sharecropping households in all regions.

Number of cereal producers is higher compared to other product types, in all regions except Aegean and East Black Sea. Cereal production is more prevalent in Northeast, Central and West Anatolia, as expected. This pattern did not change drastically from 2002 to 2004. The number of cereal producers has increased or remained in the same levels for all regions except for Northeast and Central East Anatolia.

There is a modest decline in the number of households engaged in industrial crop production from 2002 to 2004. This is something expected, under ARIP. Production shifts to newer product types from conventionally highly subsidized crops.

Number of households that produce fruits comes in the third place. It is prominent for East Black sea while fruit production is a quite rare production activity in Central, Northeast, Southeast and West Anatolia and East Marmara.

Number of fruit producers is highest in West Marmara and it has increased slightly.

Vegetable production turns out to be the most insignificant activity. It is highest in Mediterranean and West Black Sea regions. Although it remained intact for these two regions, there have been slight declines in the other regions from 2002 to 2004.

Table 3-6: Percentage share of households that rented land or took land for sharecropping

Region	Rented Land		Sharecropping	
	2002	2004	2002	2004
West Marmara	34	23	5	3
Aegean	37	38	8	5
East Marmara	22	19	6	1
West Anatolia	31	32	13	6
Mediterranean	27	30	4	3
Central Anatolia	30	35	13	4
West Black Sea	18	21	5	5
East Black Sea	1	3	4	2
Northeast Anatolia	26	43	1	5
Central East Anatolia	22	17	2	0
Southeast Anatolia	16	16	8	4
Turkey	24	24	6	3

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

According to survey results, 57 percent of households received DIS payments in 2002. This figure has increased to 76 percent in 2004. A higher percentage of households in Central Anatolia, West Anatolia and West Marmara receive DIS, in 2002. In 2004, households receiving DIS has increased in all regions, though the increase is higher in Mediterranean and Eastern regions. However, percentage of households receiving DIS is still higher in Central and Western regions with 80 percent to 90 percent.

Credit access turns out to be low with 11 percent and 16 percent for 2002 and 2004 respectively. It is higher in western parts of the country, while it is as low as

1 percent for eastern regions. Increase in credit access is higher in West Anatolia, East and West Marmara regions.

Number of households that has access to technical support is quite low throughout the country. Although it is higher in western parts of the country, it is still inadequate. Percentage share of households that receive technical support changes between 4 percent and 8 percent in western regions while it is between 0 percent and 5 percent in eastern regions. The figure has noticeably declined from 2002 to 2004.

About 17 percent of households were members of Agricultural Sales Cooperative Unions (ASCU) in 2002. Membership to ASCUs is higher in western parts of the country and East Black Sea region, as expected. The percentage of households that are members of ASCUs has declined slightly in all regions from 2002 to 2004. This can be explained by reduced roles of ASCUs in agricultural policies after ARIP.

Education level of household chiefs is higher in the western parts of the country. An important portion of household chiefs has a primary school diploma. Number of household chiefs that has educated after primary school is quite low. The change in education level from 2002 to 2004 is quite interesting. There is an increase in the number of household chiefs educated after primary school. The number of illiterates has also been increased from 2002 to 2004. However, the change is not very significant.

The dominant farm size varies among regions. 2-10 Hectare size group is dominant in the western parts of the country while 5-10 Hectares is more prominent in the central parts. The eastern regions are concentrated in 10-20 Hectares of land. There is a tendency in farm size to get smaller especially in the Eastern parts of the country. The underlying reason is likely to be the application of DIS. DIS program does not make any payments for the land over 50 Hectares, until 2003. Thus, people started to register their land above 50 Hectares with different names. The decrease in the number of farms greater than 50 Hectares can be explained by this fact. However, there is also a significant increase in the number of farms sized 20-50 Hectares. Table 3-7 depicts that land controlled by 10-20 Hectares is higher than the other size groups. Exceptions to this conclusion

Table 3-7: Land controlled according to farm size

	Region	0-2 Ha.	2-5 Ha.	5-10. Ha	10-20 Ha.	20-50 Ha.	50+ Ha.
2002	West Marmara	48	270	731	1325	1130	740
	Aegean	107	512	1037	571	942	607
	East Marmara	52	231	541	771	599	741
	West Anatolia	8	64	244	1394	796	951
	Mediterranean	63	361	543	1038	764	1138
	Central Anatolia	3	71	358	1930	970	2580
	West Black Sea	55	427	720	495	725	64
	East Black Sea	170	324	264	40	103	612
	Northeast Anatolia	7	24	77	579	290	547
	Central East Anatolia	12	56	106	466	330	451
	Southeast Anatolia	23	147	354	865	839	1440
	Turkey	547	2487	4976	9472	7487	9871
2004	West Marmara	52	308	685	1108	1026	699
	Aegean	103	539	1086	723	834	162
	East Marmara	58	244	448	714	586	626
	West Anatolia	3	64	233	1181	873	1383
	Mediterranean	75	331	495	1175	762	1114
	Central Anatolia	5	101	301	1939	974	1574
	West Black Sea	87	452	602	312	534	105
	East Black Sea	180	320	181	30	77	0
	Northeast Anatolia	5	32	114	577	230	578
	Central East Anatolia	15	65	101	320	367	265
	Southeast Anatolia	19	172	362	886	657	1407
	Turkey	602	2626	4606	8966	6921	7912

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

are Aegean, West and East Black Sea. The distribution of land among farm size groups is quite uneven in eastern parts of the country.

The most important conclusion from the descriptive findings is that structure of agricultural production comprises a complicated composition. Western parts of the country turn out to be developed in terms of agricultural infrastructure, market orientation and production technology. The central parts can be classified as "developing" while the eastern parts of the country is obviously least developed. Characteristic variables justify this classification for rural development status. Thus, agricultural policies should be designed by considering these complications. Applying different incentive creating policies is unavoidable under the existence of such a complicated variation across regions.

Another important conclusion of descriptive findings is that ARIP has started to transform the structure of agriculture, but the current situation is far off from supporting the smaller and poorer farmers. Table 3-8 depict that there is a huge discrepancy between average supports received by different size groups. Distribution of DIS payments is utterly uneven. An important part of this inequality follows from the variety in the geographical properties of regions. Correlation between land size and subsidies is 0.88. This should be an expected result on the basis that DIS is distributed according to land size. However, correlation between DIS payments and agricultural revenue is quite low with 0.14. These findings point out an important problem about the rationale of making DIS payments according to land size. G.G. *et. al.* (2003 and 2005) data reveal the fact that DIS payments and market access are only just connected. Subsidies in the form of direct payments do not create enough incentives for farmers to make production for market.

Table 3-8: Average DIS receiving according to farm size

	Region	0-2 Ha.	2-5 Ha.	5-10. Ha	10-20 Ha.	20-50 Ha.	50+ Ha.
2002	West Marmara	408	210	520	728	1483	2947
	Aegean	77	220	336	493	973	917
	East Marmara	266	138	352	801	1313	2108
	West Anatolia	60	538	891	1030	1488	1178
	Mediterranean	33	148	367	643	1069	2502
	Central Anatolia	150	671	502	674	1398	1708
	West Black Sea	56	158	393	642	697	1000
	East Black Sea	49	178	322	245	4995	208
	Northeast Anatolia	43	241	319	659	438	3210
	Central East Anatolia	15	176	267	2332	528	466
	Southeast Anatolia	61	192	294	694	1656	2304
	Turkey	103	203	408	769	1251	1848
2004	West Marmara	131	410	707	1057	2008	4967
	Aegean	157	356	523	861	1487	1473
	East Marmara	177	367	854	1519	1592	4102
	West Anatolia	304	663	977	1204	2172	3000
	Mediterranean	67	266	603	816	1827	2871
	Central Anatolia	39	441	777	1138	2180	2596
	West Black Sea	123	280	599	798	1637	2651
	East Black Sea	160	307	442	753	0	
	Northeast Anatolia	76	220	503	687	1318	4034
	Central East Anatolia	213	262	730	1195	1703	1171
	Southeast Anatolia	166	664	527	1014	2372	6931
	Turkey	143	360	644	1039	1935	3705

Source: Author’s calculations from G.G. *et. al.* (2003 and 2005)

High correlation between G.G. *et. al.* (2003 and 2005) and Agricultural Structure and Production Reports (SIS, 2003, 2004 and 2005a) data also reveals the fact that the sample of the survey is quite representative of the overall Turkish agriculture. The bias in the sample due to sample selection, which intended to observe the effects of ARIP, is rather ignorable. Further, the inconsistency in the part of the data set that is used in our work is quite low and can be considered as exceptions. Thus, any policy recommendations based on the analysis of the data will be also valid for Turkey.

3.2 Estimation

3.2.1 Model

Inefficiency effects are estimated by using three models, developed in Batesse and Coelli (1992), Batesse and Coelli (1995) and Batesse and Broca (1997). The former, namely the "technical varying decay model" (TVDM), is described in section 2.2.3.2 while the details of the latter named as "neutral technical inefficiency effects model" (N-TIEM) "non-neutral technical inefficiency effects model" (NN-TIEM) are given in section 2.2.5 of Chapter 2.

The independent variables of TVDM are merely the inputs, namely labor, livestock, land, money spent on seed, fertilizers, pesticides, water, diesel, electricity, other operational costs, and animal feed. Thus, the model can be written as:

$$\ln\left(REV_{it}\right)=\beta_0+\beta_1\ln\left(LAB_{it}\right)+\beta_2\ln\left(LVST_{it}\right)+\beta_3\ln\left(LAND_{it}\right)+\beta_4\ln\left(SEED_{it}\right)$$
$$+\beta_5\ln\left(FERT_{it}\right)+\beta_6\ln\left(PEST_{it}\right)+\beta_7\ln\left(WATER_{it}\right)+\beta_8\ln\left(DIES_{it}\right)$$
$$+\beta_9\ln\left(ELEC_{it}\right)+\beta_{10}\ln\left(OTHER_{it}\right)+\beta_{11}\ln\left(FEED_{it}\right)+v_{it}-u_{it} \quad (3.2.2)$$

$$u_{it}=u_i.\beta\left(t\right) \quad (3.2.3)$$

$$\beta\left(t\right)=\exp\left(\eta\left(t-T\right)\right) \quad (3.2.4)$$

The distributional assumptions are same as in section 2.2.3.2 of Chapter 2. This model is preferred in applied work due to its simplicity and flexibility. The simplicity restricts the number of parameters to be estimated. Modeling the variation in efficiency across time with equation (3.2.3) and (3.2.4) requires estimation of only one extra parameter, namely η. However, this simplicity comes at a cost. Specification of time effect is in fact rigid, since it does not allow for efficiency to increase or decrease at a decreasing rate (Batesse and Coelli, 1992).

Since logarithm of variables is used in estimation, estimated coefficients are output elasticities of inputs. The significance of β_k indicates a statistically significant effect of input *k* on agricultural revenue.

TVDM is estimated under two different distributional assumptions, first is the truncated normal and second the half normal distribution. Although estimated coefficients do not differ much, since μ, the mean of truncated normal distribution is found to be insignificant half normal specification is preferred for the distribution of u in hypothesis testing.

Independent variables of N-TIEM are technical inefficiency effects variables in addition to inputs variables. The variables that are used to analyze the characteristics of agricultural production in section 3.1.2 are used as technical inefficiency effects variables. Thus, the N-TIEM can be written as:

$$\begin{aligned}\ln\left(REV_{it}\right) &= \beta_0 + \beta_1 \ln\left(LAB_{it}\right) + \beta_2 \ln\left(LVST_{it}\right) + \beta_3 \ln\left(LAND_{it}\right) + \beta_4 \ln\left(SEED_{it}\right) \\ &+ \beta_5 \ln\left(FERT_{it}\right) + \beta_6 \ln\left(PEST_{it}\right) + \beta_7 \ln\left(WATER_{it}\right) + \beta_8 \ln\left(DIES_{it}\right) \\ &+ \beta_9 \ln\left(ELEC_{it}\right) + \beta_{10} \ln\left(OTHER_{it}\right) + \beta_{11} \ln\left(FEED_{it}\right) + v_{it} - u_{it}\end{aligned} \tag{3.2.5}$$

where

$$\begin{aligned}u_{it} &= \delta_0 + \delta_1\left(irr\right) + \delta_2\left(orch\right) + \delta_3\left(fallow\right) + \delta_4\left(crop\right) + \delta_5\left(ind\right) \\ &+ \delta_6\left(vege\right) + \delta_7\left(frui\right) + \delta_8\left(rent\right) + \delta_9\left(shrcropr\right) + \delta_{10}\left(dis\right) + \delta_{11}\left(cred\right) \\ &+ \delta_{12}\left(tech\right) + \delta_{13}\left(ASC\right) + \delta_{14}\left(t\right) + \delta_{15}\left(reg2\right) + \delta_{16}\left(reg3\right) + \delta_{17}\left(reg4\right) \\ &+ \delta_{18}\left(reg5\right) + \delta_{19}\left(reg6\right) + \delta_{20}\left(reg7\right) + \delta_{21}\left(reg8\right) + \delta_{22}\left(reg9\right) + \delta_{23}\left(reg10\right) \\ &+ \delta_{24}\left(reg11\right) + \delta_{25}\left(hhe1\right) + \delta_{26}\left(hhe2\right) + \delta_{27}\left(siz1\right) + \delta_{28}\left(siz2\right) + \delta_{29}\left(siz3\right) \\ &\delta_{30}\left(siz4\right) + \delta_{31}\left(siz5\right) + w_{it}\end{aligned} \tag{3.2.6}$$

The distributional assumptions are same as in section 2.2.5 of Chapter 2.

The coefficients of input variables in N-TIEM are output elasticities of inputs. The coefficients of technical inefficiency effects variables depict the effect of corresponding variable on technical inefficiency. Since u_{it} enters the frontier equation with a negative sign a negative, a negative coefficient means efficiency improving effect.

The third model is a modification of the N-TIEM, in which u_{it} is specified as;

$$u_{it} = \delta_0 + \sum_{i}^{l} \delta_i Z_{it} + \sum_{j}^{l} \sum_{i}^{k} \theta_{ij} Z_{it} X_{jt} + w_{it} \qquad (3.2.7)$$

where Z_i denotes the technical inefficiency variables and X_j denotes the input variables. The distributional assumptions are same as N-TIEM. The coefficients of input variables are not elasticities in this model. However, the coefficients of input variables will be the elasticities at the geometric mean of the sample if estimation is made by using deviation of input variables from geometric mean of the data. To facilitate the interpretation of the NN-TIEM and to make it comparable with other models, independent variables except dummy variables are divided by their geometric mean.

Agricultural revenue, which is dependent on output prices, is used as dependent variable, in all three models. Although there are many examples of this approach in the literature, such as Batesse and Coelli (1992) and Batesse *et. al.* (2004), this seems to be inappropriate as soon as the households are not price taker revenue maximizers. The estimated frontier is not a production frontier but a revenue frontier. Our efficiency scores measures the failure of households in satisfying the first order conditions of revenue maximization problem. This failure is not only due to choosing wrong input mix that will yield the revenue maximizing output. Therefore, for a country like Turkey where production is not well integrated with input and output markets and thus there are serious problems in marketing conditions, one should be careful in using the efficiency scores based on revenue data (Çakmak *et. al.*, 2004). Estimated efficiency scores will not only reflect the households' ability to obtain maximum output by using minimum input, but also their capability of marketing their products.

Another problem about using revenue as dependent variable is that, production for self-consumption or kept as inventory cannot be incorporated into the analysis. Thus the efficiency of those households that makes relatively high self-consumption or hoard their production due to unfavorable market conditions are likely to be underestimated. Although not selling the output due to unfavorable market conditions is something that should favor revenue efficiency, the estimated efficiency scores does not consider this. One can claim that exclusion of self-consumed production from efficiency analysis makes sense since when the situation is considered strictly in terms of economics, any production that is not sold in market does not have any economic value. However, if the aim is to measure the efficiency of "production process", those items should be included in the analysis since some of the inputs are used for self-consumed products. Accordingly, we can say that the estimated efficiency scores does not measure the efficiency of production process merely but also the efficiency of marketing process. This should be kept in mind while making comments on the estimated efficiency results. This suggests that the regions where marketing facilities of main products are developed should be more efficient in our analysis. This, on the other hand, brings about a key forewarning about the policy implications. Policy recommendations should be related to marketing conditions as well as production structures.

A last point to be mentioned is about the exclusion of climate and geographical conditions such as land quality or climate variables from the analysis. Apparently G.G. *et. al.* (2003 and 2005) data does not give any information about the climatic and geographical conditions of households. An alternative would have been incorporating regional data for these factors, obtained from other sources. However, this would impose the same geographical and climatic conditions to the households that are in the same region. This is likely to cause multi-collinearity in the estimation, since we comprised regional dummies for the regions.

The estimations of all three models are made by Frontier® 4.1 (CEPA, 2000) which estimates the model developed by Batesse and Coelli (1995) for panel data by employing Davidson-Fletcher-Powell Quasi-Newton method for maximum-likelihood estimation (Coelli, 1996).

3.2.2 Results

3.2.2.1 Estimated Frontier and Coefficients

As described afore, all models are estimated by using deviation from the geometric mean of data. The output elasticity of inputs, significance of technical inefficiency effects variables and efficiency scores that are estimated by N-TIEM model are used. Consequently, the main model is N-TIEM model in elaborating the efficient frontier. TVDM is used only for testing the significance of technical inefficiency effects variables. NN-TIEM on the other hand is used to reveal the interaction of input variables with technical inefficiency effects variables. Thus, the main focus is on the significance and sign of coefficients of cross terms for the NN-TIEM. The conducted tests using various models are summarized in Table 3-9.

Table 3-9: The null hypothesis and test statistics

Test	H_0		Test Statistic		Result	
			N-TIEM	NN-TIEM	N-TIEM	NN-TIEM
Existence of technical inefficiency across farms	$\sigma^2 = 0$		-3.65	-6.91	Reject	Reject
	$\gamma = 0$		3.91	4.01	Reject	Reject
Time Invariant Efficiency	$\delta_t = 0$		171.59	4.37	Reject	Reject
Significance of Technical Inefficiency Variables	$\delta_i = 0$ for all *i*	Wald	415.50	720.45	Reject	Reject
		LR	629.697	1372.28	Reject	Reject
Cross terms are insignificant	$\theta_{ij} = 0$ for all *i* and *j*	Wald	-	445.27	-	Reject
		LR	-	742.583	-	Reject
Constant Returns to Scale	$\sum \beta$		1.32	1.16		
	$\sum \beta = 1$		30.2	2.19	Reject	Accept

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

σ^2 and γ are statistically significant at 1 percent significance level that implies to the existence of a significant technical inefficiency among the farms.

Time invariant technical inefficiency is also rejected since the coefficient of time dummy is statistically significant for both models. However, significance of time is stronger in N-TIEM model. Thus, it can be concluded that interaction of inputs with time dummy, i.e. change in input utilization over time, explains an important part of change in inefficiency over time.

Significance of technical inefficiency effects variables is tested for both models by Wald test and likelihood ratio test. Both test statistics for N-TIEM are larger than the critical value of $\chi^2_{31} = 44.99$. The critical value for NN-TIEM is $\chi^2_{341} = 385.062$, and it is smaller than the test statistics. Thus, null hypothesis is strongly rejected by both tests for both models. Accordingly, it can be concluded that technical inefficiency is explained by the technical inefficiency effects variables and TVDM is not an appropriate specification to measure the technical inefficiency[11].

Significance of cross terms is tested by a Wald test. Test statistic turns out to be 415.50 while the critical value is $\chi^2_{341} = 379.75$. Thus, the Wald test statistic fails to rejects the null hypothesis of insignificant cross terms.[12]

CRS is strongly rejected in N-TIEM. Sum of coefficients of inputs is 1.32 and this implies increasing returns to scale. Test statistic for CRS is 2.19 which is smaller than $\chi^2_1 = 3.94$. Thus, NN-TIEM model fails to reject CRS. Sum of coefficients of input variables is 1.12 and it is not statistically different from one.

The coefficients of input variables for N-TIEM are reported in Table 3-10. Land turns out to be the most important factor of production with an output elasticity of 0.38. Underlying reason for land being the most important input to affect the agricultural production can be insufficiency of modern infrastructure and technological progress. Accordingly, agricultural production has remained to be crucially dependant on land. Agricultural policies followed since the establishment

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[11] Estimated coefficients of TVDM are given in appendix Table A – 6 and A – 7.

[12] Estimated coefficients of NN-TIEM are given in appendix Table A - 8.

of the Republic has always considered extension of cultivated area as the most important source of agricultural output growth in Turkey (Çakmak and Akder, 1999). Governments had supported the cultivation of even marginal areas with limited potential yield.

Table 3-10: Estimated coefficients for input variables of N-TIEM

Variable	Coefficient	Standard Error
Constant X	7.92	0.10 ***
Labour	0.07	0.04
Livestock	0.05	0.01 ***
Land	0.38	0.04 ***
Seed	0.03	0.01 ***
Fertilizer	0.33	0.04 ***
Pesticides	0.15	0.02 ***
Water	0.02	0.01 ***
Diesel	0.17	0.02 ***
Electricity	0.02	0.00 ***
Other Costs	0.04	0.02 **
Animal Feed	0.07	0.01 ***
$ln\,\sigma^2$	-0.14	0.04 ***
$ln\,\gamma$	0.55	0.14 ***

***: 1% significance, **: 5% significance, *: 10% significance,

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

Coefficients of inputs are positive and statistically significant except for labor in N-TIEM model. Insignificance of labor can be explained by measurement problems described afore. Besides, many authors report insignificant coefficients of labor for various countries. To count a few, work of Xu and Jeffrey (1998) for Chinese rice production, Coelli, Rahman and Thirtle (2003) for Bangladeshi crop production, Alvarez, Arias and Greene (2004) and Alvarez and Arias (2004) for Spanish dairy production, Sharma and Leung (2000) for carp pond culture in India, Pender and Fafchamps (2001) for Ethiopian crop production, Wilson, Hadley and Asbyc (2001) for crop production of Eastern England and Syed and Sarı (2002) for Turkish agricultural sector, all report insignificant coefficients for labor. Xu and Jeffrey (1998) relate insignificance of labor to the extension in modern input usage while Coelli, Rahman and Thirtle (2003) explain the same fact with labor surplus in these economies. Syed and Sarı (2002) explain their finding by excessive usage of labor in Turkish agriculture. Both explanations are appropriate for Turkish case since descriptive statistics depicts the extension in modern input usage and the existence of excess labor in Turkish agricultural sector is a well-known fact (Çakmak *et. al.* 2004).

Land turns out to be the most important factor of production with an output elasticity of 0.38. Underlying reason for land being the most important input to affect the agricultural production can be insufficiency of modern infrastructure and technological progress. Accordingly, agricultural production has remained to be crucially dependant on land. Agricultural policies followed since the establishment of the Republic has always considered extension of cultivated area as the most important source of agricultural output growth in Turkey (Çakmak and Akder, 1999). Governments had supported the cultivation of even marginal areas with limited potential yield.

Fertilizer, diesel and pesticides follow the land as inputs with significantly higher output elasticities. This offers that fertilizer, diesel and pesticides are the most important source of increase in the yield of land. Agricultural policies followed after 1960s confirms this conclusion. After agricultural land has reached its feasible frontier in terms of area, governments had focused on increasing the yield of land by encouraging farmers to use modern inputs more extensively (Çakmak and Akder, 1999). Several input subsidy programs are held for this purpose.

Second group of inputs that are relatively more effective on agricultural output is animal feed, number of livestock and other costs that mainly consist of expenditure on fodder. Output elasticities of these inputs are much smaller than that of the land and land related inputs. This point out that dairy production does not contribute as much as vegetal production to the agricultural revenue. Besides, the output elasticity of number of livestock is smaller than that of animal feed. Therefore, one can characterize households in two groups according to livestock ownership. Households that use animal feed are likely to be more market oriented while others are likely to consider livestock holding as a kind of investment. Thus, animal feed turns out to be more important for agricultural revenue. This turns out to be rational when the insufficiency of social security network that covers the rural households is taken into account. Since most of the small farmers are left outside the social security system, they invest on livestock in order to use in “bad days”. The financial instruments can be quite problematic for households. One possible problem may be prohibition of interest bearing assets by the religion. Secondly, the financial instruments are complicated for most of the household chiefs who does not have an education further than primary school. The last but not the least, the availability of financial intermediaries is quite limited in the rural areas (Çakmak *et. al.* 2004). Lower output elasticity of other costs supports this hypothesis since fodder is the main component of other costs and it is the “cheaper” way of feeding livestock. Naturally, there is a trade of between the yield of livestock and cost of feeding. Since the households that do not care much about the amount of dairy production are also likely to use fodder instead of animal feed.

The last group of inputs that are less effective on agricultural revenue is composed of seed, water and electricity. Since money spent on seed is used as independent variable, importance of seed usage in production process can be underestimated. The seed variable does not comprise any information about seed usage in view of the fact that households are likely to use self-produced seeds, especially for cereal production where seeds are among the main inputs. Despite the underestimation problem, low output elasticity of money spent on seeds reveals and important fact. Money spent on seeds covers the cost of buying high-qualified seeds. Low output elasticity of this variable recommends that high quality seeds are not as effective as other inputs in increasing the production.

Underestimation problem also prevails in water and electricity usage that are mainly used for irrigation. There is a registration and pricing problem in irrigation from the water channels managed by the state institutions or irrigation associations. In most cases, farmers are let to use these facilities at low fees to encourage irrigation that results as the overuse of water. Similar problems also exist in electricity usage. Descriptive statistics for money spent on water and electricity and share of irrigated land substantiate these conclusions.

Table 3-11: Estimated coefficients for input variables of NN-TIEM

Variable	Coefficient	Standard Error
Constant X	8.02	0.15 ***
Labour	0.06	0.09
Livestock	0.02	0.01
Land	0.49	0.05 ***
Seed	0.05	0.02 **
Fertilizer	0.20	0.08 ***
Pesticides	0.21	0.05 ***
Water	0.04	0.01 ***
Diesel	0.06	0.05
Electricity	0.05	0.01 ***
Other Costs	-0.03	0.04
Animal Feed	0.00	0.03
ln σ^2	0.79	0.03 ***
ln γ	0.62	0.03 ***

***: 1% significance, **: 5% significance, *: 10% significance,

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

Estimated coefficients obtained by NN-TIEM for input variables are given in Table 3-11 and they do not differ much from the N-TIEM. Inputs related to livestock production along with diesel usage became statistically insignificant in NN-TIEM model. This suggests that the cross-terms explain an important part of deviation in revenue, and thus effect of livestock production and diesel usage (or machinery usage since diesel can be considered as a proxy for machinery usage as denoted afore) is region and size specific. Coefficient of other costs supports the hypothesis developed above about livestock production: Farmers who use fodder as animal feed, are not market oriented and thus marginal effect of other costs, which is mostly composed of money spent on fodder, is negative.

Coefficients of inefficiency effects variables obtained from N-TIEM are as expected and most of them are significant at conventional levels of significance. The results are given in Table 3-12.

Table 3-12: Estimated coefficients for input variables of N-TIEM

Variable	Coefficient	Standard Error
Constant Z	1.59	0.15 ***
Irrigated	-0.08	0.01 ***
Orchard	-0.06	0.01 ***
Fallow	0.05	0.01 ***
Rented	0.04	0.01 ***
Sharecropper	0.01	0.00 ***
Cereals	0.27	0.05 ***
Ind. Crops	-0.34	0.04 ***
Vegetable	-0.08	0.04 **
Fruit	-0.08	0.05 **
DIS	-0.02	0.03
Credit	-0.04	0.05
Tech. Sup.	-0.05	0.08
ASC	-0.10	0.05 *
West Marmara	-0.40	0.08 ***
Agean	-0.14	0.07 **
East Marmara	-0.27	0.08 ***
West Anatolia	0.09	0.08
Mediterranean	-0.34	0.07 ***
Central Anatolia	0.05	0.07
West Black Sea	0.05	0.07
East Black Sea	-0.14	0.09
Northeast Anatolia	0.19	0.10 *
Central East Anatolia	0.07	0.09
Illiterate	0.35	0.08 ***
Literate or Primary	0.17	0.07 **
Size 2-5 Ha.	-0.12	0.05 **
Size 5-10 Ha.	-0.23	0.07 ***
Size 10-20 Ha.	-0.40	0.09 ***
Size 20-50 Ha.	-0.54	0.11 ***
Size 50+ Ha.	-0.73	0.15 ***
Time	-0.52	0.04 ***

***: 1% significance, **: 5% significance, *: 10% significance,

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

Coefficient of share of irrigated land and orchards is negative and significant indicating a positive effect of irrigation on efficiency. This result is in line with expectations since irrigation is expected to increase the yield of land and products of orchards have higher value added. Share of fallow land is positive and significant indicating a negative effect on efficiency. This is also expected since the model considers that the alternative cost of fallow land is not cultivating some part of land and thus giving up some output. Therefore, a household that make fallow is using an input that does not increase output at least at the current production period. Coefficient of share of rented land and land taken for sharecropping in the total cultivated area and land taken for sharecropping is positive and significant indicating a negative effect on efficiency. This relationship can be explained by duration of contracts. In most instances, these contracts are short-term contracts. Thus, renter or sharecropper is likely to prefer to increase the short-term output at the cost of future output when there is a trade-off. Such a trade-off is exists if efficiency improving investments that will be effective in the long run, are had to be made in the short run.

Coefficients of dummy variables which designate the dominant products of the farm households are all in expected signs and significant at the conventional levels of significance. Being a producer of cereals affects efficiency negatively. This is not surprising especially under the production technology prevailing in Turkey. Another possible explanation can be made by considering the long lasting distortions of price support policies that has weaken the sensitivity of producers to market signals. Hence, efficiency has not been a criterion for survival of cereal producers and all kinds of investments both on physical capital and technological progress are ignored for a long time. Reforms made by ARIP turn out to be ineffective in increasing the efficiency of cereal producers.

Being a producer of other product groups effects efficiency positively. Effects of vegetable and fruit production are close to each other while the effect of industrial crops is considerably higher.

Coefficients of DIS receiving status, credit access and technical support receiving status are negative but insignificant. Insignificance of these variables offers that these factors cannot explain the variation in efficiency. Thus, it may reasonable to question the success of DIS program and quality of credit access and technical support services. The implementation period of DIS was too short (only three years) to give final verdict. Nevertheless, one would expect farmers to move closer to the efficient frontier as the distortionary price support and other production based subsidy programs are cancelled. Another factor that limited the impact of DIS is the fact that the distortionary support picked up in 2003 and 2004 (OECD, 2005), hence limiting its expected impact. Moreover, DIS program, by itself, is not designed to create any incentive for inefficient farmers to be more efficient. The program is introduced to compensate the revenue losses of farmers due to the cancelled subsidy programs. So any efficiency improvements that occurred because of ARIP cannot be observed in the coefficient of DIS variable. Insignificance of effect of DIS variable on efficiency depicts that households who received support did not or could not use this money to improve their efficiency, or they used it for this purpose but its effects cannot be observed yet. Both are possible when the irregularities and delays in payments are taken into account. Farmers cannot finance their investments, especially the long-term investments that are likely to be more effective on efficiency, by relying on frequently delayed DIS payments.

Coefficient of being a member of agricultural sales cooperative unions (ASCUs) is negative and significant at 10 percent level. This is something expected since members of ASCUs are still likely to have a better access to the market even during the restructuring period of the ASCUs.

Region dummies compare the effect of being at the designated region compared to being in Southeast Anatolia. Thus, smaller coefficients imply a better effect on efficiency weighed against the effect of being in Southeast Anatolia. In line with expectations, being in the western and southern parts of the country has a significant and positive effect on efficiency. The coefficients of other regions are insignificant suggesting that effect of being in these regions is not statistically different from being in Southeast Anatolia.

Coefficients of education level variables compare the effect of being illiterate and being literate or having a primary school degree with that of having a degree higher than primary school. Both coefficients are significant and positive indicating a negative effect on efficiency. As education level falls efficiency gets worse off.

Coefficients of size dummies compare the effect of corresponding farm size with that of 0-2 Hectares size group. Coefficients depicts that the efficiency of household increases as their farm size grows. This is consistent with the test results that depict increasing returns to scale on the efficient frontier.

Lastly, the time dummy recommends that the efficiency has increased over time. Although time dimension of data is small, this can be taken as implication of positive effect of ARIP and macroeconomic stability that persist since 2002.

Table 3-13: Estimated coefficients for technical inefficiency effects variables of NN-TIEM

Variable	Coefficient	Standard Error
Constant Z	2.07	0.17 ***
Irrigated	-0.06	0.05
Orchard	-0.15	0.06 **
Fallow	0.03	0.03
Rented	0.13	0.04 ***
Sharecropper	-0.01	0.01
Cereals	-0.37	0.21 *
Ind. Crops	-0.32	0.17 *
Vegetable	-0.53	0.19 ***
Fruit	0.12	0.22
DIS	-0.03	0.14
Credit	0.38	0.23 *
Tech. Sup.	-0.55	0.41
ASC	-0.62	0.25 **
West Marmara	-0.76	0.32 **
Agean	-0.44	0.28
East Marmara	0.36	0.35
West Anatolia	-0.75	0.31 **
Mediterranean	-0.73	0.29 **
Central Anatolia	-0.79	0.30 ***
West Black Sea	-0.19	0.28
East Black Sea	0.27	0.34
Northeast Anatolia	-0.41	0.38
Central East Anatolia	0.19	0.39
Illiterate	0.54	0.28 *
Literate or Primary	0.59	0.26 **
Size 2-5 Ha.	-0.26	0.21
Size 5-10 Ha.	0.17	0.35
Size 10-20 Ha.	0.02	0.51
Size 20-50 Ha.	0.02	0.66
Size 50+ Ha.	-1.91	0.99 *
Time	-0.29	0.14 **

***: 1% significance, **: 5% significance, *: 10% significance,

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

Coefficients of technical inefficiency effects variables are depicted in Table 3-13. There is a significant difference between N-TIEM and NN-TIEM estimates of these coefficients. This implies input usage is not neutral to technical inefficiency effects variables and the interaction between inputs and these variables explains the deviation in efficiency. NN-TIEM model takes into account the use of inputs according to the technical inefficiency variables in estimating the efficient frontier. Thus, it compares the input utilization among the households that are in the same group defined by technical inefficiency variables. Coefficients of cross-terms of inputs and dummy variables represent the ability of the corresponding household to utilize the corresponding input compared to the other households.

The most important difference stems from the regional and size dummies. NN-TIEM model favors central and western parts or the country with regard to efficiency. Thus, households in central parts of the country are closer to efficient frontier estimated by NN-TIEM, compared to households in southern parts that were found to be more efficient by N-TIEM. This result offers that households in the southern parts of the country operate less efficiently when the in-group input utilization is taken into account.

Secondly, the size variables, except the 50+ Hectares group, are found to be insignificant in NN-TIEM model. Thus, we can conclude that, input utilization of households in these size groups is not significantly lower than 0-2 Hectares group. Similar arguments are also valid for share of irrigated land, membership of ASCUs and education level.

Interaction between input variables and technical inefficiency effects variables can be analyzed by using the results of NN-TIEM. A positive and significant interaction between an input and technical inefficiency variable implies that corresponding input increases the marginal effect of technical inefficiency variable on efficiency; either the marginal effect of technical efficiency variable on efficiency is positive or negative. A negative and significant interaction, on the other hand, implies that increase in the employment of the corresponding input decreases the marginal effect of technical inefficiency effects variable on efficiency either the relationship between technical inefficiency and the corresponding factor is positive or negative.

A last point to be mentioned about the results of NN-TIEM is the change in the sign of effect of being a cereal producer. NN-TIEM depicts that, being cereal producer effects efficiency positively. This difference implies that within-group utilization of inputs explains the inefficiency of most of the cereal producers.

The significant interactions obtained from NN-TIEM are given in Table 3-14. First column designates the effect of corresponding technical inefficiency variable on efficiency. The magnitudes of significant interactions can be found in appendix Table A – 10.

Interaction of labor with technical inefficiency variables yields important information. A negative interaction applies to excessive employment of labor. On the other hand, a positive interaction implies looser constraint than that of the other inputs. According to this conclusion there turns out to be excess labor employment in fruit production and industrial crops production. Members of ASCUs also use excess labor compared to the other households. In addition, households in 5-10 Hectares size group also have excess labor, indicating a concentration of labor in this size group.

Significant interactions of livestock with technical inefficiency effects variables are all positive, indicating that marginal effect of these variables increase as the number of livestock increases. Results depict that livestock production increases efficiency in central and western parts of the country. Besides, having livestock increases the effect of cereal production on efficiency and this suggests that there are positive externalities between livestock holding and cereal production. The significant interactions of other inputs related to livestock production with technical inefficiency variables are also positive with the exception of medium size farms.

Table 3-14: Interactions between inputs and technical inefficiency variables

		Interaction										
		Lab.	Livst.	Land	Seed	Fert.	Pest.	Water	Diesel	Electr.	Other	Feed
Irrigated							Dec.	Inc.	Inc.	Dec.		Inc.
Orchard	Pos.	Dec.		Dec.							Dec.	
Fallow						Dec.		Inc.				Inc.
Rented	Neg.	Inc.								Inc.	Inc.	
Sharecropper		Inc.					Dec.					
Cereals	Pos.		Inc.				Dec.			Inc.		
Ind. Crops	Pos.	Dec.						Inc.				
Vegetable	Pos.	Inc.								Dec.		
Fruit				Dec.			Inc.					
DIS											Inc.	
Credit	Neg.											
Tech. Sup.		Inc.										
ASC	Pos.	Dec.		Dec.						Dec.	Inc.	
West Marmara	Pos.		Inc.					Dec.			Inc.	Inc.
Agean			Inc.					Inc.				Inc.
East Marmara						Dec.			Inc.			Inc.
West Anatolia	Pos.			Dec.					Inc.	Dec.		Inc.
Mediterranean	Pos.			Dec.					Inc.			
Central Anatolia	Pos.		Inc.	Dec.					Inc.			Inc.
West Black Sea				Dec.				Inc.	Inc.			
East Black Sea				Dec.					Inc.			
Northeast Anatolia		Inc.		Dec.							Inc.	
Central East Anatolia			Inc.									
Illiterate	Neg.	Inc.	Inc.									
Literate or Primary	Neg.								Dec.	Dec.		
Size 2-5 Ha.								Dec.	Dec.			
Size 5-10 Ha.		Dec.					Inc.	Dec.	Inc.			Dec.
Size 10-20 Ha.							Inc.		Inc.			Dec.
Size 20-50 Ha.						Inc.	Inc.	Dec.	Inc.			
Size 50+ Ha.	Pos.			Inc.				Dec.				Dec.
Time	Pos.	Dec.				Inc.		Dec.	Inc.			Inc.

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

Interactions of land with technical inefficiency effects variables are all negative. Land decreases the effects of regional dummies on efficiency except for East Marmara and Central East Anatolia. Thus, one can conclude that there is an excess land usage in all regions excluding these two regions. Moreover, land increases the effect of being in 50+ Hectares size group on efficiency. This is something expected since this size group is likely to have relatively looser constraints for the other inputs.

Interaction between share of irrigated land and electricity reveals an important fact about irrigation methods. Irrigation by electrical pumps turns out to be less efficiency enhancing. The positive interaction between water and irrigated land justifies this conclusion. Money paid on water covers the expenditures of households for using the water that is brought to the field by irrigation facilities. A positive interaction between this cost and share of irrigated land implies that this kind of irrigation increases the marginal effect of share of irrigated land on efficiency.

Money spent on water negatively affects the efficiencies of all household groups compared to less than 2 Hectares group. This can be explained by the greenhouse producers most of which are in less than 2 Hectares group and spend relatively higher amounts of money on irrigation. Since greenhouse producers are better integrated to markets, they operate more efficiently and hence the effect of water usage on efficiency become negative for the other households that are compared with them.

Interactions of diesel are positive except the education level dummy for literate and primary school graduates and 2-5 Hectares size group. This is inline with the anticipation of mechanization to increase the efficiency. The negative interaction with smaller size groups, on the hand, can be explained by non-optimal use of extensive machinery in small-scale production.

To sum up, estimated frontier reflects the many characteristics of agricultural production in Turkey. The output elasticities of input variables reflect a conventional production function in which land and the inputs that are used to enhance the yield of land play a major role. The coefficients of technical inefficiency effects variables are in line with expectations and justify most of the conventional standpoints. The interactions between inputs and technical inefficiency effects variables on the other and reveal some important facts such as the efficiency impeding effect of irrigation by electrical pumps or low quality of technical support or significance of livestock production for the efficiency of different household groups.

3.2.2.2 Estimated Efficiency Scores

Descriptive statistics for estimated efficiency scores for NUTS II regions obtained by N-TIEM and NN-TIEM are given in Table 3-15. The efficiency scores of TVDM model can be found in the appendix, Table A–11. Comparison of mean efficiencies estimated by TVDM and N-TIEM depicts at the first glance that

Table 3-15: Mean efficiency scores for N-TIEM and NN- TIEM

N-TIEM	HH	Rank		Average		Std. Dev.		Max		Min		Geometric Mean	
	Number	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004
West Marmara	365	1	2	37.95	50.64	16.31	16.07	89.13	87.27	5.56	8.69	34.06	47.56
Agean	505	2	5	34.81	45.46	17.87	16.97	80.74	82.37	1.39	2.88	29.69	41.54
East Marmara	272	5	1	32.37	52.49	16.88	18.25	76.23	79.67	3.68	6.03	27.58	48.22
West Anatolia	179	8	8	24.01	33.38	13.37	16.30	67.31	68.02	2.56	4.72	20.28	29.19
Mediterranean	357	4	4	34.12	46.88	18.50	18.96	84.44	85.68	1.45	6.03	28.43	42.18
Central Anatolia	238	10	9	22.61	32.89	13.33	15.23	77.68	79.48	1.09	4.19	18.87	28.93
West Black Sea	363	9	6	23.48	34.42	12.86	14.99	62.34	82.20	2.53	4.54	20.00	30.95
East Black Sea	336	3	3	33.47	46.56	14.26	16.59	81.65	85.81	1.92	5.67	29.91	42.83
Northeast Anatolia	75	11	7	19.86	33.72	10.10	16.55	45.08	72.23	3.15	7.99	17.28	29.63
Central East Anatolia	94	7	11	24.60	32.67	13.12	17.13	67.06	71.08	4.85	4.93	21.34	27.95
Southeast Anatolia	230	6	10	27.45	33.26	16.19	17.23	78.55	79.32	3.71	5.98	23.04	28.76
Turkey	3014	-	-	30.52	42.35	16.64	18.33	89.13	87.27	1.09	2.88	25.72	37.64

NN-TIEM	HH	Rank		Average		Std. Dev.		Max		Min		Geometric Mean	
	Number	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004
West Marmara	365	1	2	43.87	57.98	19.29	19.04	89.70	87.60	5.63	8.13	38.71	53.74
Agean	505	2	3	36.36	49.70	19.35	19.02	82.77	86.42	1.09	1.73	30.55	44.70
East Marmara	272	3	1	36.07	58.85	20.05	20.62	83.39	87.63	3.17	5.44	29.60	53.29
West Anatolia	179	9	7	25.06	36.74	15.94	18.17	77.73	77.57	2.61	4.85	20.15	31.33
Mediterranean	357	4	5	35.84	46.87	19.63	20.17	86.01	86.80	0.45	4.96	29.20	41.34
Central Anatolia	238	10	9	24.68	35.62	15.76	17.35	86.33	83.03	0.77	4.08	20.09	30.87
West Black Sea	363	8	8	26.04	36.54	14.74	16.47	74.46	85.71	3.25	3.55	21.87	32.47
East Black Sea	336	5	4	35.55	48.80	16.65	19.28	83.08	84.94	1.28	3.22	31.03	43.81
Northeast Anatolia	75	11	6	21.66	37.74	12.89	21.19	57.61	87.99	3.10	5.50	18.02	31.31
Central East Anatolia	94	7	10	26.25	34.56	14.93	21.04	72.89	81.55	5.45	5.66	22.24	28.02
Southeast Anatolia	230	6	11	26.96	32.38	17.36	18.82	81.11	81.44	3.57	5.62	21.96	27.08
Turkey	3014	-	-	32.86	45.53	18.86	20.95	89.70	87.99	0.45	1.73	26.98	39.49

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

introduction of technical efficiency variables change the mean efficiencies significantly, while cross-terms have limited impact on the efficiency, but they change the ranking of regions. This justifies our conclusion about the significance of technical efficiency variables in explaining the efficiency of households. The comparison of mean efficiencies obtained from N-TIEM and NN-TIEM shows that incorporation of cross terms into analysis does not change the mean efficiency considerably but it affects the ranking of regions.

There is a significant increase in the efficiencies from 2002 to 2004. This increase offers an increased integration of households to market. The increase is highest in western and southeastern parts of the country. East Marmara leads the increase with 22.78 percent. It is followed by Northeast Anatolia with 16.09 percent, West Marmara with 14.11 percent, Aegean with 13.34 percent and East Black Sea with 13.25 percent. Increase in the central parts of the country is around 10 percent while it is lowest with 8.31 percent in Central East and 5.42 percent in Southeast Anatolia.

Comparison of increase in efficiency with the increase in agricultural revenue reveals an interesting fact. The increase in agricultural revenue has been well above for all regions except Southeast Anatolia. Table 3-16 compares the increase in agricultural revenue with increase in efficiency.

Table 3-16: Change in efficiency and agricultural revenue

Region	Efficiency	Revenue	Difference
West Marmara	14.11	15.61	1.50
Agean	13.34	22.18	8.84
East Marmara	22.78	82.09	59.31
West Anatolia	11.68	50.64	38.96
Mediterranean	11.03	41.90	30.87
Central Anatolia	10.94	43.98	33.04
West Black Sea	10.49	26.70	16.20
East Black Sea	13.25	33.23	19.98
Northeast Anatolia	16.09	89.86	73.78
Central East Anatolia	8.31	12.17	3.86
Southeast Anatolia	5.42	0.22	-5.20
Turkey	12.68	32.80	20.12

Source: Author’s calculations from G.G. *et. al.* (2003 and 2005)

As can be seen from Table 3-16, increase in agricultural revenue is quite higher than the increase in efficiency for most regions. Efficiency scores denote the ability of households to transform their inputs to revenue. However, increase in revenue cannot be explained by increase in the households' ability to transform inputs to revenue. Thus, it can be concluded that agricultural revenue is mostly determined by factors that are independent of production. This can be interpreted as a sign of disunity of agricultural production and market. According to Table 3-16, this disunity is higher in Northeast Anatolia and central western parts of the country.

Table 3-15 further depicts that agricultural production in the western parts of the country is more efficient. Ranking of regions changes from 2002 to 2004. West Marmara, Aegean and East Marmara regions are in the first three ranks in both in 2002 and 2004. Mediterranean and East Black Sea regions share the 4th and 5th place in both years. Ranking of regions in central parts of the country, namely West, Central, Central East Anatolia and West Black Sea also did not change significantly. However, there has been a significant change in the ranking of Northeast and Southeast Anatolia. Northeast Anatolia has soared to sixth position from 11, and Southeast Anatolia has felt to 11 in 2004 while it was 6th in 2002. This drastic change can be explained by increasing protection in meat that is the main product of Northeast Anatolia, as suggested by descriptive statistics of number of livestock. On the other hand, the plummet of Southeast Anatolia is probably due to the rigidity of the region to the changes in the macro and agricultural policy environment.

Standard deviation of the efficiency for the whole sample is around 18-20 percent. Standard deviation is higher in western regions while it increases significantly in eastern parts of the country from 2002 to 2004. Increase is highest in Northeast and Central East Anatolia. Standard deviation in central parts of the country is lower in both periods. The comparison of standard deviations for TVDM, N-TIEM and NN-TIEM depicts that it is found to be higher in NN-TIEM model while it is lowest in TVDM. This implies that introduction of technical inefficiency variables and cross-terms increase the variation in estimated

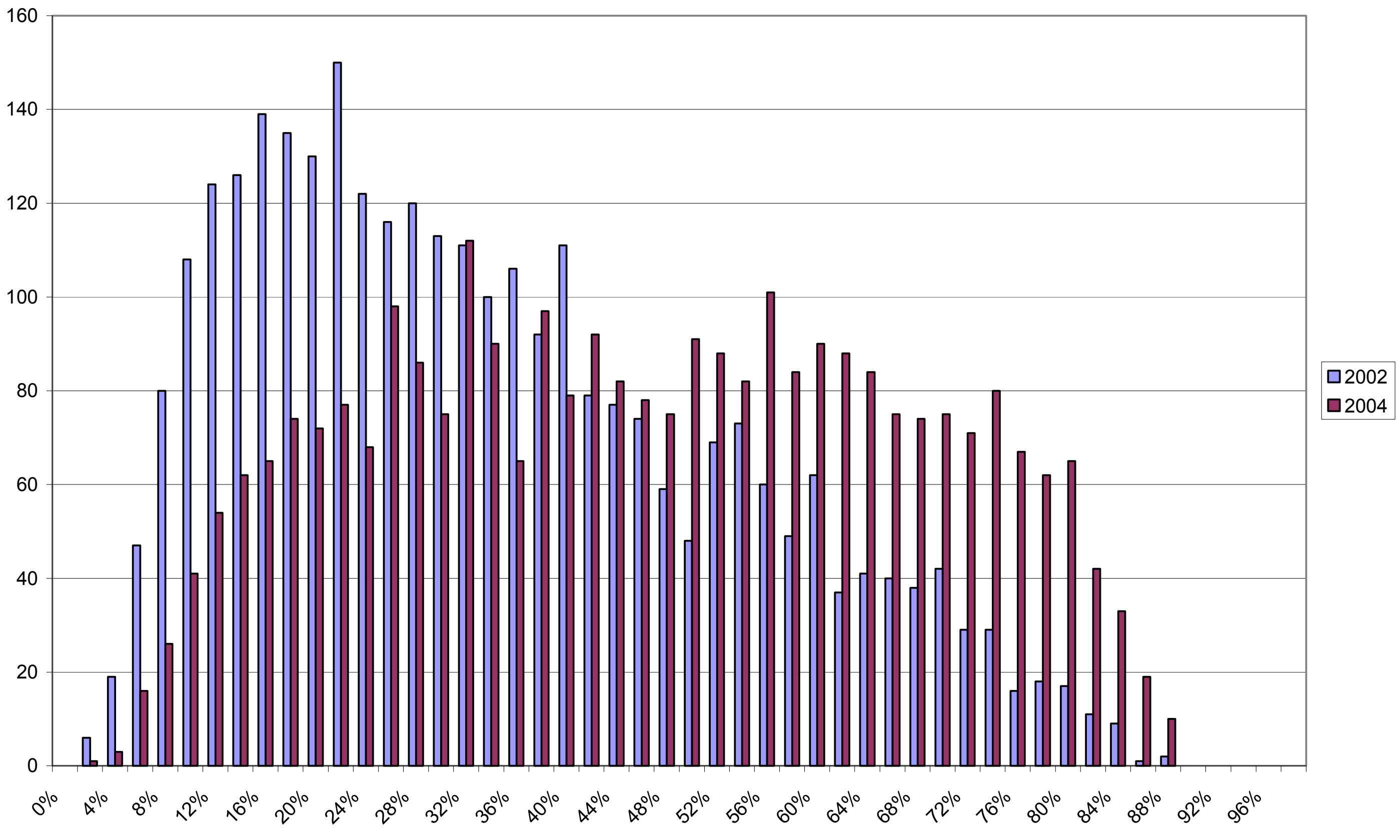

Figure 3-5: Histogram of Efficiency Scores for the whole sample

Source: Author’s calculations from G.G. *et. al.* (2003 and 2005)

efficiency scores. Geometric mean of the efficiency scores also depicts this fact. The ranking of regions based on geometric mean is slightly different from the ranking based on arithmetic mean. East Black Sea turns out to be more efficient by standing in the second position according to geometric mean compared to the fifth according to arithmetic mean. Changes in rankings from 2002 to 2004 are relatively smoother for geometric mean of efficiency. This implies that the distribution of efficiency scores between zero and one is not even. Efficiency is concentrated in relatively lower values for East Black Sea and Central East Anatolia in 2002 and for West Black Sea in 2004, while concentration is in relatively higher values for Northeast Anatolia in 2004.

Overall distribution of efficiency scores is shown as a histogram in **Figure 3-5**. Kurtosis of histogram is -1.3 and -0.8 for 2002 and 2004, respectively. This denotes a rather flatter distribution for 2004. On the other hand, skewness is 0.24 and -0.7 respectively for 2002 and 2004 denoting a rather slanted distribution in 2002.

Mean efficiencies for several groups of households defined by technical inefficiency effects variables are given in Table 3-17. These figures justify our findings and comments on the coefficients of technical inefficiency variables. However, there are some important conclusions that could not have been reached by merely considering the coefficients. First of all, although the coefficients of DIS recipients, credit access, taking technical support and ASCU membership status were found to be ineffective on efficiency, one can observe that households that receive credit, take technical support or are ASCU members are considerably more efficient. Households that receive DIS are also more efficient even if the difference is not that noteworthy. Moreover, the gap between DIS receivers and the others has increased from 2002 to 2004. Table 3-18 compares the mean efficiencies of DIS receivers that are in different land size groups.

Table 3-17: Mean efficiencies for groups of households defined by technical inefficiency variables

Producer Type		2002		2004	
		Mean	Std Dev	Mean	Std Dev
Cereal	~Produce	39.62	18.74	53.91	20.03
	Produce	30.81	18.42	43.55	20.68
Industrial Crops	~Produce	27.24	16.64	39.84	20.44
	Produce	39.63	19.17	53.12	19.15
Vegetable	~Produce	32.51	18.70	45.41	21.32
	Produce	34.77	19.66	45.94	19.70
Fruit	~Produce	32.03	18.92	43.87	20.89
	Produce	35.40	18.47	50.40	20.37
DIS	~Receive	32.13	19.03	43.24	20.85
	Receive	33.40	18.73	46.25	20.94
Credit Access	~Have	32.00	18.47	44.21	20.77
	Have	39.66	20.55	52.40	20.58
Technical Support	~Take	32.36	18.57	45.26	20.83
	Take	42.45	21.82	55.02	23.04
ASC	~Member	30.55	17.78	43.67	20.48
	Member	44.42	19.89	57.42	20.06
Education	Illiterate	26.44	16.50	37.76	20.52
	Primary	33.66	18.83	46.66	20.63
	Higher	42.32	20.33	54.09	19.90
Size	0-2 Ha.	33.10	18.92	45.05	20.70
	2-5 Ha.	31.27	17.36	42.92	20.54
	5-10 Ha.	32.24	18.39	45.87	20.55
	10-20 Ha.	32.47	19.42	47.07	21.50
	20-50 Ha.	36.44	20.54	47.79	21.28
	50+ Ha.	37.66	21.54	52.78	21.84

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

Two results in the table are worth highlighting. Households that did not received DIS payments in less than 2 Hectares group are more efficient than the ones that received DIS payments, in 2002. Note that difference is greater than the sample average. Secondly, households that received DIS in the 20-50 Hectares group are drastically more efficient than those that did not receive DIS. The situation is reversed in 2004. DIS receivers of 20-50 Hectares group turn out to be less efficient, while less than 2 Hectares group became more efficient. The percentage of households that received DIS in each group explains these findings. Percentage of households that receive DIS increases by farm size. It is the highest for 20-50 Hectares group in 2002, while the gap is moderately closed in 2004. Share of households that received DIS is lowest in less than 2 Hectares group in both periods. Thus even if DIS receiving has a positive effect on efficiency, it is hard to observe this effect from mean efficiency of size groups.

Table 3-18: Mean efficiencies of DIS receivers and others according to farm size

2002					
Size	% of DIS Receivers	Efficiency of HH not Receiving DIS		Efficiency of HH Receiving DIS	
		Mean	Std Dev	Mean	Std Dev
0-2 Ha.	33.59	33.77	19.75	31.77	17.12
2-5 Ha.	54.70	31.00	17.90	31.50	16.91
5-10 Ha.	62.93	31.16	18.21	32.88	18.49
10-20 Ha.	66.24	31.74	19.56	32.85	19.37
20-50 Ha.	67.87	32.13	20.66	38.48	20.21
50+ Ha.	77.19	37.82	20.53	37.61	21.94

2004					
Size	% of DIS Receivers	Efficiency of HH not Receiving DIS		Efficiency of HH Receiving DIS	
		Mean	Std Dev	Mean	Std Dev
0-2 Ha.	53.69	44.90	20.77	45.18	20.67
2-5 Ha.	73.85	41.55	20.61	43.41	20.51
5-10 Ha.	83.28	40.35	18.92	46.98	20.71
10-20 Ha.	86.43	41.86	22.98	47.89	21.16
20-50 Ha.	88.61	52.36	20.15	47.20	21.39
50+ Ha.	86.60	44.14	26.17	54.12	20.95

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

Another interesting statistics is obtained by the comparison of DIS receivers that produces different product types. Table 3-19 depicts this information. Share of cereal producers that receive DIS are notably low while the efficiency of cereal producers are significantly higher than the other groups with lower standard deviations. The lowest efficiency score belongs to industrial crop producers. It is worth mentioning the fact that industrial crop production covers items such as tobacco, sugar beets and cotton, which are heavily subsidized for a long period. The figures suggest that distortion subsidization programs have prevented industrial crop producers to operate under more market friendly environment.

Table 3-19: Mean efficiencies of DIS receivers and others according to product type

2002						
Product Type	Production Status	% of DIS Receivers	Efficiency of Others		Efficiency of DIS Receivers	
			Mean	Std Dev	Mean	Std Dev
Cereal	Produces	43.78	38.89	19.22	40.57	18.08
	Not produces	61.51	29.15	18.17	31.86	18.51
Ind. Crop	Produces	56.67	27.18	17.26	27.29	16.16
	Not produces	58.27	38.32	19.35	40.56	19.00
Vegetable	Produces	57.84	31.72	18.72	33.09	18.67
	Not produces	54.92	34.25	20.49	35.20	18.98
Fruit	Produces	57.61	31.16	19.04	32.66	18.81
	Not produces	56.76	35.04	18.72	35.68	18.29

2004						
Product Type	Production Status	% of DIS Receivers	Efficiency of Others		Efficiency of DIS	
			Mean	Std Dev	Mean	Std Dev
Cereal	Produces	59.69	51.69	20.84	55.40	19.36
	Not produces	80.09	39.18	19.63	44.63	20.79
Ind. Crop	Produces	74.85	38.86	20.45	40.17	20.43
	Not produces	77.94	49.91	19.70	54.03	18.91
Vegetable	Produces	76.79	43.54	21.44	45.98	21.25
	Not produces	74.14	42.34	19.04	47.20	19.79
Fruit	Produces	75.68	41.87	21.00	44.51	20.82
	Not produces	77.63	47.59	19.81	51.20	20.47

Source: Author's calculations from G.G. *et. al.* (2003 and 2005)

To sum up our main findings, the efficiency levels put forward an important integration problem across the country. The problem is more serious in the Eastern parts of the country. Besides, the gap between east and west works out to be increasing.

Secondly, sectors that have been subsidized historically by distortionary measures turn out to be inefficient. There seems to be slight but inadequate adjustments after the implementation of ARIP, especially when one considers the necessity, exigency and urgency of transformation in agricultural sector in the context of EU accession negotiations and Millennium Round of the WTO Negotiations.

The problems in the implementation of ARIP are reflected in results. First of all, ARIP could not reach small farmers and cereal producers, if DIS receiving are taken as an indicator of this. A drastically small percentage of small farmers are enrolled in DIS program compared the other farm groups. Secondly, the least developed parts of the country also cannot enjoy the benefits of ARIP sufficiently. Although DIS is revealed as being a better way of subsidizing farmers, it needs to be developed to reach the poorer farmers.

Although outcomes of N-TIEM model support the need to increase the average farm size, the results of NN-TIEM model, which suggests that 2-5 Hectares size group is more efficient than the mid-sized farms, should be kept in mind. Besides, average farm size does not look like an urgent and serious problem for agricultural production.

The positive effect of irrigation on efficiency is another important conclusion derived from out analysis. However, we found that using electricity for irrigation hinders the effect of irrigation. Thus, canal irrigation increases the efficiency of irrigation.

Our findings supports that there is an excess employment of labor in agriculture. This is not surprising for a country where 33 percent of the employed labor force is in the agricultural sector in 2004. It is obvious that this situation cannot be sustained especially under the increased competition that will be imposed by multilateral agreements and EU accession in future. However as interactions of labor with technical inefficiency variables offers, rather than trying to “exile” people from agriculture, introducing policies that will create incentives for labor to move to the more efficient areas inside the agricultural sector would be both less costly and more productive.

A similar argument is also valid for land. Land is found to hinder the positive effects of most of the technical inefficiency variables on efficiency. The problem with land can be more challenging since it cannot be moved to the more efficient areas. The solution is likely to lie in making long term investments, to increase the quality of the land which will diminish the climate dependency of the crop production.

Modern inputs are found to be dominating the production process. In addition, this had been encouraged by governments in the past, especially by distorting the prices paid by the farmers. However, this can create serious environmental problems in the future. Although our analysis cannot exactly identify the magnitude of the problem, negative interactions of pesticides and fertilizers suggest that excessive use of these inputs may not only harm the environment, but also affects the productivity of the basic factors of production.

CHAPTER 4

CONCLUSION

Probably the most challenging problems of agriculture stems from the production and marketing side. The main findings outlined in Chapter III justify the fact that production side problems are profound structural problems. Mean efficiency of producers is quite low for both 2002 and 2004. This inefficiency is explained significantly by variables that describe the structure of agricultural production. Thus, increasing efficiency of production is not an easy task. Firstly the factors that effect efficiency have a complicated pattern. Any reform program that aim to change the structure should be designed to address the issues arising from this complex system.

The main conclusion revealed by this study is that for all practical purposes there has been an increase in the efficiency levels of producers through out the country from 2002 to 2004. That is to say, the producers' ability to generate revenue from inputs by production and marketing has increased. This implies a better integration of producers to the markets. This process should be encouraged by appropriate policies. Along with the increase in efficiency there is a considerable variation among efficiency levels of producers. The efficiency gap between Western and Eastern parts of the country turns out to be increasing. This finding suggests a differential treatment of agricultural policies for different regions.

The parameters of efficient frontier suggest that agricultural production is crucially dependant on land. First implication of this finding is that, any policies to improve the efficiency of production should put a special emphasis on land as a production factor. There is an illusion about the quality of Turkish agricultural land. It is believed that land on average is in quite low quality basically due to climatic conditions prevailing in the major regions of the country. This conclusion stems from the international comparisons of partial efficiency measures, especially yields, of Turkey usually with EU averages. First of all, it should be understood that although the maximum natural yields are determined by the land quality and climate conditions, yields may increase by changing the production technology and the amount of other inputs. The analysis related to fertilizers, irrigation and pesticides suggests that quality of land has a material effect on the efficiency of production, together with land. Thus, low average yields are not the "destiny" of Turkish farmer, but a consequence of rather arcane production techniques. The results depicted in this thesis clearly state that with the current state of production technology it is not possible to increase output without increasing cultivated land. For all practical purposes, output elasticity of land is quite high compared to other inputs. However, the interaction of land with the factors affecting the efficiency shows that there is already an excess employment of land. This implies that efficiency of production can be increased only if the efficiency of land use is increased.

The size of rural population has been a hot topic of discussion especially in the context of EU accession. The high share of rural population in total is put forward as a sing of underdevelopment. Some people argued that, Turkey cannot be a member as long as 35 percent of her population remains to be dependent mainly on agricultural production. An illusion has emerged during the discussions. People started to even spell out single digit rural population shares as a criterion for the accession to the EU. Some have even started to talk about "rehabilitating and transferring the rural population to other sectors". Yet, arguments that are more realistic stated that Turkey could not integrate to the CAP with 35 percent rural population since an enormous amount of funds will have to be transferred to these people from agricultural budget of EU. It is argued that to avoid this "danger" EU will not give any financial support to Turkish agriculture. On the other hand, those who do not consider the situation in the context of EU have stated that high rural population is supported by the consumers and taxpayers via subsidies. In short, rural population problem has been very popular in recent years and everybody seems to agree on the necessity to decrease the rural population for one reason or the other.

The most important deficiency of the arguments above is that they do not say any word about economic role of the rural population: Agricultural labor. The arguments stated in the previous paragraph consider rural population as a sign or reason of underdevelopment but not as a production factor. Our findings about labor support the conclusion of these arguments, though, due to very different reasons and under completely different motives. Labor is found to be statistically insignificant contributor to efficiency. Further, it is found to have an efficiency deteriorating effect on many factors. It should be noted that this approach is very different from the arguments listed above. Once this policy is designed on the grounds of efficiency improvement, the problem becomes decreasing the size of rural population that is employed in agricultural production rather than decreasing the rural population itself. Unpaid family labor constitutes an important account of labor employed in agriculture. Thus, policies to create alternative job opportunities in rural areas are both necessary and sufficient to solve the problem. Though, carrying people from rural areas to urban centers seems to be easier, its costs to the whole economy are likely to be more than its benefits. Thus, policymakers should undertake this challenging task without losing time, since such a restructuring will require a prominent effort and time.

Another important finding is that, livestock production is a "secondary" source of agricultural revenue. Contribution of livestock holding on agricultural revenue is not as much as crop production. However, livestock production increases the effect of most of the factors that promote efficiency. Findings about animal feed and fodder justify the fact that market oriented livestock production increases the effect of several factors on efficiency. Creating appropriate incentives to organize livestock and diary production in a market oriented direction works out to be an efficiency improving policy. Further, although livestock production is sustainable as a secondary revenue source under high protection for meat and diary products, livestock production may decrease drastically in the absence of an efficient organization of livestock production as market access increases through the multilateral liberalization and most important of all with the EU accession.

Employing modern technologies in agricultural production is generally achieved by giving technical support to farmers. However, technical support is found to be immaterial for efficiency. The only possible explanation of this is the low quality of technical support. Thus, institutions that provide technical support to farmers should be reorganized to sustain the quality and availability. ASCUs can be considered as an alternative to the state institutions to provide more effective technical support. Even though the ASCUs went through a restructuring process and deprived from most of the budgetary transfers in the pre-reform era by ARIP, being a member of ASCUs is still found to have a positive effect on efficiency. This shows that affiliation with ASCUs promotes efficiency. This affirmative relationship can be reinforced by equipping ASCUs with proper devices to provide more technical support to farmers and by encouraging farmers to affiliate ASCUs.

To sum up, problems arising from the production side of agriculture are though, and they work out to be the underlying reason of issues that are discussed publicly. Designing ultimate solutions is beyond the scope of this work and probably any single work. Turkish agriculture is in the eve of an inevitable transformation. Most important challenge that awaits the policymakers is that they need to move the economy closer to the production possibility frontier. Economic agents that are more or less enrolled in agriculture are likely to resist this change until the current situation become undesirable for them. However, Turkey may not have enough time to wait for a general consensus to transform the agriculture. Two important factors, namely expansion of market access by the forthcoming WTO-Agreement on Agriculture and EU accession, are going to be more and more effectual in the near future. If Turkey cannot start to reorganize its agriculture in line with requirements of extensive competition in the world markets, everyone related to agriculture and hence Turkey will be worse off.

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APPENDICES

APPENDIX A

Additional Topics and Tables

Cost minimization problem can be stated as;

$\min w^T x$ s.t. $y \le f(x)$ and $x \ge 0$

The lagrangian will be;

$L = w^T x + \lambda_1 (y - f(x)) - \lambda_2 x$

Then the Kuhn-Tucker necessity conditions will be;

$\frac{\partial L}{\partial x_i} = w_i - \lambda_1 \frac{\partial f(x)}{\partial x_i} - \lambda_2 = 0$ for $i = 1, \dots, n$

$\lambda_1 (y - f(x)) = 0$

$\lambda_2 x = 0$

Since $x \succ 0$ is assumed, $\lambda_2 = 0$. Thus first equation becomes;

$$L = w_i - \lambda_1 \frac{\partial f(x)}{\partial x_i} = 0$$

Then, $w_i = \lambda_1 \frac{\partial f(x)}{\partial x_i}$ for $\forall i$. Taking pair wise ratios for each input will yield;

$$\frac{w_i}{w_j} = \frac{\partial f(x) / \partial x_i}{\partial f(x) / \partial x_j}$$

The left side of this equation is the slope of isoquant, while the right side is the slope of isocost.

Table A-1 : Nuts II regions and provinces

Region	**Provinces**									
İstanbul	İstanbul									
West Marmara	Balıkesir	Çanakkale	Edirne	Kırklareli	Tekirdağ					
Aegean	Afyon	Aydın	Denizli	İzmir	Kütahya	Manisa	Muğla	Uşak		
East Marmara	Bilecik	Bolu	Bursa	Düzce	Eskişehir	Kocaeli	Sakarya	Yalova		
West Anatolia	Ankara	Karaman	Konya							
Mediterranean	Adana	Antalya	Burdur	Hatay	Isparta	K.Maraş	Mersin	Osmaniye		
Central Anatolia	Aksaray	Kayseri	Kırıkkale	Kırşehir	Nevşehir		Sivas	Yozgat	Niğde	
West Black Sea	Amasya	Bartın	Çankırı	Çorum	Karabük	Kastamonu	Samsun	Sinop	Tokat	Zonguldak
East Black Sea	Artvin	Giresun	Trabzon	Ordu	Rize	Gümüşhane				
Northeast Anatolia	Ağrı	Ardahan	Bayburt	Erzincan	Erzurum	Iğdır	Kars			
Central East Anatolia	Bingöl	Bitlis	Elazığ	Hakkari	Malatya	Muş	Tunceli	Van		
Southeast Anatolia	Adıyaman	Batman	Diyarbakır	Gaziantep	Kilis	Mardin	Siirt	Şanlıurfa		Şırnak

Source: SIS (2005a)

Table A-2: Standard deviations of input variables

	Regions	Numb. Of HHs	agr_inc	sub	lab	lvst	land	seed	fert	pest	water	dies	elec	other	feed
2002	West Marmara	365	10913	1200	75	3.90	15.68	564	1610	457	217	1820	273	1778	2161
	Agean	505	7628	508	142	3.01	14.98	334	1066	786	442	1454	396	1683	1630
	East Marmara	272	6287	843	98	4.98	15.79	702	871	513	444	2434	628	1800	1592
	West Anatolia	179	4582	1774	176	2.68	19.74	728	1440	274	952	1966	935	1089	1173
	Mediterranean	357	9383	1131	174	2.41	20.57	4528	3134	2242	1094	2891	315	1309	955
	Central Anatolia	238	5571	1303	42	3.56	32.51	435	3817	531	228	1756	427	1076	1004
	West Black Sea	363	3473	562	114	2.97	7.07	860	924	399	243	1324	104	733	652
	East Black Sea	336	2091	519	62	2.04	20.64	311	1107	276	82	281	77	360	1127
	Northeast Anatolia	75	3584	1320	37	4.69	24.88	450	971	5538	373	1439	65	1124	707
	Central East Anatolia	94	3281	4742	61	4.57	17.02	264	446	77	69	699	70	582	450
	Southeast Anatolia	230	9394	1120	127	2.64	25.10	1645	1695	1455	507	1276	936	1410	546
	Turkey	3014	7302	1312	122	3.39	20.09	1722	1908	1329	546	1834	470	1360	1342
2004	West Marmara	365	7432	1544	125	4.10	16.15	383	2973	1959	341	1754	306	2125	1963
	Agean	505	7075	679	148	2.69	7.63	457	1639	2837	1041	1745	665	2539	1181
	East Marmara	272	8300	1413	95	3.61	14.31	493	2048	1689	787	1712	189	1955	1735
	West Anatolia	179	6276	1470	217	3.73	27.06	1104	1837	796	2619	3037	1871	2774	1360
	Mediterranean	357	11114	1522	207	2.22	18.22	1748	3229	1800	1740	1362	499	2674	1051
	Central Anatolia	238	6140	1402	66	4.50	23.17	559	2273	1176	1178	1617	214	2481	786
	West Black Sea	363	4447	758	150	2.93	6.30	220	864	663	789	1116	97	1202	702
	East Black Sea	336	3449	381	112	1.26	2.78	93	337	81	631	184	13	640	245
	Northeast Anatolia	75	7938	1452	56	3.99	31.26	408	2072	153	1768	726	246	1885	1062
	Central East Anatolia	94	4598	1084	181	6.17	15.31	99	981	962	0	1265	25	294	555
	Southeast Anatolia	230	8676	2669	164	3.23	25.97	708	3129	778	802	977	946	2327	1499
	Turkey	3014	7552	1400	151	3.40	17.42	792	2243	1663	1183	1615	647	2156	1278

Source: Author’s calculations from G.G. et. al. (2003 and 2005)

Table A-3 Ratio of means to standard deviations for input variables

	Regions	agr_inc	sub	lab	lvst	land	seed	fert	pest	water	dies	elec	other	feed
2002	West Marmara	0.64	0.56	0.96	0.69	0.74	0.55	0.62	0.45	0.22	0.61	0.20	0.61	0.49
	Agean	0.69	0.61	1.01	0.48	0.50	0.51	0.50	0.41	0.43	0.63	0.27	0.44	0.30
	East Marmara	0.80	0.59	0.99	0.53	0.68	0.38	0.86	0.46	0.32	0.51	0.20	0.47	0.35
	West Anatolia	0.95	0.59	0.61	0.49	0.98	0.61	0.82	0.67	0.43	0.90	0.24	0.70	0.43
	Mediterranean	0.66	0.37	0.76	0.49	0.53	0.23	0.47	0.34	0.25	0.42	0.18	0.55	0.44
	Central Anatolia	0.75	0.74	1.03	0.66	0.76	0.44	0.35	0.28	0.30	0.94	0.15	0.70	0.32
	West Black Sea	0.85	0.56	0.85	0.75	0.97	0.27	0.52	0.44	0.21	0.53	0.20	0.70	0.42
	East Black Sea	1.01	0.30	1.19	0.56	0.22	0.08	0.30	0.19	0.05	0.20	0.17	0.28	0.20
	Northeast Anatolia	0.77	0.49	1.30	0.89	0.82	0.49	0.34	0.18	0.23	0.63	0.19	0.68	0.36
	Central East Anatolia	1.01	0.18	1.43	0.66	0.89	0.39	0.70	0.77	0.38	0.55	0.36	1.12	0.77
	Southeast Anatolia	0.57	0.61	0.69	0.40	0.64	0.25	0.48	0.19	0.26	0.52	0.17	0.57	0.38
	Turkey	0.64	0.39	0.80	0.56	0.58	0.19	0.42	0.22	0.24	0.52	0.17	0.51	0.34
2004	West Marmara	1.08	0.56	0.57	0.72	0.66	0.40	0.66	0.18	0.22	0.61	0.15	0.45	0.60
	Agean	0.90	0.73	0.93	0.63	0.89	0.38	0.53	0.18	0.36	0.56	0.20	0.48	0.54
	East Marmara	1.10	0.61	0.89	0.59	0.69	0.30	0.70	0.34	0.31	0.59	0.18	0.48	0.44
	West Anatolia	1.05	1.00	0.50	0.72	0.77	0.52	0.89	0.37	0.26	0.64	0.33	0.52	0.55
	Mediterranean	0.79	0.43	0.61	0.59	0.61	0.41	0.59	0.41	0.24	0.64	0.23	0.49	0.33
	Central Anatolia	0.97	0.99	0.61	0.56	0.89	0.37	0.76	0.27	0.23	0.88	0.28	0.38	0.46
	West Black Sea	0.84	0.59	0.59	0.67	0.92	0.31	0.78	0.35	0.14	0.57	0.18	0.28	0.36
	East Black Sea	0.81	0.63	0.67	0.68	0.84	0.13	1.15	0.34	0.06	0.19	0.10	0.23	0.48
	Northeast Anatolia	0.66	0.68	0.80	0.96	0.65	0.53	0.37	0.39	0.24	0.80	0.31	0.47	0.57
	Central East Anatolia	0.81	0.74	0.56	0.65	0.79	0.38	0.48	0.26	0.00	0.28	0.12	0.57	0.52
	Southeast Anatolia	0.61	0.49	0.47	0.51	0.59	0.35	0.47	0.41	0.21	0.52	0.21	0.29	0.21
	Turkey	0.82	0.55	0.62	0.59	0.60	0.29	0.55	0.23	0.21	0.53	0.16	0.40	0.41

Source: Author’s calculations from G.G. et. al. (2003 and 2005)

Table A-4: Percentage change in production quantities for the whole sample

Product	2002 Tons	2004 Tons	% Change	Product	2002 Tons	2004 Tons	% Change
Barley	6832	7702	13%	Cotton	2794	2933	5%
Sunflower	2594	2521	-3%	Eggplant	205	646	216%
Green Pepper	720	1453	102%	Rice	135	76	-44%
Wheat	23598	32000	36%	Orange	140	352	152%
Rye	217	159	-27%	Sugar Beats	23134	22065	-5%
Tea	1014	1150	13%	Tobacco	352	2952	738%
Tomato	4835	5401	12%	Grapes	774	1506	95%
Bean	577	1438	149%	Clover	892	726	-19%
Hazelnut	967	652	-33%	Oats	608	590	-3%
Fig	67	250	273%	Butter	68	74	8%
Watermelon	2389	6271	162%	Olive oil	169	144	-15%
Apricot	171	88	-49%	Milk	4391	8968	104%
Cherry	69	136	97%	Cheese	158	199	26%
Lentil	431	281	-35%	Dried Figs	42	48	14%
Maize	4738	10848	129%	Raisin	88	216	145%
Chickpeas	456	961	111%				

Source: Author's calculations from G.G. et. al. (2003 and 2005)

Table A-5: Standard deviations of technical efficiency effects variables

	Region	Count	irr	orch	fallow	crop	ind	vege	frui	proces	rent	shrcropr
2002	West Marmara	365	0.24	0.25	0.09	0.33	0.32	0.19	0.09	0.00	0.18	0.07
	Aegean	511	0.41	0.25	0.14	0.38	0.42	0.14	0.31	0.04	0.19	0.10
	East Marmara	273	0.32	0.37	0.17	0.41	0.33	0.18	0.42	0.00	0.13	0.08
	West Anatolia	181	0.32	0.00	0.22	0.34	0.26	0.17	0.01	0.07	0.17	0.11
	Mediterranean	359	0.43	0.11	0.17	0.39	0.29	0.29	0.16	0.11	0.18	0.06
	Central Anatolia	238	0.21	0.01	0.22	0.30	0.28	0.14	0.02	0.00	0.16	0.09
	West Black Sea	367	0.35	0.26	0.21	0.39	0.34	0.21	0.33	0.00	0.12	0.08
	East Black Sea	364	0.04	0.39	0.07	0.19	0.43	0.04	0.45	0.07	0.05	0.10
	Northeast Anatolia	76	0.39	0.00	0.25	0.33	0.32	0.05	0.02	0.00	0.21	0.06
	Central East Anatolia	94	0.34	0.09	0.20	0.36	0.36	0.13	0.13	0.00	0.20	0.07
	Southeast Anatolia	231	0.35	0.11	0.18	0.39	0.38	0.12	0.04	0.00	0.15	0.11
	Turkey	3059	0.35	0.32	0.18	0.42	0.38	0.18	0.34	0.05	0.16	0.09
2004	West Marmara	365	0.24	0.28	0.09	0.37	0.38	0.15	0.10	0.36	0.16	0.05
	Aegean	511	0.44	0.34	0.10	0.35	0.46	0.17	0.27	0.35	0.19	0.09
	East Marmara	273	0.33	0.41	0.18	0.39	0.33	0.17	0.44	0.21	0.12	0.03
	West Anatolia	181	0.30	0.01	0.22	0.39	0.25	0.12	0.08	0.25	0.16	0.08
	Mediterranean	359	0.44	0.15	0.13	0.42	0.27	0.29	0.16	0.22	0.19	0.06
	Central Anatolia	238	0.20	0.01	0.24	0.32	0.23	0.02	0.00	0.14	0.17	0.07
	West Black Sea	367	0.34	0.29	0.16	0.42	0.35	0.22	0.31	0.20	0.13	0.07
	East Black Sea	364	0.11	0.25	0.06	0.13	0.45	0.01	0.49	0.16	0.07	0.06
	Northeast Anatolia	76	0.39	0.13	0.20	0.37	0.38	0.04	0.00	0.31	0.20	0.05
	Central East Anatolia	94	0.39	0.13	0.26	0.45	0.41	0.06	0.32	0.02	0.16	0.00
	Southeast Anatolia	231	0.36	0.14	0.20	0.46	0.40	0.04	0.13	0.17	0.16	0.08
	Turkey	3059	0.36	0.37	0.17	0.44	0.39	0.17	0.32	0.26	0.16	0.07

Source: Authors' calculations from ARIP QHS data set

Table A-6: Estimated coefficients of TVDM under half normal distribution

Variable	Coefficient	Standard Error
Constant X	6.77	0.06 ***
Labour	0.42	0.04 ***
Livestock	0.05	0.01 ***
Land	0.33	0.02 ***
Seed	0.04	0.01 ***
Fertilizer	0.39	0.04 ***
Pesticides	0.19	0.02 ***
Water	0.05	0.01 ***
Diesel	0.19	0.02 ***
Electricity	0.02	0.00 ***
Other Costs	0.03	0.02 *
Animal Feed	0.08	0.01 ***
σ^2	0.83	0.03 ***
γ	0.25	0.03 ***
η	0.72	0.05 ***

***: %1 significance **: %5 significance *: %10 significance

Source: Authors' calculations from ARIP QHS data set

Table A-7: Estimated coefficients of TVDM under truncated normal distribution

Variable	Coefficient	Standard Error
Constant X	6.64	0.06 ***
Labour	0.42	0.04 ***
Livestock	0.05	0.01 ***
Land	0.33	0.02 ***
Seed	0.04	0.01 ***
Fertilizer	0.40	0.04 ***
Pesticides	0.18	0.02 ***
Water	0.05	0.01 ***
Diesel	0.19	0.02 ***
Electricity	0.02	0.00 ***
Other Costs	0.03	0.02
Animal Feed	0.08	0.01 ***
σ^2	1.11	0.19 ***
γ	0.43	0.10 ***
μ	-1.37	0.92
η	0.90	0.08 ***

***: %1 significance **: %5 significance *: %10 significance

Source: Author's calculations from G.G. et. al. (2003 and 2005)

Table A-8: Results of NN-TIEM model with mean deviation data

Variable	Coef	Std Err		Variable	Coef	Std Err		Variable	Coef	Std Err	
ConsX	8.02	0.15	***	lab*irr	0.05	0.04		lvst*reg2	-0.06	0.03	**
lab	0.06	0.09		lab*orch	0.09	0.05	*	lvst*reg3	-0.09	0.04	**
lvst	0.02	0.01		lab*fallow	0.02	0.02		lvst*reg4	-0.05	0.04	
land	0.49	0.05	***	lab*rent	-0.06	0.03	**	lvst*reg5	0.00	0.04	
seed	0.05	0.02	**	lab*shrcr	-0.30	0.11	***	lvst*reg6	-0.01	0.04	
fert	0.20	0.08	***	lab*crop	-0.02	0.01		lvst*reg7	-0.07	0.04	*
pest	0.21	0.05	***	lab*ind	0.36	0.18	**	lvst*reg8	0.00	0.04	
water	0.04	0.01	***	lab*vege	-0.28	0.13	**	lvst*reg9	0.01	0.03	
dies	0.06	0.05		lab*frui	0.18	0.15		lvst*reg10	-0.04	0.04	
elec	0.05	0.01	***	lab*dis	-0.16	0.17		lvst*reg11	-0.17	0.05	***
other	-0.03	0.04		lab*cred	0.04	0.12		lvst*hhe1	-0.08	0.04	*
feed	0.00	0.03		lab*tech	-0.36	0.18	**	lvst*hhe2	0.03	0.03	
ConsZ	2.07	0.17	***	lab*asc	0.64	0.33	*	lvst*siz1	0.02	0.03	
irr	-0.06	0.05		lab*reg2	0.11	0.21		lvst*siz2	0.01	0.03	
orch	-0.15	0.06	**	lab*reg3	0.40	0.27		lvst*siz3	0.01	0.03	
fallow	0.03	0.03		lab*reg4	-0.11	0.22		lvst*siz4	0.01	0.03	
rent	0.13	0.04	***	lab*reg5	-0.41	0.29		lvst*siz5	0.04	0.04	
shrcr	-0.01	0.01		lab*reg6	0.35	0.25		lvst*t	-0.09	0.06	
crop	-0.37	0.21	*	lab*reg7	0.06	0.21		land*irr	-0.01	0.02	
ind	-0.32	0.17	*	lab*reg8	0.07	0.25		land*orch	0.06	0.03	**
vege	-0.53	0.19	***	lab*reg9	-0.01	0.21		land*fallow	0.00	0.01	
frui	0.12	0.22		lab*reg10	-0.57	0.29	*	land*rent	-0.01	0.02	
dis	-0.03	0.14		lab*reg11	0.12	0.39		land*shrcr	-0.06	0.06	
cred	0.38	0.23	*	lab*hhe1	-0.76	0.34	**	land*crop	0.00	0.01	
tech	-0.55	0.41		lab*hhe2	-0.11	0.21		land*ind	0.14	0.09	
asc	-0.62	0.25	**	lab*siz1	-0.15	0.20		land*vege	-0.05	0.07	
reg2	-0.76	0.32	**	lab*siz2	0.26	0.15	*	land*frui	0.14	0.08	*
reg3	-0.44	0.28		lab*siz3	0.07	0.17		land*dis	0.07	0.08	
reg4	0.36	0.35		lab*siz4	0.09	0.20		land*cred	-0.09	0.06	
reg5	-0.75	0.31	**	lab*siz5	0.20	0.26		land*tech	0.07	0.09	
reg6	-0.73	0.29	**	lab*t	0.71	0.40	*	land*asc	0.42	0.15	***
reg7	-0.79	0.30	***	lvst*irr	0.00	0.01		land*reg2	0.14	0.11	
reg8	-0.19	0.28		lvst*orch	0.00	0.01		land*reg3	-0.06	0.16	
reg9	0.27	0.34		lvst*fallow	0.00	0.00		land*reg4	0.21	0.13	
reg10	-0.41	0.38		lvst*rent	0.00	0.00		land*reg5	0.37	0.15	**
reg11	0.19	0.39		lvst*shrcr	-0.02	0.02		land*reg6	0.46	0.15	***
hhe1	0.54	0.28	*	lvst*crop	0.00	0.00	*	land*reg7	0.29	0.12	**
hhe2	0.59	0.26	**	lvst*ind	-0.04	0.03		land*reg8	0.53	0.15	***
siz1	-0.26	0.21		lvst*vege	0.01	0.02		land*reg9	0.28	0.13	**
siz2	0.17	0.35		lvst*frui	-0.01	0.02		land*reg10	0.47	0.15	***
siz3	0.02	0.51		lvst*dis	0.01	0.03		land*reg11	0.14	0.20	
siz4	0.02	0.66		lvst*cred	0.02	0.02		land*hhe1	0.18	0.17	
siz5	-1.91	0.99	*	lvst*tech	-0.03	0.03		land*hhe2	-0.01	0.11	
t	-0.29	0.14	**	lvst*asc	-0.03	0.05		land*siz1	-0.05	0.10	

***: %1 significance **: %5 significance *: %10 significance

Table A-8 (continued) : Results of NN-TIEM model with mean deviation data

Variable	Coef	Std Err	
land*siz2	-0.04	0.21	
land*siz3	-0.45	0.28	
land*siz4	-0.24	0.33	
land*siz5	-0.60	0.35	*
land*t	0.08	0.37	
seed*irr	0.00	0.01	
seed*orch	-0.02	0.02	
seed*fallow	0.00	0.01	
seed*rent	-0.01	0.01	
seed*shrcr	0.04	0.03	
seed*crop	0.00	0.00	
seed*ind	-0.05	0.05	
seed*vege	0.03	0.03	
seed*frui	-0.04	0.04	
seed*dis	0.05	0.04	
seed*cred	-0.01	0.03	
seed*tech	-0.05	0.04	
seed*asc	0.00	0.07	
seed*reg2	0.01	0.05	
seed*reg3	-0.05	0.07	
seed*reg4	-0.02	0.06	
seed*reg5	0.09	0.07	
seed*reg6	0.09	0.06	
seed*reg7	-0.08	0.05	
seed*reg8	0.04	0.06	
seed*reg9	0.03	0.06	
seed*reg10	0.07	0.10	
seed*reg11	0.12	0.08	
seed*hhe1	0.07	0.09	
seed*hhe2	0.01	0.05	
seed*siz1	0.00	0.05	
seed*siz2	0.07	0.05	
seed*siz3	0.08	0.05	
seed*siz4	0.05	0.05	
seed*siz5	0.05	0.06	
seed*t	0.12	0.08	
fert*irr	-0.05	0.04	
fert*orch	-0.07	0.04	
fert*fallow	0.04	0.02	*
fert*rent	0.02	0.03	
fert*shrcr	0.05	0.11	
fert*crop	0.01	0.01	
fert*ind	0.20	0.16	
fert*vege	0.17	0.13	

Variable	Coef	Std Err	
fert*frui	0.24	0.17	
fert*dis	-0.10	0.18	
fert*cred	-0.07	0.12	
fert*tech	-0.01	0.16	
fert*asc	0.11	0.29	
fert*reg2	0.28	0.19	
fert*reg3	-0.13	0.28	
fert*reg4	0.52	0.24	**
fert*reg5	-0.09	0.29	
fert*reg6	0.03	0.24	
fert*reg7	-0.09	0.27	
fert*reg8	0.23	0.26	
fert*reg9	-0.06	0.25	
fert*reg10	0.01	0.27	
fert*reg11	0.10	0.28	
fert*hhe1	0.34	0.28	
fert*hhe2	-0.21	0.22	
fert*siz1	-0.32	0.20	
fert*siz2	-0.16	0.16	
fert*siz3	-0.15	0.18	
fert*siz4	-0.49	0.20	**
fert*siz5	-0.32	0.23	
fert*t	-0.63	0.34	*
pest*irr	0.04	0.02	*
pest*orch	0.04	0.03	
pest*fallow	-0.01	0.01	
pest*rent	0.01	0.02	
pest*shrcr	0.20	0.07	***
pest*crop	0.01	0.01	*
pest*ind	0.14	0.10	
pest*vege	0.02	0.08	
pest*frui	-0.22	0.09	**
pest*dis	-0.11	0.09	
pest*cred	0.05	0.07	
pest*tech	-0.10	0.10	
pest*asc	-0.25	0.21	
pest*reg2	0.02	0.12	
pest*reg3	0.15	0.17	
pest*reg4	-0.07	0.14	
pest*reg5	-0.23	0.16	
pest*reg6	0.18	0.17	
pest*reg7	0.08	0.14	
pest*reg8	0.11	0.15	
pest*reg9	0.09	0.13	

Variable	Coef	Std Err	
pest*reg10	0.19	0.16	
pest*reg11	0.12	0.20	
pest*hhe1	0.27	0.19	
pest*hhe2	-0.11	0.13	
pest*siz1	-0.05	0.12	
pest*siz2	-0.20	0.09	**
pest*siz3	-0.20	0.11	*
pest*siz4	-0.25	0.12	**
pest*siz5	-0.23	0.15	
pest*t	0.20	0.23	
water*irr	-0.01	0.01	*
water*orch	-0.02	0.01	
water*fallow	-0.01	0.00	***
water*rent	0.00	0.01	
water*shrcr	0.02	0.02	
water*crop	0.00	0.00	
water*ind	-0.08	0.03	***
water*vege	0.01	0.02	
water*frui	-0.01	0.02	
water*dis	0.02	0.03	
water*cred	0.00	0.02	
water*tech	0.00	0.03	
water*asc	0.01	0.04	
water*reg2	0.11	0.03	***
water*reg3	-0.09	0.05	*
water*reg4	-0.04	0.04	
water*reg5	-0.07	0.05	
water*reg6	0.01	0.04	
water*reg7	0.03	0.04	
water*reg8	-0.08	0.04	*
water*reg9	0.05	0.04	
water*reg10	-0.17	0.12	
water*reg11	0.07	0.06	
water*hhe1	0.07	0.08	
water*hhe2	0.04	0.04	
water*siz1	0.06	0.03	**
water*siz2	0.07	0.03	**
water*siz3	0.04	0.04	
water*siz4	0.07	0.04	*
water*siz5	0.15	0.04	***
water*t	0.14	0.06	**
dies*irr	-0.03	0.02	**
dies*orch	-0.04	0.02	
dies*fallow	0.01	0.01	

***: %1 significance   **: %5 significance   *: %10 significance

Table A-8 (continued) : Results of NN-TIEM model with mean deviation data

Variable	Coef	Std Err		Variable	Coef	Std Err		Variable	Coef	Std Err	
dies*rent	0.02	0.01		elec*reg5	0.05	0.03	*	other*siz5	0.13	0.12	
dies*shrcr	-0.07	0.05		elec*reg6	-0.01	0.02		other*t	0.12	0.16	
dies*crop	0.01	0.01		elec*reg7	-0.01	0.02		feed*irr	-0.02	0.01	**
dies*ind	0.00	0.08		elec*reg8	-0.02	0.03		feed*orch	-0.01	0.01	
dies*vege	0.04	0.06		elec*reg9	0.00	0.03		feed*fallow	-0.02	0.01	**
dies*frui	0.09	0.06		elec*reg10	-0.01	0.04		feed*rent	0.00	0.01	
dies*dis	0.05	0.08		elec*reg11	0.04	0.04		feed*shrcr	0.00	0.00	
dies*cred	0.07	0.05		elec*hhe1	-0.05	0.04		feed*crop	-0.03	0.05	
dies*tech	-0.02	0.08		elec*hhe2	0.04	0.02	*	feed*ind	0.03	0.04	
dies*asc	-0.03	0.16		elec*siz1	0.01	0.02		feed*vege	-0.05	0.04	
dies*reg2	-0.05	0.08		elec*siz2	0.00	0.02		feed*frui	0.04	0.05	
dies*reg3	0.07	0.12		elec*siz3	0.00	0.02		feed*dis	0.05	0.04	
dies*reg4	-0.27	0.10	***	elec*siz4	-0.01	0.02		feed*cred	0.05	0.05	
dies*reg5	-0.35	0.13	***	elec*siz5	0.02	0.03		feed*tech	-0.05	0.10	
dies*reg6	-0.35	0.12	***	elec*t	0.04	0.03		feed*asc	0.05	0.05	
dies*reg7	-0.17	0.10	*	other*irr	0.00	0.02		feed*reg2	-0.17	0.08	**
dies*reg8	-0.25	0.11	**	other*orch	0.06	0.02	**	feed*reg3	-0.12	0.07	*
dies*reg9	-0.28	0.10	***	other*fallow	-0.02	0.01		feed*reg4	-0.22	0.08	***
dies*reg10	-0.19	0.16		other*rent	-0.04	0.02	**	feed*reg5	-0.19	0.08	**
dies*reg11	0.15	0.16		other*shrcr	-0.04	0.06		feed*reg6	0.05	0.07	
dies*hhe1	0.02	0.14		other*crop	0.01	0.01		feed*reg7	-0.16	0.07	**
dies*hhe2	0.20	0.10	**	other*ind	-0.04	0.08		feed*reg8	0.06	0.07	
dies*siz1	0.19	0.09	**	other*vege	-0.05	0.06		feed*reg9	-0.06	0.08	
dies*siz2	-0.14	0.08	*	other*frui	0.07	0.07		feed*reg10	0.01	0.10	
dies*siz3	-0.17	0.08	**	other*dis	-0.15	0.08	*	feed*reg11	0.02	0.10	
dies*siz4	-0.23	0.09	**	other*cred	-0.03	0.06		feed*hhe1	-0.04	0.06	
dies*siz5	-0.19	0.12		other*tech	0.08	0.08		feed*hhe2	-0.05	0.06	
dies*t	-0.59	0.18	***	other*asc	-0.37	0.17	**	feed*siz1	-0.03	0.05	
elec*irr	0.01	0.00	*	other*reg2	-0.16	0.08	*	feed*siz2	0.09	0.06	*
elec*orch	0.00	0.01		other*reg3	0.16	0.12		feed*siz3	0.17	0.06	***
elec*fallow	0.00	0.00		other*reg4	0.06	0.10		feed*siz4	0.09	0.07	
elec*rent	-0.01	0.00	*	other*reg5	0.12	0.12		feed*siz5	0.24	0.10	**
elec*shrcr	0.01	0.01		other*reg6	0.09	0.12		feed*t	-0.06	0.04	*
elec*crop	0.00	0.00	*	other*reg7	0.16	0.10					
elec*ind	0.00	0.02		other*reg8	0.12	0.10					
elec*vege	0.03	0.01	**	other*reg9	-0.06	0.10					
elec*frui	0.00	0.01		other*reg10	-0.24	0.13	*				
elec*dis	0.02	0.02		other*reg11	0.11	0.21					
elec*cred	-0.02	0.01		other*hhe1	-0.12	0.15					
elec*tech	-0.03	0.02		other*hhe2	-0.02	0.10					
elec*asc	0.04	0.03	*	other*siz1	-0.07	0.09					
elec*reg2	0.01	0.02		other*siz2	0.06	0.08					
elec*reg3	0.03	0.03		other*siz3	0.01	0.08					
elec*reg4	0.04	0.02		other*siz4	0.12	0.10					

***: %1 significance   **: %5 significance   *: %10 significance

Source: Author’s calculations from G.G. et. al. (2003 and 2005)

Table A-9: Estimated coefficients of TIEM-RS

Variable	Coefficient	Standard Error
Constant X	0.88	0.01 ***
Labour	0.21	0.01 ***
Livestock	0.01	0.00 ***
Land	0.05	0.00 ***
Seed	0.00	0.00 ***
Fertilizer	0.05	0.00 ***
Pesticides	0.02	0.00 ***
Water	0.01	0.00 ***
Diesel	0.02	0.00 ***
Electricity	0.00	0.00 ***
Other Costs	0.00	0.00
Animal Feed	0.01	0.00 ***
Constant Z	-4.05	0.26 ***
Irrigated	-0.07	0.02 ***
Orchard	-0.13	0.03 ***
Fallow	0.06	0.01 ***
Rented	0.04	0.02 **
Sharecropper	0.01	0.01
Cereals	0.45	0.12 ***
Ind. Crops	-0.51	0.08 ***
Vegetable	-0.02	0.09
Fruit	-0.15	0.10
DIS	-0.06	0.07
Credit	-0.10	0.10
Tech. Sup.	0.50	0.16 ***
ASC	0.04	0.11
West Marmara	-0.92	0.18 ***
Agean	-0.11	0.14
East Marmara	-0.41	0.16 **
West Anatolia	0.27	0.16 *
Mediterranean	-0.25	0.14 *
Central Anatolia	0.09	0.15
West Black Sea	0.08	0.14
East Black Sea	-0.18	0.19
Northeast Anatolia	0.12	0.21
Central East Anatolia	0.10	0.19
Illiterate	0.55	0.17 ***
Literate or Primary	0.24	0.16
Size 0.2-0.5 Ha.	-0.06	0.11
Size 0.5-1 Ha.	-0.17	0.12
Size 1-2 Ha.	-0.46	0.15 ***
Size 2-5 Ha.	-0.46	0.18 ***
Size 5+ Ha.	-0.35	0.24
Time	-1.00	0.09 ***
σ^2	0.01	0.00 ***
γ	0.63	0.03 ***

***: %1 significance **: %5 significance *: %10 significance

Source: Author's calculations from G.G. et. al. (2003 and 2005)

Table A-10: Magnitude of interactions between inputs and technical inefficiency variables

		Interaction										
		Lab	Livst.	Land	Seed	Fert.	Pest.	Water	Diesel	Electr.	Other	Feed
Irrigated							0.04	-0.01	-0.03	0.01		-0.02
Orchard	-0.15	0.09		0.06							0.06	
Fallow						0.04		-0.01				-0.02
Rented	0.13	-0.06								-0.01	-0.04	
Sharecropper		-0.30					0.20					
Cereals	-0.37		0.00				0.01			0.00		
Ind. Crops	-0.32	0.36						-0.08				
Vegetable	-0.53	-0.28								0.03		
Fruit				0.14			-0.22					
DIS											-0.15	
Credit	0.38											
Tech. Sup.		-0.36										
ASC	-0.62	0.64		0.42						0.04	-0.37	
West Marmara	-0.76		-0.06					0.11			-0.16	-0.17
Agean			-0.09					-0.09				-0.12
East Marmara						0.52			-0.27			-0.22
West Anatolia	-0.75			0.37					-0.35	0.05		-0.19
Mediterranean	-0.73			0.46					-0.35			
Central Anatolia	-0.79		-0.07	0.29					-0.17			-0.16
West Black Sea				0.53				-0.08	-0.25			
East Black Sea				0.28					-0.28			
Northeast Anatolia		-0.57		0.47							-0.24	
Central East Anatolia			-0.17									
Illiterate	0.54	-0.76	-0.08									
Literate or Primary	0.59								0.20	0.04		
Size 2-5 Ha.								0.06	0.19			
Size 5-10 Ha.		0.26					-0.20	0.07	-0.14			0.09
Size 10-20 Ha.							-0.20		-0.17			0.17
Size 20-50 Ha.						-0.49	-0.25	0.07	-0.23			
Size 50+ Ha.	-1.91			-0.60				0.15				0.24
Time	-0.29	0.71				-0.63		0.14	-0.59			-0.06

Source: Author’s calculations from G.G. et. al. (2003 and 2005)

Table A-11: Mean efficiency scores for TVDM

TVDM	HH	Rank		Average		Std. Dev.		Max		Min		Geometric Mean	
	Number	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004
West Marmara	365	1	1	59.69	76.10	12.55	9.03	86.55	93.02	15.24	38.60	58.02	75.48
Agean	505	5	4	55.40	72.98	14.10	10.50	81.87	90.38	4.80	22.04	53.08	72.10
East Marmara	272	3	3	56.10	73.50	13.84	10.29	79.46	88.98	12.41	34.92	53.89	72.67
West Anatolia	179	11	11	49.37	68.47	15.27	11.88	79.28	88.88	9.37	30.48	46.39	67.29
Mediterranean	357	4	5	55.48	72.85	15.67	11.94	81.59	90.21	2.87	17.16	52.35	71.63
Central Anatolia	238	8	8	50.05	69.08	14.36	11.07	81.58	90.21	7.09	26.62	47.47	68.07
West Black Sea	363	10	10	49.44	68.74	13.55	10.30	76.70	87.35	10.61	32.37	47.28	67.90
East Black Sea	336	2	2	57.62	74.68	12.40	9.13	81.85	90.37	10.50	32.21	55.89	74.03
Northeast Anatolia	75	9	9	49.77	68.96	13.55	10.47	72.66	84.90	13.48	36.36	47.50	68.07
Central East Anatolia	94	7	7	51.03	70.00	12.47	9.44	74.60	86.08	12.42	34.94	49.20	69.29
Southeast Anatolia	230	6	6	52.01	70.52	14.78	11.00	80.29	89.47	15.06	38.37	49.57	69.59
Turkey	3014	-	-	54.21	72.11	14.35	10.76	86.55	93.02	2.87	17.16	51.78	71.18

Source: Author's calculations from G.G. et. al. (2003 and 2005)