ASSESSMENT OF TECHNICAL EFFICIENCY OF SELECTED COMMERCIAL BANKS IN ETHIOPIA

A Thesis Submitted to Department of Accounting and Finance for the Partial Fulfillment of the Requirement for the Master of Science in Accounting and Finance

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ADAMA, ETHIOPIA

May, 2015

Adama Science and Technology University
School Of Graduate Studies
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This is to certify that the thesis prepared by Getenat H/Michael Ayano, entitled "Assessment of Technical Efficiency of Selected Commercial Banks in Ethiopia" and submitted in partial fulfillment of the requirements for the Degree of Master in Accounting and Finance complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Acknowledgements

First of all I would like to express my sincere thanks to the almighty **God** –the father and the Son and the Holy Spirit. Oh my God! You helped me to realize my dream! I do not have words to express my thanks!

I am incredibly much indebted to my respectful thesis Advisor **Dr. D. Guruswamy**, for his vital professional comment, constructive criticism, regular follow up, devotion; suggestion and useful advice have been invaluable inputs that have improved the quality of my work. Without his support this study would have never reached its present stage.

Hence, I remain grateful and thankful always to my colleagues at Adama University, department of Accounting and Finance post graduate class and to all my friends who were always happy to cooperate in everything I needed.

I add a special thanks and gratitude for the prior researchers who works on the same title to use their research as a reference to build my paper.

I lack appropriate words to express my gratitude for their unreserved support without which my success in higher education would have been impossible. Thank you my **DAD** for your help, love, discipline, patience, and strength amidst adversity all showed me a path of gratitude. Thank you my **MOM** for your unique maternal affection. I also thank my brother and fiancée **Girma** and **Sara** for their sincere love and passion they provide me all the time

Finally I would like to give my deepest gratitude to my work partner **Dawit**, for his support and affection.

Thanks

Abstract

The main aim of this study was to measures the relative efficiency of selected commercial banks in Ethiopia for the period of 2007 to 2013 with an integrated approach includes Data Envelopment Analysis (DEA) and Malmquist index. The researcher employed Data Envelopment Analysis (DEA) and Malmquist index to measure the extent of overall technical, pure technical, scale efficiencies and productivity of selected commercial banks in Ethiopia. And under the study the quantitative data type, secondary source and purposive sampling methods were used. Using Data Envelopment Analysis (DEA) and Malmquist index, in this study aims to measure the extent of overall technical, pure technical, scale efficiencies and productivity in eight commercial banks of Ethiopia with operating experience of seven years starting from 2007 up to 2013. CCR and BCC models under input oriented method were used to arrive at their technical efficiencies. The empirical findings reveal that during the study period BOA were the lowest scorer of overall technical efficiency of 73.4%, i.e., input could be reduced by 26.6% without sacrificing output if BOA were efficient. The lowest score of pure and scale efficiency were 81% and 80.8% by AIB and CBB during the study period. The average Malmquist index of the banks was 94.8% these decrease in overall productivity of banks resulted because of an average 0.01% decrease in scale efficiency and average of 5.1% decrease in technology adaptation by the banks during the study periods.

Key words: *Data Envelopment Analysis, Malmquist index, Technical Efficiency, Pure Technical Efficiency, Scale Efficiency.*

CHAPTER ONE

INTRODUCTION

This chapter presents the overall introduction of the paper, it includes the background of the study and background of the organization, followed by statement of the problem, objective of the study, significance of the study, scope and limitation of the study, and finally, the organization of the paper is presented.

1. 1. Background of the Study

According to Farrell(1957), (as cited by Bryan E. N. and Tsegaye M., 2007) a technical efficiency measure is defined by one minus the maximum equi- proportionate reduction in all inputs that still allows continuous production of given outputs. Technical efficiency is linked to the possibility of avoiding waste by producing as much outputs as the use of input allows it (output oriented measure), or by using as less input as the production objective plans it (input oriented measure). This efficiency is measured by comparing observed and optimal values of production, cost, revenue, profit or all that the production system can follow as objective and which is under appropriate quantities and prices constraints. Therefore it can analyze technical efficiency, in terms of deviation compared with idealistic production frontier.

Giustiniani A. and Ross K. (2008), states there is evidence that weak and inefficient financial systems can be a significant obstacle to economic growth. This is due to the fact that financial intermediation the process of channeling surplus into productive investment is an essential part of private sector development. (Allen, L. and Gottesman, 2006), states that a weak and inefficient financial sector, with limited competition, can adversely affect saving decisions and the optimal allocation of credit, thus hindering investment and economic growth.

Banking sector in transition and developing economies has experienced major transformations since the 1990s. Over the last few decades, the banking sectors around the world have experienced financial globalization, technological changes, and competition. Banks are also faced with increasing competition and rising costs as a result of regulatory requirements, financial and technological innovation, and challenges of the recent financial crisis (Grigorian & Manole, 2002).

Moreover, banking sector has changed with the advanced applications in computer and communications technology and introduction of new financial instruments. Such changes have significantly modified bank production. In this regard, a frequently asked question is about the effect of these changes on the efficiency of banks (Rajan, 2005; Beck, 2006; Padoa-Schippoa, 2004). Investigating the efficiency of the financial system and in particular banks has gained a lot of popularity in recent times for several reasons.

First, the efficiency of banks is directly linked to the productivity of the economy. Banking system assets constitute a substantial proportion of total output (Bauer Paul et al, 1992). Banks provide liquidity, payments and safekeeping for depositors` and channel these funds into investment and working capital requirements, Second the banking sector in Ethiopia is also the most common instrument in exercising economic and monetary policy. In addition, banks are supposed to play a special role in funding small businesses that often have very limited access to other sources of external finance.

Last but not list banks play a major role in ensuring a smoothly functioning payment system, which allows financial and real resources to flow freely to their highest-returns uses. A basic benefit of enhanced efficiency is a reduction in spreads between lending and deposit rates. This is likely to stimulate both greater loan demands for industrial investment (and thus contribute to higher economic growth) and greater mobilization of savings through the banking system. Banks in most developing countries operate with relatively wide spreads. Although government policies and regulations are considered major causes of such wide spreads, studies on banking efficiency has pointed at operating inefficiencies as one other possible source that needs to be investigated. Wide spreads affect intermediation and distort prices thus impairing the role of the financial system in contributing to rapid economic growth (Ikhide. S, 2000).

The Ethiopian financial sector reform has greatly changed the face of Ethiopian Banking system, as a result several private Banks have created. In the face of increased competition, the banks have to operate more efficiently in order to sustain and perform better. In the context of increased competition and the importance of banks in financial markets, it becomes very much essential to evaluate whether these banks operate efficiently.

According to Kablan Sandrine, (2007), commercial banks play important role in the economy of a country as they serve as an intermediation between the households and the economy sector (finance). This makes connecting the one who have surplus and the other deficit which benefits the two through minimizing uncertainties. Therefore, the best financial system is that which the mediator performs efficiently. Such a system limits, quantify, gather and negotiate all operational risks and incite the savers to invest by offering them a proportional payment to the scale of the risk incurred. The risk and return therefore cannot be the same with different economies and banks. Operating performance in corporations is frequently measured using ratios such as return on sales and return on investment. These ratios provide a means for assessing firm‘s financial positions/ performance which could be used for comparisons across time and with other similar firms. Nevertheless, there are limitations to the use of these measures. Among these one is that such measurement doesn‘t provide the overall performance of the firms and also financial ratios may fail to consider the value of management's actions and investment decisions taken with the intent of affecting future as opposed to current performance. The continued and pervasive use of untransformed, accounting-based financial ratios despite the associated problems, suggests that (i) the convenience of using ratios may exceed the cost of errors in analysis caused by ratio-related model miss-specification, and/or (ii) in general, no equally convenient, or superior alternative to transformed ratios has been developed and applied to financial ratio analysis" (Kane and Meade, 1998).

To excel the shortcomings of ratio analysis efficiency measurement is the best performance measurement in the Banking sector. Thus, efficiency analysis of the banks is the key issue in the Ethiopian commercial bank managers', since the performance in banking sector rather than simply other traditional analysis. Also, efficiency measurement of the banks has an important role in the efficiency of Ethiopia financial system. It is not surprising that the banking sector and its efficiency is one of the most popular issues in Ethiopia because of the above stated limitations in the traditional performance measurement techniques. Therefore, the aim of the study would be to assess technical efficiency of selected commercial banks of Ethiopia.

1.2 Background of the organization

1.2.1 Historical Background of Banking Industry in Ethiopia

Modern banking in Ethiopia was introduced in 1905. At the time, an agreement was reached between Emperor Minelik II and a representative of the British owned National Bank of Egypt to open a new bank in Ethiopia. February 15, 1906 marked the beginning of banking in Ethiopia history when the Bank of Abyssinia was inaugurated by Emperor Minelik II. It was a private bank whose shares were sold in Addis Ababa, New York, Paris, London, and Vienna (NBE, 2010).

According to National bank of Ethiopia (NBE 2010), in 1931, Emperor Haile Selassie introduced reforms into the banking system and the Bank of Abyssinia was liquidated and became the Bank of Ethiopia, a fully government-owned bank providing central and commercial banking services until the Italian invasion of 1936.

During the Italian invasion, Bank of Italy was formed to issue legal tender in Ethiopia. In 1943, after Ethiopia regained its independence from fascist Italy, the State Bank of Ethiopia was established, with two departments performing the separate functions of a legal tender issuing bank and a commercial bank. In 1963, these functions were formally separated and the National Bank of Ethiopia (the central and issuing bank) and the Commercial Bank of Ethiopia were formed.

In the period up to 1974, several other financial institutions emerged including the state owned as well as private financial institution. Further, as per the NBE (2010), following the declaration of command economy by Dergue regime in 1974 the government extended its control and nationalized all of previously established private banks and merged into one bank (NBE, 2010).

After nationalization the Dergue regime leave only three government banks; the National Bank of Ethiopia, Commercial Bank of Ethiopia and Agricultural and Industrial Development Bank (Mortgage Bank) until the socialist regime overthrown in

1991. Subsequently, the licensing and supervision of Banking Business Proclamation No. 84/1994 was issued in 1994 which led to the beginning of a new era for Ethiopia banking sector. Following the enactment of the banking legislations in the country in the 1990s, a fairly good number of private banks have been established. In the 2012/13 fiscal year the total number of banks already operational in the country reached nineteen. Of these banks, sixteen were private and the other three were government owned. (Sofia L. A. & Seid H.Y. 2014).

1.3. Statement of the Problem

In a dynamic and competitive market environment, only efficient banks will survive and maintain their market shares, and inefficient ones will eventually be eliminated. The efficient banks are better able to compete because of their lower operational costs and can steal business away from less efficient banks. In sum, the relative efficiency of banks is always a matter of serious interest to the regulators, customers, stockholders, and managers (Kumar S. et al, 2008).

As Piyu Y. (2011), explained in his work, commercial banks play a vital role in economy for the following reasons: They provide a major source of financial intermediation and their checkable deposit liabilities represent the bulk of the nation‘s money stock. Evaluating their overall performance and monitoring their financial condition is important to depositors, owners, potential investors, managers and, of course regulators.

In today‘s business world which is dynamic and high pressure of global competition, development of hi-tech and boundary less market environment, a business needs to be efficient in its resource utilization, maintain its market share and stand for its customers and stakeholders‘ satisfaction for the sake of survival. The changing nature of the banking industry has made financial ratio evaluations even more difficult, increasing the need for more flexible alternative forms of financial analysis such as Data Envelopment Analysis (Piyu Y, 2011).

In Ethiopia the banking industry has been an increase in the number of new banks opened and an expansion of branches over the last few years. The increase in the number of banks entering in to the market is mainly due to the profits registered by most of the private banks operating in the country. This doesn‘t mean, however, that the banks will remain profitable forever. As more and more banks join the market, competition is going to be tough and only the efficient ones could keep on enjoying the benefits. Determining the efficiency of the banks is, therefore, an important issue which is interest to many stakeholders (Mesay, 2011).

Most of the studies conducted in Ethiopia particularly in Banking sector are focused on financial performance (Sofia L.A & Seid H.Y, 2006), (Bashir, 2000), (Tesfay, 2013), (Nestant, 2014), by using ratio analysis and determinants of profitability performance (Damena, 2011), (Abera, 2012), (Amare, 2012), (Ayele, N, 2012), (Raole, and Lakew, 2012), (Abdulkarim, 2014). But using ratio analysis and showing determinants of profitability, it is difficult to get genuine information about the efficiency level of the financial institutions. Therefore; in the study the DEA model was used for several reasons. First, the DEA model is able to incorporate multiple inputs and outputs easily. Second, a parametric functional form does not have to be specified for the production function. Third, DEA does not require any price information for dual cost function as is required for parametric approaches. Fourth, DEA has the potential to provide information to the supervisors in improving the productive efficiency of the organization. Finally, DEA presents a generalization on approach because other assumptions than constant return to scale can be accommodated within a convex piecewise linear best practice frontier. Due to all the captioned reasons DEA Model has better benefits to asses' technical efficiency of commercial banks. Thus, the researcher focused on measuring the efficiency, determinants of inefficiency and productivity changes over the period of 2007–2013 for the selected commercial banks in Ethiopia in order to determine whether there is a rise in efficiency and productivity of these banks in the study period.

1.4. Objectives of the study

1.4.1. General objective

The general objective of this study was to assess technical efficiency of selected commercial banks in Ethiopia.

1.4.2. Specific objectives

The specific objectives of the study were as follows:

1. Investigate the relativity level of technical efficiency of selected commercial banks in Ethiopia.
2. To explain the degree of factors that influence efficiency of selected commercial banks in Ethiopia.
3. To assess the effect of technology on productivity of selected commercial banks during the study period in Ethiopia.
4. To compare the mean result of productivity of the selected commercial banks in Ethiopia.

1.5. Significance of the study

The study will be significant for the following reasons:

- For the Ethiopian commercial banks, this paper will be valuable input to consider their technical efficiency.
- Assessment of efficiency of the operating banks may be use as information for the new opening banks.
- There was no enough literature on technical efficiency of bank level in Ethiopia so this may serve a means of embarking.

1.6. Scope of the study

There are nineteen commercial banks in Ethiopia in both public and private sectors, of which nine commercial banks are fully engaged in commercial banking activity for more than ten years. So the study was delaminated to the efficiency measurement of commercial banks operating in Ethiopia that has an operational experience of a minimum of seven years starting 2007. A minimum of seven years taken to include more samples in the study and also 2007 was taken as a base year due to the fact that under DEA at least five years data required to get meaningful results. It would be perfect if all other banking institutions have been included but however because of shortage of experience the study restricted to commercial banks which were operating a minimum of five years in the market as of 2007. To measure the technical efficiency the researcher used both the CCR (Charnes, Cooper and Rhodes) and BCC (Banker, Charnes and Cooper) models input based approach. In CCR (Charnes, Cooper and Rhodes) model the researcher arrived at overall technical efficiency of the DMUs (Decision Making Units) and using the BCC (Banker, Charnes and Cooper) model the individual DMUs (Decision Making Units) pure technical efficiency was determined and as a result of the two, the ratio of overall and pure technical efficiency, scale efficiency was determined.

1.7. Limitation of the study

Although there are about nineteen governmental and privately owned commercial banks in Ethiopia, the study limited to eight selected commercial banks with seven years data. Therefore, since this study has been done based on only eight banks; the findings may not be representative of the whole financial institutions in Ethiopia, even if including public banks in this study due to the fact that they are highly supported & influenced by government strategies designed to achieve its own goal even if they are also profit making institutions. In addition to this, the study was conducted entirely based on secondary sources (seven year audited financial statements which by itself has own limitation since it shows only the yearend balance & doesn't indicate the financial position that has been observed throughout the year) but also most of the commercial banks were being audited at the end of 2014. Hence their 2014 reports were excluded: There are a number of factors could affect the level of efficiency of decision making units (DMUs), in this case, but factors such as the economic, inflations and regulatory system of the country and their contribution to efficiency of the banks were ignored.

1.8. Organization of the study

The paper is organized into five chapters. Chapter one covers about background of the study and organization, statement of the problem, significance of the study, objectives of the study, scope and limitations of the study. Chapter two describes the theoretical and empirical relevant literatures. Chapter three covers the methodology. Chapter four presents results and discussion of the study. Finally, chapter five presents an overview of the study paper, summaries of findings, conclusion and recommendation based on the major findings.

CHAPTER TWO

LITERATURE REVIEW

This chapter presents the review of related literature. Therefore the chapter is divided in to two parts the first part presents the theoretical review of literature related topic of the study and the second part discusses the empirical studies by, different researchers.

2.1 Theoretical literature

2.1.1 Conventional microeconomic theory

Conventional economic efficiency theory states that companies should structure their output to achieve the lowest possible cost per unit produced. Given the combination of fixed and variable costs typical in business, low levels of output are inefficient because fixed costs are shared out across a relatively small number of units. At the other extreme, although above-optimal production can, in theory, generate economies of scale, in practice this apparent benefit is often more than offset by additional costs related to the overstressing of existing systems. In the short term, the point of maximum operational efficiency is achieved at the level of output at which all available economies of scale are taken advantage of, yet short of the level at which the diseconomies of overstraining existing systems come into play. Over the longer term, however, the optimal level of productive efficiency can be raised by increasing the capacity of existing systems.

Conventional microeconomic theory is concerned with allocation or market efficiency. However, there are no markets inside productive organizations. We cannot simply assume that such organization handle their affairs as well as they possibly can, as the conventional cost-minimization assumption implies .The failure of conventional theory points up the need for a theory that enables us to examine, analyze, and predict instances where this type of inefficiency exists (Leibenstein, 1994).

Other element of conventional economic efficiency theory relates to the way existing resources are allocated. The logic is that high levels of competition among producers should prevent them from making excessive profits by raising their selling prices to an unreasonable level above their marginal costs. At the company level, maximum allocative efficiency is achieved when the firm produces the optimal output level of a combination of goods or services to maximize the benefit to the company as a whole. The theory takes account of the fact that company resources are finite and can be used only once, with the result that using a quantity of a material for one purpose involves an opportunity cost-that is, it denies the company the chance to use the same material for another purpose. Allocative efficiency is achieved only when no other pattern of utilization of resources can deliver a better overall result in terms of the welfare of all interested parties. This point of maximum allocative efficiency, at which improvements in one aspect of usage can only be achieved at the expense of losses elsewhere, is sometimes referred to as the Pareto optimal allocation of resources (Leibenstein, 1994).

2.1.2 X-efficiency theory

The conventional theory views the expansion of international trade as a good thing on comparative advantage grounds. X-efficiency theory also sees it as beneficial because it puts pressure on domestic producers to lower costs. For reasons that are too technical to present here, it seems likely that the X-efficiency improvements would be considerably greater than the comparative advantage benefits to the conventional view, X-efficiency theory suggests that profits are not a good indicator of efficiency if production takes place in sheltered environments. Thus, it would probably not be good public policy to control natural monopolies such as electric utilities by controlling the profit rate. X-efficiency holds that incentives must be provided for operators to reduce costs toward the minimum.

The X-efficiency approach is in the spirit of the development of models based on different postulates than those already existing-a conventional procedure in many sciences. Relaxing the maximization postulate would permit the study of different types of economic activities, including those undertaken by governments, in terms of a continuum of environments which provide different degrees of motivation toward efficiency of performance. In general, once the cost-minimization postulate is dropped, X-efficiency theory opens the way for the analysis of cost-containment problems and countermeasures, (Leibenstein, 1994).

All well-formulated theories in science are based on postulates (i.e., assumptions). Consider two of the critical postulates of traditional microeconomics: 1) maximization and 2) the production function. By maximization (or the rationality postulate) we usually refer to the idea that decision units try to do as well as they possibly can, given their objectives. Thus, it is usually assumed that enterprises try to maximize profits; most important this implies that they attempt to *minimize costs* for a given output. The reader should note that it is the cost minimization postulates that, in a basic way, X-efficiency theory questions. The production function postulate says that there is a unique relationship between inputs and outputs. To some economists it seems obvious that businessmen are sensible, and that sensible businessmen will know what they are doing-hence they will want as much profit as possible, as low costs as possible, and they will know the relation between any particular aggregate of inputs and any particular aggregate of outputs (Leibenstein, 1994).

Efficiency of a production unit we mean a comparison between observed and optimal values of its outputs and inputs. The comparison can take the form of the ratio of observed to maximum potential output obtainable from the given input, or the ratio of minimum potential to observed input required to produce the given output, or some combination of the two. In these two comparisons the optimum is defined in terms of production possibilities. It is also possible to define the optimum in terms of behavioral goal of the production unit. In this event efficiency is economic and is measured by comparing observed and optimum cost, revenue, profit, or whatever the production unit is assumed to pursue, subject to the appropriate constraints on quantities and prices (Lovell, 1993).

The idea of efficiency of a production unit was first introduced by (Farell, 1957), under the concept of “input oriented measure”. According to Farell, a technical efficiency measure is defined by one minus the maximum equi proportionate reduction in all inputs that still allows continuous production of given outputs. Technical efficiency is linked to the possibility of avoiding wasting by producing as much outputs as the use of input allows it (output oriented measure), or by using as less as input that the production objective plans it (input oriented measure). This efficiency is measured by comparing observed and optimal values of production, costs, revenue, profit or all that the production system can follow as objective and which is under appropriate quantities and prices constraints. Therefore, we can analyze technical efficiency, in terms of deviation compared with an idealistic production frontier isoquant (Kablan, 2007).

2.2. Basics of DEA

DEA represents a mathematical programming methodology that can be applied to assess the efficiency of a variety of institutions using a variety of data. This section provides an intuitive explanation of the DEA approach. DEA is based on a concept of efficiency that is widely used in engineering and the natural sciences.

Engineering efficiency is defined as the ratio of the amount of work performed by a machine to the amount of energy consumed in the process. Since machines must be operated according to the law of conservation of energy, their efficiency ratios are always less than or equal to unity.

This concept of engineering efficiency is not immediately applicable to economic production because the value of output is expected to exceed the value of inputs due to the value added in production. Nevertheless, under certain circumstances, an economic efficiency standard similar to the engineering standard can be defined and used to compare the relative efficiencies of economic entities. For example, a firm can be said to be efficient relative to another if it produces either the same level of output with fewer inputs or more output with the same or fewer inputs. A single firm is considered technically efficient if it cannot increase any output or reduce any input without reducing other outputs or increasing other inputs. Consequently, this concept of technical efficiency is similar to the engineering concept. (Tanvir A. and Waseem A, 2008).

2.3 Efficiency measurement method

There are two widely used method were employed in order to measure efficiency of the decision making unit. These are ***parametric*** and ***non parametric***.

2.3.1 Parametric (Econometric)

The parametric approach is based on the underlying relationship between the parameter under study and various observed independent variables. It is an econometric application in which one specifies some explicit form of the production, cost, or profit function to represent the benchmark technology for efficiency measurement. The validity of the derived measures of efficiency, however, does critically depend on the appropriateness of the functional specification, therefore requires a specific pre-specified function form of the production or cost function (Gupta *etal*, 2003).

The econometric approach consists of an econometric estimate of the best practice frontier by its specification in a Cobb-Douglas, cost or production function. The econometric method can be deterministic. In this case, every deviation from the frontier is attributed to inefficiency. It can also be stochastic; it is then possible to separate random errors from the production unit inefficiency. The stochastic frontier method has two principal advantages compared to non-parametric DEA method. First, it allows separating random error from the production unit inefficiency and takes into account the existence of exogenous shocks. At this purpose, the error term is divided into two components: an inefficiency component and a random one (which is composed of the error measurement and the exogenous shocks). Second, the stochastic frontier analysis is less sensitive to absurd values. The question that we are addressing by using the stochastic frontier analysis is what is the optimal combination of inputs? Which makes, it possible to produce an optimal combination of outputs while minimizing production costs (Kablan, 2007).

2.3.2 Non parametric

Non-parametric approach is based on the concept of efficiency similar to one in the parametric approach but differs from it since this approach does not require any pre-specified function. It takes the data of the actual operations of the firms under study and frontier is formed as the piecewise linear combination of the “most efficient observations.” Thus, efficiency so determined is relative to the “observed best”, rather than an absolute value (Gupta etal, 2003).

It is also mathematical approach known under the name of DEA method (Data Envelopment Analysis) consists in estimating the frontier by using non parametric mathematical linear programming. It offers an analysis based on the relative evaluation of the efficiency in an input/output multiple situations, by taking into account each bank and measuring its relative efficiency to an envelopment surface made up with the best banks. However, this method doesn’t allow for noise treatments. The non parametric method was usually used by making the assumption of constant return to scale (CRS). But recently, the assumption of variable return to scale (VRS) was used in specifications because this hypothesis is more relevant with the environment of imperfect competition in which banks operate (Kablan, 2007).

2.4 Conceptual frame work

Farrell, (1957) proposed that the efficiency of a firm consisting of two components: technical efficiency which reflects the ability of a firm to obtain maximal output from a given set of inputs, and allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology. Price information is necessary for any discussion of allocative efficiency. The overall efficiency is the product of pure technical, allocative and scale efficiency measures.

Farrell's idea can be illustrated using easy example involving firms that use two inputs to produce a single output. Consider a firm using two inputs **X1** and **X2** producing output **Y** under the assumption of constant return to scale. The unit isoquant of efficient firm is represented by **SS**$^{/}$. If a firm uses a quantity of inputs, defined by the point **P**, to produce a unit of output, the technical inefficiency of that firm could be represented by the distance **QP**, which is the amount by which all inputs could be proportionally reduced without reduction in output. This is usually represented in terms of percentage or ratios, which represent the percentage by which all inputs could be reduced. So based on the above the technical efficiency of a firm is measured as follows.

TE = OQ / OP

Which is equal to one minus **OQ / OP**, which always take value between **0** and **1**, that indicate the degree of technical inefficiency of the firm and a value of **1** indicate the firm is fully efficient because it lies on efficient isoquant.

Suppose the input price ratio is represented by line **AA**$^{/}$, it also known as allocative efficiency which is measured as follows:

AE = OR / OQ

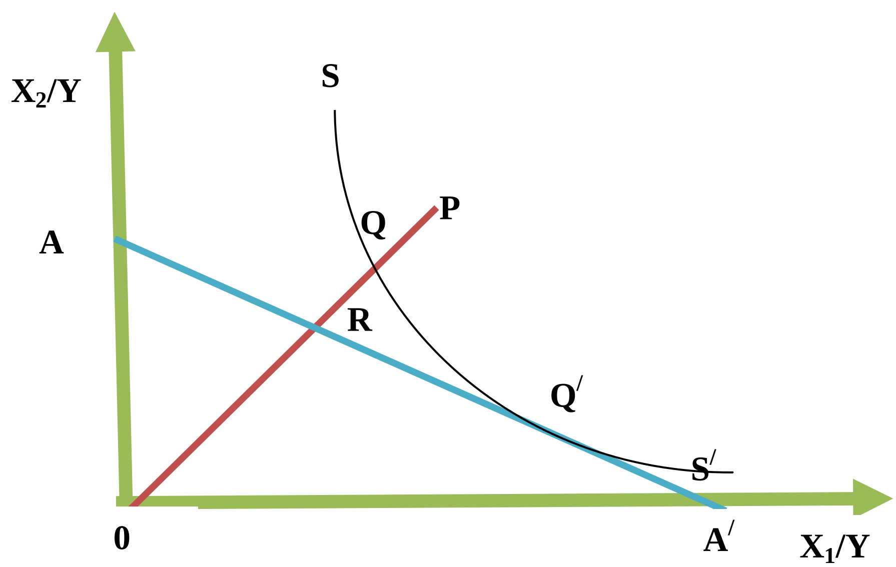
Because the distance **RQ** denote the reduction in production cost that would occur if production were occur at point **Q**$^{/}$ which is allocatively and technically efficient, but point **Q** is technically efficient but allocatively inefficient.

So based on the above frame work the total economic efficiency is defined as follows:

EE = OR / OP

Since the distance between **RP** could be interpreted in terms of cost reduction. It is remembered that the product of technical and allocative efficiency provide the overall efficiency of a firm.

Figure 1: **Technical and Allocative Efficiency on input orientation**



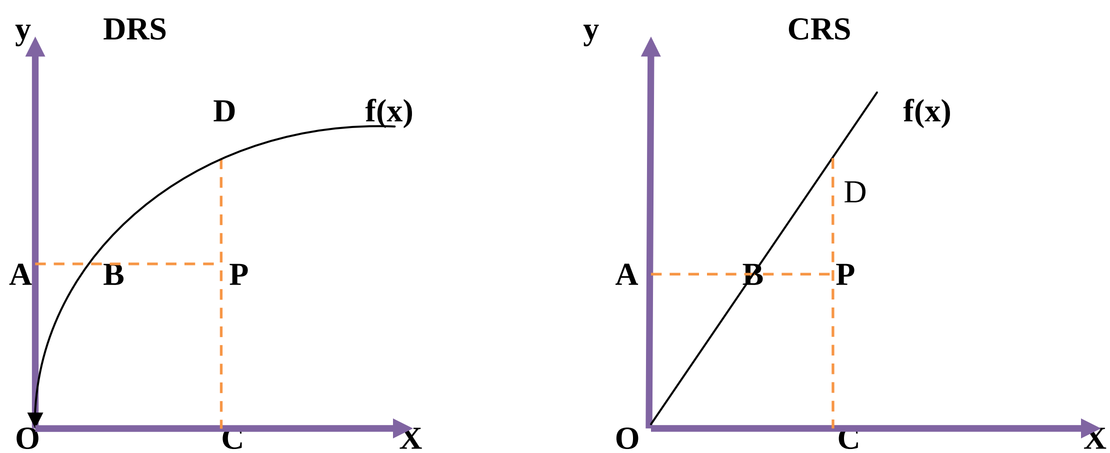
Source: Coelli (1996: p. 5)

Moreover, Farrell's original idea has an emphasis on input-reduction and thus it is usually termed as input-orientated measure. Similarly the concepts of efficiency can be explained by using output oriented measure.

The input orientation measure of efficiency addresses the question, "by how much the input quantities can be reduced without changing the output quantities produced?" On the other hand the output orientation efficiency measurements can tell us by how much can output quantities could be expanded without changing the input quantities used. (Fare and Lovell, 1978), argued that under constant return to scale both the input and output measure of efficiency provide the same result of technical efficiency, but they unequal under the assumption of variable (increase or decrease) return to scale. (Charnes, *et al.*, 1978) by assuming constant returns to scale established an input oriented model, on the other hand, the constant return to scale assumption is only fitting when all firm or decision making units are operating at the optimum scale, but operation at optimal scale can be affected by uncontrolled constraints. So on the other hand, (Banker, *et al*., 1984), suggested another edition model to which is a variable returns to scale. A variable return to scale is situation where all firms are not operated at optimal scale. The difference between the input and output oriented measure can be illustrated by using one input and one output. I.e. when we have a decreasing return to scale represented by **f(x)**, and an inefficient firm operating at point **P**. based on Farrell input oriented measure of technical efficiency would be equal to the ratio of **AB /AP**, while the output oriented measure of technical efficiency would be:

Figure 2: **Decreasing/ Constant return to scale**

CP /CD.



Source: Coelli (1996:p.7)

2.4.1. CCR and BCC Models

The original formulation of the DEA model introduced by Charnes, Cooper and Rhodes (1978), demoted CCR hereafter, assume Constant Returns to Scale (CRS) and the production frontier is a piecewise linear envelopment surface.

Let us first define the following measures:

An interpretation of the CCR model that estimates the proportional increase θ, in all outputs requited to achieve efficiency in DMU '*k*' is given by

$$\text{Min } \mu_k \qquad (1)$$

Subject to: $\sum j^{n}=1\lambda_j y_{rj} \geq y_{rk}\,\mu$, r = 1, 2…..5

$$\sum_{J=1}^{n} \lambda_j x_{ij} \leq x_{ik},\ I = 1, 2.....m$$

$$\lambda_j \geq 0\ j = 1, 2\ ...., n$$

Where: $S = \{1... s\}$ is the set of outputs considered in the analysis

$M = \{1... m\}$ is the set of inputs considered in the analysis

$y\,rj$ = known positive output level of production unit j, $r \in S$

xij = known positive input level of production unit j, $i \in M$

n = total number of production units evaluate.

The variables in the CCR model are μ_k and λ_j. The sufficient condition for efficiency of DMU '*k*' is that the optimum value μ_k 1. Otherwise, it is labeled as inefficient compared to other DMUs in the sample. The constraints in the model ensure that relative technical efficiency of DMU '*k*', given by μk never exceeds 1. In the CRS model, the technical efficiency estimated with input and output orientation is the same. The optimal value of μ will be the Farrell (technical) efficiency. A DEA run involves solving the above model *n* times, once for each DMU analyzed.

The measure of efficiency obtained from the solution to model (1) consists of two components:

i. Pure technical efficiency and scale efficiency. Banker, Charnes and Cooper (1984), proposed the variable-returns-to-scale (VRS) version of the model (1), denoted as BCC hereafter. The BCC model is (1) together with the additional constraint that captures returns to scale characteristics.

$$\sum^{n}{}_{j} = 1\lambda j = 1 \quad .... 2$$

The constraint given in (2) is referred to as the convexity constraint and accounts for VRS. BCC model measures technical efficiency only. Hence, the efficiency estimates obtained in the BCC model may be considered as pure technical efficiency estimates.

When the convexity constraint is removes the resulting model represents the CRS situation.

ii. The relative efficiency score obtained for a designated unit under CRS is a measure of overall technical efficiency of the unit and is always at least as much as the corresponding value obtained under VRS. The relative efficiency score obtained under VRS is a measure of pure technical efficiency. The difference in overall and pure technical efficiencies is attributed to scale efficiency. A measure of scale efficiency is simply the ratio of overall and pure technical efficiencies, (Don U.A.G and Piyadasa E., 2011).

2.4.2. Malmquist productivity index

Malmquist productivity index is defined using distance Functions. Suppose the function that describe the technology of production is given as:

F (X, Y) = 0

Where $X = (x_1, x_2, x_3, ..., x_M)$ is the input vector and

$Y = (y_1, y_2, y_3, ..., y_s)$ is the output vector

Caves, Christensen and Diewert, (1982) provided an alternative interpretation of production technology using the concept of 'distance function'. They defined the output distance function as:

$$D_o(x, y) = \min \mu(\mu : F(x, y/\mu) = 0)$$

Where μ_Y the minimum equi-proportional change in the output vector. The output distance function measures the maximum proportional change in output required to place (X,Y) on the efficiency frontier. If the evaluated production unit is efficient, D0 (x, y) = 1 otherwise, D 0 (x, y) < 1. Distance function may also be computed with input orientation, reference technology in a certain time period and CRS or VRS specification. Let D^t 0 (CRS) and D^t 0 (VRS) denote the output distance function computed with period technology and with CRS and VRS specification respectively.

Caves D.W, Christensen L.R and Diewert W.E (1982) defined the output based Malmquist productivity index to compare performance of a production unit in time period *t* and *t+1* with reference to period *t* technology as:

$$M_0^{t+1}(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)}$$

Mo > 1 indicates higher production in period t than in period t+1.

Fare, Grosskopf, Norris and Zhang, (1994) defines an index that incorporates Malmquist indices in both periods, this they suggest helps to avoid choice of the time period arbitrarily Fare Grosskopf, Norris and Zhang specified the based Malmquist productive change index as:

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \sqrt{[(\frac{d_0^{t}(x_{t+1}, y_{t+1})}{d_0^{t}(x_t, y_t)})(\frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)})]}$$

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = (\frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t}(x_t, y_t)})\sqrt{[(\frac{d_0^{t}(x_{t+1}, y_{t+1})}{d_0^{t}(x_t, y_t)})(\frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)})]}$$

Where $\frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t}(x_t, y_t)}$ is the change in relative technical efficiency between periods *t* and *t+1*

and $\sqrt{[(\frac{d_0^{t}(x_{t+1}, y_{t+1})}{d_0^{t}(x_t, y_t)})(\frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)})]}$ captures the shift in technology (technological change) between the two time periods evaluated at (Xt, Yt) and (X_{t+1}, Y_{t+1}). A value of less than 1 in the index indicates a decline in efficiency, equal to 1 indicates stagnation and greater than 1 indicates a growth between period *t* and *t+1* from the perspective of period *t* technology (Don U.A.G and Piyadasa E., 2011).

2.5. Empirical literature

2.5.1. Efficiency and Determinants

Several studies have been carried out on measuring the bank performance using the DEA approach. since the work of Charnes, Cooper and others (1978), in operations research in DEA technique and the approach developed by (Farrell, Fare and Grosskopf, 1990), in different countries.

Tanvir A. and Waseem A. (1998) made a study on the Analysis of Technical Efficiency in Banking Sector with Respect to Its Inputs and Outputs selection case of Pakistan. They consider outputs and inputs for the banking sector. Advances, investments and lending to financial institutions are considered as outputs of the bank while number of employees, bills payable, borrowing from financial institutions and deposits and other accounts are considered as inputs of the bank. Inputs of the commercial banks are considered as factors that produce profit. After analysis Commercial banks operating in Pakistan got 27 different technical efficiency scores under this specification of DEA and among these banks 7 got the highest technical efficiency score. Lowest technical efficiency score obtained by a bank under this specification is 0.003 so the highest input reduction under this specification that should be carried out by that bank to achieve obtained level of profit efficiently is about 99.70 per cent of the current level of inputs.

Mahadzir I. (2004) studied on, If PTE > SE, then inefficiency is caused by scale inefficiency. The results show that on average, the main source of inefficiency was caused by inappropriate scale operation. This implies that the banks have difficulty in finding an optimal combination between various inputs to produce the desired output.

Sunil K. & Rachita G. (2008), in their research used an intermediation approach to select input and output variables. The output vector contains two outputs: i) net-interest income, and ii) non-interest income, while input vector contains three inputs: i) physical capital, ii) Labor, and iii) loan able funds. The input-oriented efficiency scores obtained from the CCR and BCC models have been discussed.

According to Peter M. J. & Meryem D. F. (2000), made a study on the estimations of both bank size and bank profitability have significant positive effects on efficiency, indicating that the larger and more profitable banks have higher technical efficiency. On the other hand, the capital adequacy variable is significantly negatively related to the technical efficiency. This adverse effect on performance may reflect a risk-return trade-off in the sector. Banks with low-risk portfolios, as measured by a higher capital adequacy ratio are likely to be less efficient. This may be because they rather prefer safer and lower-earning portfolios over riskier but higher-earning portfolios. Interestingly, the number of branches, the second proxy for bank size, yields a negative and insignificant coefficient. The expansion of branch networks to direct services to rural as well as to metropolitan areas may have increased costs and thus, affected efficiency negatively. Another insignificant coefficient with negative sign is the ownership dummy. The negative coefficient on the state ownership binary variable confirms that state ownership worsens efficiency.

Ayadi, Adebayo and Omolehinwa, (2008), measured the bank performance in Nigeria by applying data envelopment analysis to the financial data of ten banks from 1991 to 1994. They used interest paid on deposits, total expenses, and total deposits as inputs while total loans, interest and non-interest incomes were considered as outputs. They found that banks in existence for long period of time were relatively efficient than other banks in the sample and banks having poor management showed bad performance and was key determinant of the bad performance of banks in Nigeria.

Tahir, Bakar and Haron (2009), found that Overall, for all the years (2000-2006), pure technical efficiency dominates the scale efficiency effects in determining the Malaysian commercial banks overall or technical efficiency. 79.6 percent of the banks experienced decreasing returns to scale, 7.5 percent experienced increasing returns to scale while 12.9 percent were operating at optimal scale.

Shanmugam and Das, (as cited by Prasad V.J. and Bhalerao J.V., 2011), studied on banking efficiency using stochastic frontier production function model during the reform period, 1992-1999. The study considers four input variables (viz. deposits, borrowings, labor and fixed assets) and four output variables (viz. net interest income, non interest income, credits and investments). They found that deposits are dominant in producing all outputs and the technical efficiency of raising interest margin is varied across the banks.

Prasad V. J. and Bhalerao J.V., (2011), DEA was used with Deposits, Interest expenses, Operating expenses and Assets as Inputs and Advances, Investments, Interest income and Non-interest income as outputs to analyze the efficiency of major representatives of commercial banks in India and it can be seen that most of the banks are satisfactorily efficient. The average performance of the banking sector ranges above 80%, which indicates the appropriate conversion of inputs into outputs. The public and the private sector are equally efficient; however the private sector has a margin over the public sector. The major factor resulting in the poor performance by these banks is their huge amounts of deposits, advances and other assets. So here either these banks possess blocked/non-performing assets or are not able to make a set off between the deposits and advances.

Omprakash K.G, Yogesh D., and Aneesh C., (2008) used intermediation approach with three inputs and two outputs, they determined the technical and scale efficiency of public sector banks for 1993. They found average technical inefficiency of 3.75 percent, of which two thirds was due to scale inefficiency. Hence they concluded that efficiency of banks in India could increase by increasing the scale.

Bhattacharya (2011), examined the efficiency of Indian banks using a two step procedure, DEA technique to determine the technical efficiency and then applying stochastic frontier approach to explain variation in calculated efficiency (as cited by Omprakash K.G, Yogesh D., and Aneesh C., 2008). They applied intermediation approach using two inputs (interest expense and operating expense) and three outputs (deposits, advances and investments) on five-year data of 70 banks, for the period 1986-1991. They constructed one grand frontier on the entire data set for DEA analysis and found that the public sector banks were more efficient than foreign banks, which in turn were marginally more efficient than private sector banks. The average efficiency of the sector as a whole was found to be 80.35 percent, ranging from an average of 75.37 percent for private sector banks and 87.40 percent for public sector banks. They also found that 78 percent of banks operated with decreasing returns to scale while 16 percent showed increasing returns to scale.

Bruce Q. B and Catherine R. B, (2006), used the Tobit model; six variables are regressed against the efficiency scores. It is important to note that the dependent variables in all models are obtained by transforming the DEA efficiency scores. Thus the sign of the coefficients are reversed – a positive coefficient implies an inefficiency increase whereas a negative coefficient means an association with inefficiency decline or increased efficiency. The proxy for bank size, log of total assets, shows a significant and negative coefficient suggesting the larger the bank, the more efficient the bank will be purely because of the economies of scale arguments.

The proxy for bank size, log of total assets, shows a significant and negative coefficient suggesting the larger the bank, the more efficient the bank will be purely because of the economies of scale arguments. The proxy for profitability that is log of net income also reveals a negative relationship with the inefficiency scores. The association suggests, the more profitable the bank, the more efficient the bank will be, on the assumption that greater efficiency translates into greater profits. The proxy for market power, individual bank‘s deposits/total deposits; reveal a negative statistical relationship, suggesting the more efficient banks are associated to the banks with the largest market share. Thus, supporting the assumptions that market leadership enhances greater efficiency. The proxy for risk, capital adequacy, also shows a negative relationship with inefficiency scores, that is, an inefficiency decline. The adequacy ratio acts as a proxy for bank’s attitude to risk. In the face of global competition, the UAE banks are safeguarding their reserves and banks, with large market concentration power, and are inclined to rely on loans which are less profitable but also less risky. Growth in total equity, the proxy for capitalization, shows a positive relationship with the dependent variable inefficiency. This is interpreted as the higher a bank's capitalization ratio, the less efficient is its performance.

Sathye (2003), conducted a study on the productive efficiency of 94 banks in India, including public sector and private sector banks and foreign banks, assuming VRS technology, applying DEA. The efficiency is calculated for 1996-97. In one model, he used interest expense and non-interest expense as inputs and interest income and non-interest income as outputs. A second DEA analysis was also run using deposits and staff members as inputs and loans and non-interest income as outputs. The study found that the average efficiency score of 0.83, and that the public sector banks were on average more efficient than foreign banks, which in turn were more efficient than private banks.

Tanvir A. and Zulfiqar A.G. (2007), worked to explain variations in the technical efficiency score of commercial banks under VRS due to important factors and results of this estimated Tobit model showed that the assets of the bank and markup interest earning were positively related to the technical efficiency of the commercial banks, while liabilities of the bank, non-markup interest earnings, markup and non-markup interest expenses contributed negatively to quantitative variables considered. Significant contributors to efficiency were total assets and liabilities at 5% level of significance. Ownership characteristic of the bank was also significant contributor in the efficiency of commercial banks. In the estimated Tobit model assets of the bank have significant positive impact on the technical efficiency of commercial banks under VRS. As far as the liabilities of the bank are concerned, it has negative effect on the technical efficiency of commercial banks under VRS. Commercial banks expenses can be categorized into markup interest expenses and non-markup interest expenses. From estimated models, one can see that the expenses have negative impact on commercial banks efficiency. Earning side of the commercial banks is captured by incorporating markup interest earning and non-markup interest earnings. Markup interest earnings have positive impact on the efficiency of commercial banks. Similarly, ownership characteristic of the bank has significant impact on the efficiency of commercial banks.

Akhtar *et al* (2010), made a study on implication of data envelopment analysis (DEA) in investigating the efficiency of commercial banks of Pakistan, By using data from 2006-2009 from annual report of the banks. The combination of inputs and outputs for their study were operating expense, advances and capital as input and operating income and net-interest income as outputs. For analysis they employ input-oriented DEA model. Their results show some very constructive managerial insights into evaluation and advancing of banking operations. Their estimated result shows that 6 banks are relatively efficient when their efficiency is measured in terms of 'constant return to scale' and 8 banks are relatively efficient when their efficiency is measured in terms of 'variable return to scale'. By improved handling of operating expenses, advances, capital and by boosting banking investment operations, the less efficient banks can successfully endorse resource utilization efficiency.

Ray, S. C (2011), studied on overall cost efficiency of a network of branches of a single large public sector bank in India within the city of Calcutta using the data for the year 2002. His objective is to determine the optimal number of branches within a postal district that could provide the observed amounts of banking services to the customers in that area at the minimum operating cost.

He uses total deposit and total credit as outputs and labor and physical capital are inputs. His DEA results show that while in many cases, consolidating multiple branches would be more cost efficient, there are numerous instances, where increasing the number of branches would be optimal and he finally summarized his main findings of the study as the actual number of branches of the bank exceeds the optimal number in most districts, many districts where it would be optimal to increase the number of branches, Eliminating cost inefficiency could result in 27% reduction in total costs and Another 8% saving could come from restructuring of the network primarily through consolidation of branches within the districts.

2.6. Productivity

Ly Kirikal (2005), compared the banks over the period of 1999-2002; and found that the newest and smallest bank in Estonia - Preatoni Bank has experienced the highest productivity growth and the highest catching up with the best practices but lower levels of technological change. He also obtained lower levels of productivity change that is mainly the result of the low catching up with the best practices and the high level of technological change, the high catching up with the best practices and therefore high level of productivity change. A biggest bank has experienced strong productivity growth and the highest technological change levels. Generally, he concludes that during 1999 to 2002, Estonian banks have increased productivity as a result of technological progress.

Fernandez, Gascon & Gonzalez (2006), studied the economic efficiency of 142 financial intermediaries from eighteen countries over the period 1989-1998 and the relationship between efficiency, productivity change and shareholders' wealth maximization. The authors applied DEA to estimate the relative efficiency of commercial banks of different geographical areas (North America, Japan and Europe). The European banks were from Austria, Belgium, Denmark, Finland, Germany, Ireland, Italy, Luxemburg, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. The three preferred outputs were total investments, total loans, and non-interest income plus other operating income. In parallel, the four input variables were property, salaries, other operating expenses and total deposits. All these values were expressed in billions of US dollars. Their results showed that commercial bank productivity across the world had grown significantly (19.6%) from 1989 to 1998. This effect had been principally due to relative efficiency improvement, with technological progress having a very moderate effect.

Schure, Wagenvoort and O'Brien (2006), estimated the productivity of the European banking sector for the period 1993-1997. They found that larger commercial banks were more productive on average than smaller banks. However, the Italian and the Spanish banks were found to be the least efficient.

Pasiouras (2008), used DEA to estimate sores efficiency of Greek commercial banking sector during the period 2000–2004. His results indicate that the inclusion of provisions on loans as input increases the efficiency score, but the off-balance sheet does not have a significant impact.

For Belkhiria (2009), who carried out a study on the impact of non-traditional activities on the performance of 10 Tunisian commercial banks measured by their cost efficiencies, lending activity is not a determinant of the efficiency of these banks because of the problem of nonperforming loans and the size of the credit institutions which implies stagnant economies of scale. Concerning non-traditional activities, they showed a significant and positive effect on bank efficiency.

Using DEA method, Sufian (2009), estimated the efficiency of the Malaysian banking sector during the Asian banking crisis in 1997; he found a significant and negative relationship between bank deposits and levels of efficiency. This implies that banks have small market shares are less efficient than banks with large market shares. On the other hand, results show that credit institutions which have ratios of loans relative to total assets amounted have higher efficiency scores. This positive relationship can be explained by the efficient market hypothesis, in fact the most efficient banks can achieve lower production costs, allowing them to offer more reasonable credits and win larger market share compared to inefficient banks. In addition, the variables ownership structure, size and profitability have a positive and significant effect on the efficiency of the Malaysian banking sector. He explained this by the fact that privately owned banks, large banks or those with high profitability are more efficient than public ownership of banks, small banks or those with low levels of profitability.

Ahmed et al (2009), conducted a study on banking efficiency dynamics with financial sector reforms effect. They used a dataset of 20 domestic commercial banks based in Pakistan and measured their efficiency using Data Envelopment Analysis-Malmquist Productivity Index of Total Factor Productivity (TFP) from 1990-2005. Caves et al (1982) initially proposed the idea of Malmquist index in the parametric frontier framework. The index measures the total factor productivity change between two data points over time. The idea was further extended by Berg et al (1991) to non-parametric frontier. For estimation purpose, they employed deposits, labour and capital as inputs and loan advances and investment as outputs. They divided their sample period into three periods, pre-reform period (1991-1997), first-reform period (1998-2001) and second-reform period (2002-2005). The data was collected from State Bank of Pakistan annual issues. Results showed that in the first phase of reforms technological change decreased by 14.3% along with total factor productivity by 12.2% but technical efficiency change increased to 2.1%. In second phase of reforms, total factor productivity, technological change and technical efficiency change was increased by 17.4%, 14.6% and 2.4% respectively. The results supported the hypothesis that the financial reforms improved the banking efficiency of Pakistan banking sectors.

Eken, M.H. and Kale, S. (2010), demonstrated performance model to measure the relative efficiency and potential improvement capabilities of bank branches by identifying their strengths and weaknesses. Another purpose of the study was to investigate the production and profitability aspects of the bank branches. Under both production and profitability approaches, efficiency characteristics of branches, which were grouped according to different sizes and regions, had similar tendencies. In both analyses, it is apparent that branch size and scale efficiency are related to each other. As branch size increases scale efficiency increases too and after the most productive scale size, however, as size increases efficiency decreases. Too small and too large branches need special attention. Putting production and profit efficiency scores on two scales revealed the performance characteristics of branches. Each region needs different handling. Branches with low production-low profit efficiency should be evolved towards high production-high profit efficiency region.

Chawki and Hassan (2010) conducted a study on assessment of the productive performance of Islamic banks operating in the GCC region, over the period 2005 - 2008. Therefore, they evaluated the productive performance of Islamic banks with the method of productive efficiency proposed by Farrell (1957). they used the method of data envelopment analysis (DEA) to decompose the productive efficiency into technical efficiency, allocative efficiency and cost efficiency .The using of this technique on a sample of 23 Islamic banks reveals that the technical inefficiency and allocative inefficiency improved bank costs, on average, by about 14% and 29% respectively. The results explained that internal and external factors seem to contribute significantly to the evolution of efficiency scores of Islamic banks operating in the GCC region.

Manlagñit, MCV (2011), examined the cost efficiency of Philippine commercial banks using the SFA method for estimating the efficiency scores. The results show that the level of inefficiency is important for national banks and risk and asset quality negatively affect the efficiency of these banks. This substantial increase in the cost-inefficiency could be attributed to the adverse effects of the Asian crisis of 1997, the cost of banking reform and regulatory changes that have been adopted to stabilize and strengthen the sector.

Nur Azura and others in (2011), the studied to examine the competitiveness of Malaysian and Indonesian commercial banks from 2001 -2007, by using the data envelopment analysis. The sample of banks was 27 Malaysian commercial banks and 21 Indonesian commercial banks. The application of Data Envelopment Analysis (DEA) methodology is formulated as a tool to estimate the technical efficiency as well as to evaluate the organization efficiency and it is more comprehensive compare with other approach. The finding has shown that no striking differences in technical efficiency of Malaysian and Indonesian commercial banks Even though commercial banking in Malaysia relatively stables in reach the level efficiency compared with commercial banking in Indonesia.

Williams (2012), examined the relationship between bank efficiency and market power for a sample of 419 commercial banks in Latin America for the period 1985–2010. The results suggest that the restructuring of banks has encouraged competition to the detriment of market power, and they had efficiencies under conditions of monopolistic competition.

Ayadi (2013), studied the x-efficiency of Tunisian commercial banks for the period 1996–2010 using DEA method. The results suggest that the cost efficiency of the sector is estimated at a score of 41.0%. Market share in terms of deposit of the banks and their involvement in risky activities including a credit negatively affecting their efficiency. High bank capitalization positively influences the latter. In addition, state-owned banks are more efficient than their private counterparts. A review of the empirical literature on banking efficiency shows that the results of its review differ between countries, types of banks and estimation methods used. It seems indeed, that the selection the most appropriate method to use to measure the efficiency of banks is important.

CHAPTER THREE

METHODOLOGY

In this section the study presents the methodology part of the research. The first section states the research design used in the study followed by data type & source, sampling method, method of data analysis and procedure finally model & variable description.

3.1. Research design

The researcher used quantitative methods by using DEA analysis model to assess the technical efficiency of selected commercial banks of Ethiopia. Therefore, the researcher is purely used quantitative data.

3.2. Data Type and sources

The researcher used in this study only secondary data which is audited financial statements of selected commercial banks from 2007 – 2013. To measure the efficiency of the banks, it requires having a quantifiable standard which can be determined by those productive units which share a common technology.

3.2.1. Specification of inputs and outputs

According to Boitumelo M. and Abbas V. (2009), there is no consensus in the frontier modeling literature regarding the specification of outputs and inputs. However, it is commonly acknowledged that the choice of variables in efficiency studies can significantly affects the results. The problem is compounded by the fact that the choice of variables (both inputs and outputs) is often constrained by the availability of data on relevant variables. The input and output measurements are especially difficult because most financial services/products are jointly produced and prices are typically assigned to a bundle of financial services. However, there are several different approaches in the literature as how to specify the input-output mix. Inter alia, these include

- The intermediation approach
- The modern (value-added) approach
- The operating approach

Based on the argument of (Casu and Molineux, 1999), that the first approach **intermediation approach** is best for evaluating the importance of frontier efficiency to the profitability of financial institutions because minimization of total costs is needed to maximize profits and not just minimization of production costs alone. According to the intermediation approach, financial institutions are regarded as intermediates that transform and transfer financial assets from savers to borrowers. Financial institutions produce intermediation services through the collection of deposits and other liabilities and then utilize them in interest-earning assets, such as loans, securities and other types of investments (Leightner and Lovell, 1998). This approach includes: deposits, labor (salaries), and capital related operating expenses as inputs, whereas loans and other major assets count (investment) as outputs. In this study intermediation approaches was used.

The production approaches which views, bank as institution that uses capital and labor to produce loans and deposit accounts or deposit. In this approach investment, loans and deposits are treated as outputs, measured in terms of the number of accounts. The common inputs are salary expense and operating expense and interest expenses paid on deposits because deposits are viewed as output (Berger &Humphrey, 1985, Yue, 1991).

Berger and Humphrey (1997), suggested the intermediation approach is best suited for analyzing bank level efficiency, whereas the production approach is well suited for measuring branch level efficiency. This is because, at the bank level, management will aim to reduce total costs and not only non-interest expenses, while at the branch level, a large number of customer service processing transactions take place and bank funding and investment decisions are mostly not under the control of branches. In most studies the banks outputs are loans and their inputs are various costs including interest expense, salary expense, and operating expense (Yue, 1991).

Finally, the **operating approach** (or income-based approach) views financial institutions as business units with the final objective of generating more revenues given total costs incurred for running a business (Leightner and Lovell, 1998). This approach defines institutions’ output as total revenues (interest and non-interest) and their inputs as total expenses (paid interest and operating expenses).

Table 3.1: Choice of input/output variables under the three approaches

Approach	**Inputs**	**outputs**
Intermediation	Deposits Labor (Salaries) Capital related operating Expenses	Loans Investment
Value-added (Production)	Labor(salaries) Capital related operating Expenses Interest expenses	Loans Investment Deposits
Operating (income)	Interest expenses Labor (salaries) Capital related operating Expenses	Interest income Non-interest

Source: Das and Ghosh (2006) (cited by Boitumelo M. and Abbas V. 2009)

3.3. Sampling Method

To carry out the study, eight commercial banks were selected based on purposive sampling technique. Even if there are nine private banks in 2007, Oromiya Cooperative Bank had not an experience of five years whereby at 2007, so this method is taken as appropriate to include those banks experienced over five years stay in the market after inaugurating. The names of banks are: Abyssinia Bank, Awash International Bank, Construction and Business Bank, Commercial Bank of Ethiopia, Dashen Bank, Nib International Bank, United Bank and Wegagen Bank.

3.4. Method of Data Analysis tool

This study used data envelopment analysis (DEA) tool in order to analyze the quantitative data which were obtained from the sample. DEA is a non- parametric linear programming technique that computes a comparative ratio of inputs and outputs for each sample or decision making units. The basic idea of DEA is to identify the most efficient decision-making unit (DMU) among all DMUs. The DEA efficiency score is usually expressed as either a number between zero and one or 0 and 100 per cent. The researchers employed this technique because it has the following *advantage.* These are:-

- ✓ DEA is particularly useful because it can simultaneously accommodate multiple outputs and inputs and does not require specific knowledge of the efficient absolute or relative amounts of inputs required for each decision making unit output (DEA can handle multiple input and multiple output models).
- ✓ Decision making unit located as inefficient are strictly inefficient, and there is no problem of false identification of efficient decision making unit as inefficient provided that all relevant outputs and inputs are included in the set.
- ✓ DEA indicates the general magnitude of inefficiencies present in the decision making unit.
- ✓ DEA objectively locates inefficient decision making unit without the need for an arbitrary cut off point to separate potentially inefficient and efficient decision making unit as is needed for ratio analysis.

- ✓ DEA locates technical or pare to inefficiencies in a manner more consistent with economic theory than econometric regression techniques i.e. DEA measures efficiency compared with the best decision making unit rather than based on mean or central tendency relationship that reflects a mixture of efficient and inefficient behavior (DMUs are directly compared against a peer or combination of peers).
- ✓ It doesn't require an assumption of a functional form relating inputs to outputs.
- ✓ Inputs and outputs can have very different units. For example, X1 could be in number of personnel and X2 could be in units of dollars without requiring an a priori tradeoff between the two.

The same characteristics that make DEA a powerful tool can also create problems. Any researcher should keep these limitations in mind when choosing whether or not to use DEA.

- ✓ Since DEA is an extreme point technique, noise (even symmetrical noise with zero mean) such as measurement error can cause significant problems.
- ✓ DEA is good at estimating "relative" efficiency of a DMU but it converges very slowly to "absolute" efficiency. In other words, it can tell you how well you are doing compared to your peers but not compared to a "theoretical maximum."
- ✓ Since DEA is a nonparametric technique, statistical hypothesis tests are difficult and are the focus of ongoing research.
- ✓ Since a standard formulation of DEA creates a separate linear program for each DMU, large problems can be computationally intensive (Farrell, Fare and Grosskopf, 1990).

3.5 Model specification

There are several alternative models in the DEA. Each model seeks to identify the DMU that provides the best efficiency frontier. This paper use DEA ***input oriented*** models which are introduced by Charnes, Cooper, and Rhodes in 1978 and Banker, Charnes, and Cooper1984, where the first model assumes ***constant returns to scale***, and the second assumes ***variable-returns to scale***.

3.5.1 Specification of CCR model/CRS

The first standard DEA model as proposed by Charnes, Cooper, and Rhodes (1978), in ratio form is expressed as follows:

$$\max_{u,v} h0 = \frac{\sum_r^n uryrj0}{\sum_i^n vi\ xij0}$$

Subject to:

$$\frac{\sum_r^n uryrj}{\sum_i^n vixij} \leq 1, \qquad j = 1,2,\ldots,n \qquad (1)$$

$u_r, v_i \geq 0$

Where $\mathbf{x_{ij}}$ is the input vector and $\mathbf{y_{ij}}$ is the output vector. The $\boldsymbol{u_r}$ and $\mathbf{v_i}$ are variables of the problem and are constrained to be greater than or equal to 0 in order to avoid any input or output being ignored in computing the efficiency. The solution to the above model gives a value **h**, the efficiency of the unit being evaluated. If **h =1** then this unit is efficient relative to the others. But, if it is less than l then some other units are more efficient than this unit that determines the most favorable set of weights. This flexibility can be a weakness because the judicious choice of weights by a unit possibly unrelated to the value of any input or output may allow a unit to appear efficient.

To solve the model, we need to convert it into linear programming formulation, which is as follows:

Max h$=\sum_r^n uryr0$

Subject to:

$\sum_r^n uryrj - \sum_i^n vixij \leq 0, \qquad j = 1,2,\ldots,n$

$$\sum_i^n vixij0 = 1 \qquad (2)$$

$$v_i \geq 0, \qquad i = 1,2,\ldots,m$$

$$u_r \geq 0, \qquad r = 1,2,\ldots,t$$

For the above linear programming problem, the dual can be written (for the given DMU_0) as:

$\min_{\lambda} Z_0 = \Theta_0$

Subject to:

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0}, \quad r = 1,2,\ldots,s$$

$$\Theta_0 \, x_{i0} - \sum_j \lambda_j x_{ij} \geq 0, \; i = 1,2,\ldots,m \qquad (3)$$

$$\lambda_j \geq 0, \quad j = 1,2,\ldots,n$$

The dual variables **λ** *'s* are the shadow prices related to the constraints limiting the efficiency of each unit to be no greater than 1. The binding constraint implies that the corresponding unit has an efficiency of 1 and there will be a positive shadow price or dual variable. Hence, positive shadow prices in the primal or positive values for **λ** *'s* in the dual correspond to and identify the peer group for any inefficient unit. Both above linear problems yield the optimal solution Θ^*, which is the efficiency score (so-called technical efficiency or CCR-efficiency) for the particular DMU_O, and repeating them for each DMU_j, j=1, 2..... ,n, efficiency scores for all of them are obtained. The value of Θ is always less than or equal to unity (since when tested, each particular DMU_O is constrained by its own virtual input-output combination too). DMUs for which $\Theta^* < 1$ are relatively inefficient and those for which $\Theta^* = 1$ are relatively efficient, having their virtual input-output combination points lying on the frontier.

3.5.2 Specification of BCC model/VRS

The above models assume CRS. If we add a variable to the model, we can construct a DEA model with VRS. Variable returns mean that we might get different levels of output due to reduced performance or economies of scale. Banker, Charnes, and Cooper (1984) propose the following DEA model, which we call the BCC model as follows:

Max h= $\sum_{r} u_r y_{r0} - u_o$

Subject to:

$\sum_{r} u_r y_{rj} - \sum_{i} v_i x_{ij} \leq 0$, j = 1,2,…,n

$$\sum_{i} v_i x_{ij0} = 1 \qquad (4)$$

$v_i \geq 0$, i= 1,2,…,m

$u_r \geq 0$, r = 1,2,…,t

For the above BCC model the dual can be written as follows:

$\min_{\lambda} Z_0 = \Theta_0$

Subject to:

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0}, \qquad r = 1, 2, \ldots, t \qquad (5)$$

$$\Theta_0 x_{i0} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0, \qquad i = 1, 2 \ldots m$$

$\sum_{j=1}^{n} \lambda_j = 1$

$\lambda_j \geq 0$, j = 1, 2,…, n

The efficiency computed from the BCC model is pure technical efficiency; whereas, the one from CRS model is an aggregate measure of technical and scale efficiency. Pure scale efficiency can therefore be defined to be CRS efficiency over BCC efficiency, (Banker et al., 1984).

3.5.6. The Malmquist productivity index

The Malmquist productivity index was used to measure the productivity of the banks over the given period of time and decomposed it to arrive at the technical efficiency change and technological changes. According to the following equation:

$$M(x_t, y_t, x_{t+1}, y_{t+1}) = \sqrt{\left(\frac{d_{t+1}(x_{t+1}, y_{t+1})}{d_t(x_t, y_t)} \frac{d_t(x_{t+1}, y_{t+1})}{d_{t+1}(x_{t+1}, y_{t+1})} \right)}$$

This decomposed into

$$M(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{d_{t+1}(y_{t+1}, x_{t+1})}{d_t(y_t, x_t)} \sqrt{\left(\frac{d_t(y_{t+1}, x_{t+1})}{d_{t+1}(y_{t+1}, x_{t+1})} * \frac{d_t(y_t, x_t)}{d_{t+1}(y_{t+1}, x_{t+1})}\right)}$$

= Technical efficiency change (TEC)* Technological change (TC)

CHAPTER FOUR

RESULTS AND DISCUSSION

The main objective of this paper is to assess technical efficiency of selected commercial banks in Ethiopia. This chapter is divided in to six sections the first section deals about the data description of the study, section-2 covers overall technical efficiency, section–3 deals about decomposing overall technical efficiency into scale and pure technical efficiency, section–4 covers peers characteristics of the banks, section–5 presents about slack characteristics of banks and section–6 deals about malmquist Productivity Index of the Commercial Banks.

4.1 Data description

In this study, eight commercial banks were selected purposively, namely, Abyssinia Bank, Awash International Bank, Construction and Business Bank, Commercial Bank of Ethiopia, Dashen Bank, Nib International Bank, United Bank and Wegagen Bank for the period of seven years from 2007 to 2013 G.C to assess their technical efficiencies.

Technical efficiency can be viewed from two perspectives. The first one is Input Oriented Technical Efficiency which focuses on the possibility of reducing inputs to produce given output levels and the second one is Output-Oriented Technical Efficiency which considers the possible expansion in outputs for a given set of input quantities. In this study, the banks efficiency were measured with input orientation method.

To quantify a measure of technical efficiency, it needs to find out the divergence between actual production and production on the boundary of the feasible production set. This set summarizes all technological possibilities of transforming inputs into outputs that are available to the organization. Technical efficiency measured under the assumption of Constant Return to Scale (CRS) represents the Overall Technical Efficiency (OTE) which measures the inefficiency due to the input/output maladjustment and the size of operation.

4.2 Overall technical efficiency

The data were collected using secondary source from audited financial statement of selected Commercial Bank of Ethiopia by using DEA computer program which is introduced by Coelli (1996) that employed for measuring the technical efficiency of Decision Making Unit (DMU). The researcher used this software for the assessment of technical efficiency of selected commercial bank of Ethiopian by using intermediation approaches based on input orientation.

The efficiency score results of the banks, which are under consideration for this study, was displayed using DEA software. Table 4.1 indicates that those banks which are relative efficient having efficiency score of **1**. On the other hand, those banks with relative inefficiencies do have scores less than **1**. If the efficiency scores are less than **1**, it means they can achieve the existing level of output with less amount of input (as it is an input oriented approach).

Table 4.1: Over all technical efficiency score under CCR

DMU	Year						
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
CBE	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CBB	1.000	1.000	1.000	1.000	1.000	0.808	0.959
DB	0.902	1.000	0.902	0.914	1.000	0.994	0.930
AIB	0.777	0.965	0.777	0.788	0.968	0.981	0.920
BOA	0.734	0.989	0.734	0.932	0.952	0.958	1.000
WB	0.762	0.872	0.762	1.000	0.895	1.000	0.998
UB	0.855	0.967	0.855	0.856	1.000	0.985	0.922
NIB	0.872	1.000	0.872	0.823	0.965	1.000	1.000

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

The above Table 4.1 shows the Overall Technical Efficiency (OTE) of selected Ethiopian commercial banks within the years 2007-2013 under the Constant Return to Scale (CRS) using Data Envelopment Analysis (DEA). The OTE shows the configuration of inputs and outputs in the intermediation process of the DMU. The efficiency result of the banks during the year of 2007 was 1.0000 for CBE & CBB for year 2008 were CBE, CBB, DB & NIB. But AIB, BOA, WB, UB were OTIE. For instance AIB overall technical efficiency score of 0.777 and 0.965 on 2007 & 2008 respectively. This implies that the bank is 77.7% and 96.5% efficient in these years as compared to its peers. To become efficient AIB must reduce their input by 4.255 and increase the output by 1.687. (See from appendix).

The overall technically inefficient bank in the year 2009 and 2010 were: DB, AIB, BOA, WB, UB and NIB with OTE score of 0.902, 0.777, 0.734, 0.762, 0.855, 0.872 and 0.914, 0.788, 0.932, 0.856and 0.823 respectively. But, WB became efficient in 2010. The technically inefficient bank has a chance to become efficient as their peers by reducing their input by extent of their input slacks.

The overall technically inefficient bank in the year 2011, 2012 & 2013 were: AIB, BOA, WB & NIB, CBB, DB, AIB, WB, & UB, and CBB, DB, AIB, WB & UB with OTE score of 0.968, 0.952, 0.895 & 0.965, 0.808, 0.994, 0.981, 0.958 & 0.985 and 0.959, 0.930, 0.920, 0.998 and 0.922 respectively. The above technically inefficient banks will be an adjustment efficient as their peer by reducing and adjusting their input and output mix to became on the efficient frontier.

Recall that the bank with OTE of 1.0000 is considered to be most efficient amongst the banks included in the analysis. The bank with OTE score of less than 1.0000 is then to be relatively inefficient. Banks which have OTE score of 1.0000 are used as a best practice or efficient frontier and form the reference set for inefficient banks. The input utilization process in these efficient banks is functioning well. This means that the production process of these banks was characterizing relatively good input utilization.

4.3 Decomposing overall technical efficiency into scale and pure technical efficiency

The overall technical efficiency under CRS which assumes DMUs operate at an optimal level. However, all DMUs may not operate at an optimal level due to different factors. This was the reasons that lead to decompose the OTE into PTE and SE under the VRS. This was done by conducting both CRS and VRS using the same data. When there is a difference between the two, overall and pure technical efficiency, for a particular DMU, it indicates scale inefficiency. OTE helps to measure the inefficiency of the two, pure technical and scale inefficiency, under the BCC model, with VRS assumption. PTE measures the managerial performance of the given DMU and SE also indicate about the appropriateness of bank size and scale operations.

Table 4.2: **Efficiency scores under BCC**

Year	DMU	Constant return to scale	Variable return to scale(Pure)	Scale efficiency	Return to scale
2007	**CBE**	1.000	1.000	1.000	Constant
	CBB	1.000	1.000	1.000	Constant
	DB	1.000	1.000	1.000	Constant
	AIB	0.953	0.956	0.997	Increasing
	BOA	0.908	0.941	0.965	Decreasing
	WB	0.857	0.938	0.914	Decreasing
	UB	1.000	1.000	1.000	Constant
	NIB	1.000	1.000	1.000	Constant
2008	**CBE**	1.000	1.000	1.000	Constant
	CBB	1.000	1.000	1.000	Constant
	DB	1.000	1.000	1.000	Constant
	AIB	0.965	0.999	0.966	Increasing
	BOA	0.989	0.995	0.994	Increasing
	WB	0.872	1.000	0.872	Decreasing
	UB	0.967	1.000	0.967	Increasing
	NIB	1.000	1.000	1.000	Constant
2009	**CBE**	1.000	1.000	1.000	Constant
	CBB	1.000	1.000	1.000	Constant
	DB	0.902	1.000	0.902	Decreasing
	AIB	0.777	0.865	0.899	Decreasing
	BOA	0.734	0.799	0.918	Decreasing
	WB	0.762	0.823	0.927	Decreasing
	UB	0.855	0.912	0.938	Decreasing
	NIB	0.872	1.000	0.872	Decreasing
2010	**CBE**	1.000	1.000	1.000	Constant
	CBB	1.000	1.000	1.000	Constant

	DB	0.914	0.927	0.986	Decreasing
	AIB	0.788	0.810	0.972	Increasing
	BOA	0.932	0.943	0.989	Decreasing
	WB	1.000	1.000	1.000	Constant
	UB	0.856	0.869	0.985	Decreasing
	NIB	0.823	0.908	0.906	Increasing
2011	**CBE**	1.000	1.000	1.000	Constant
	CBB	1.000	1.000	1.000	Constant
	DB	1.000	1.000	1.000	Constant
	AIB	0.968	0.972	0.996	Decreasing
	BOA	0.952	0.973	0.978	Decreasing
	WB	0.895	0.898	0.996	Decreasing
	UB	1.000	1.000	1.000	Constant
	NIB	0.965	0.971	0.994	Decreasing
2012	**CBE**	1.000	1.000	1.000	Constant
	CBB	0.808	1.000	0.808	Increasing
	DB	0.994	1.000	0.994	Decreasing
	AIB	0.981	0.983	0.998	Decreasing
	BOA	0.958	1.000	0.958	Increasing
	WB	1.000	1.000	1.000	Constant
	UB	0.985	1.000	0.985	Increasing
	NIB	1.000	1.000	1.000	Constant
2013	**CBE**	1.000	1.000	1.000	Constant
	CBB	0.959	1.000	0.959	Increasing
	DB	0.930	0.993	0.937	Decreasing
	AIB	0.920	1.000	0.920	Decreasing
	BOA	1.000	1.000	1.000	Constant
	WB	0.998	1.000	0.998	Increasing
	UB	0.922	0.935	0.985	Increasing
	NIB	1.000	1.000	1.000	Constant

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

Table 4.2 reveals the pure technical and scale efficiency scores of the banks. It has been observed that in 2007 and 2008, CBE, CBB, DB, UB and NIB were scored pure technical and scale efficient. This result shows that there was a good performance of management and had appropriate bank sizes operations during the year of 2007 and 2008, But in the year 2008, UB was inefficient. The PTE and SE of inefficient bank were: AIB, BOA, and WB with a score of 0.956, 0.941 and 0.938 (PTE) and 0.997, 0.965 and 0.914 (SE) during the year 2007 respectively and The PTE and SE of inefficient bank were: AIB, BOA, and WB with a score of 0.999, 0.995 & 1.000 (PTE) and 0.966, 0.994 & 0.872 (SE) during the year 2008 respectively. This inefficiency result was due to under performance of the management in efficiently managing the input. This scale inefficiency result was due to inappropriateness of bank sizes (inappropriate productive bank scale operation) during the given years.

In the year 2009 and 2010, the SE of inefficient bank were: DB (0.902), (AIB), (0.899), BOA (0.918), WB (0.927), UB (0.938), NIB (0.872) and DB (0.986), (AIB), (0.972), BOA (0.989), UB (0.985), NIB (0.906), respectively. This indicated that the major source of banks inefficiency in the year 2009 and 2010 was scale inefficiency. This means that the banks were relatively efficient in management performance than their scale of operation.

The PTE and SE of inefficient bank in 2011 were: AIB (0.972), BOA (0.973), WB (0.898), NIB (0.971) and AIB (0.996), BOA (0.978), WB (0.996), NIB (0.994), respectively. This result shows that there was not a good performance of management and has not appropriate bank sizes operations during the year of 2011. But the remaining banks i.e. CBE, CBB, DB and UB has no change. This result shows that there was a constant performance of management and has no increasing proportionate change in bank sizes operations during the year 2011.

The PTE and SE of inefficient bank in the year 2012 were only AIB (0.983), (0.998) and in the year 2013 the PTE and SE of inefficient bank were: DB (0.993), (0.937) and UB (0.935), (0.985). This result shows that there was not a good performance of management and has not appropriate bank sizes operations during the year of 2012 and 2013.

In the year 2012 and 2013, the SE of inefficient bank were: CBB (0.808), (DB), (0.994), AIB (0.998), BOA (0.958), UB (0.985) and CBB (0.959), DB (0.937), AIB (0.920), WB (0.998) and UB (0.985). This indicated that the major source of banks inefficiency in the year 2012 and 2013 is scale efficiency. This means that the banks were relatively efficient in management than their scale of operation.

4.4 Peers characteristics of the banks

Additionally, DEA technique is a best tool for benchmarking as it allows the discovery of most efficient DMU for each inefficient DMU. The discovery of the most frequent reference set or peers for inefficient banks indicates to which of the efficient banks an inefficient bank is closest in its combination of inputs and outputs. A bank, which appears frequently in the reference set is likely to be a bank which is efficient bank that appear seldom in the reference set of other banks are likely to possess a very uncommon input and output mix and are thus not suitable examples for other inefficient banks. Out of eight (8) banks, only four (4) banks were of these the one that appears more frequently as peer (benchmark) is CBE, CBB, DB and NIB. This implies that, the peer count number can be considered as a measure of the extent to which the performance of an efficient bank can be useful for the inefficient banks. (See from appendix).

4.5 Slack characteristics of banks

The slack characteristics provide an insight to the areas which banks needs to improve and became efficient as its peers (reference). Slacks are existed only for inefficient banks which need improvement in their input and output mixes. This slack represents only the portion of inefficiency that is needed to push the banks to efficient frontier. In input oriented DEA model, input slacks represent the input excess used that are required to reduce and the output slack represents the output which is under produced by the branch collie (1996). Technically inefficient banks to be relatively efficient, either they should decrease their excess level of inputs without changing their outputs or increase insufficient level of outputs without altering their level of inputs.

Table 4.3: Slack amount of inputs

Year	Input	Slack amount for inefficient banks					
		AIB	BOA	WB	UB	DB	NIB
2007	Salary expense	6.396	1.198	10.405	-	-	-
	Operating expense	-	-	-	-	-	-
	Deposit	533.742	-	-	-	-	-
2008	Salary expense	-	-	-	-	-	-
	Operating expense	-	116.071	-	-	-	-
	Deposit	-	116.628	-	-	-	-
2009	Salary expense	0.750	2.866	16.889	5.126	-	-
	Operating expense	-	-	-	2.847	-	-
	Deposit	-	-	-	-	-	-
2010	Salary expense	2.269	6.192	-	-	-	-
	Operating expense	-	-	-	19.916	20.014	29.874
	Deposit	-	-	-	-	-	-
2011	Salary expense	26.880	4.834	40.534	-	-	27.965
	Operating expense	-	-	76.219	-	-	37.684
	Deposit	-	-	-	-	-	-
2012	Salary expense	13.559	-	-	-	-	-
	Operating expense	9.249	-	-	-	-	-
	Deposit	-	-	-	-	-	-
2013	Salary expense	-	-	-	-	-	-
	Operating expense	-	-	-	51.650	16.487	-
	Deposit	-	-	-	-	-	-

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

The inefficient banks were required to make adjustment on their input to became efficient and to appear on efficient frontier. For instance, AIB was inefficient because of management inefficiency in effectively managing the input and output mix. Based on the input orientation, AIB was required to make decrease on input. For instance, the input slack for AIB for the year 2007 were salary expense and increase deposit respectively, with slack amount of 6.396 and 533.742. So, AIB to become efficient with a target input amount of 29.941 & 2442.000 to lie on the efficient frontier. For year 2009, the input which required adjustment was only salary expense with a slack amount of 0.750 with target adjusted amount of 49.081 to became efficient just like that of its peer. For the year 2010 & 2011, the input which required adjustment were salary expense respectively, with a slack amount of 2.269 & 26.880 to become efficient. In the year 2012, the inefficiently utilized inputs were salary expense and operating expense with amount of 13.559 and 9.249 respectively. It can be concluded that AIB adjusted the salary expense by increasing their scale of operation by launching new branches and shuffling exiting employee to new branches and try to minimize those controllable operating expenses. In the year 2013, the inefficient utilized input were only operating expense with amount of 51.650 (UB) and 16.487 (DB). It can be concluded that DB was relatively better than UB, but both banks adjusted the operating expense by increasing their management performance related to controllable operating expense.

4.6 Malmquist Productivity Index of the Commercial Banks

As in most of the cases, the shift of the border was negative and constant and it maybe concluded that MPI variations are mostly caused by a change in relative to TE. MPI greater than one represent a positive change of TFP, while MPI less than one mark a negative change of TFP. The first component of MPI, change in relative TE, has changed considerably. Change in TE by greater than one marks a positive change in relative TE, i.e., some given bank‘s approximation to the efficient productive frontier, while a value of change in TE less than one indicates a movement away from the said frontier. Which does not necessarily have to indicate any fall in the productivity of a given bank, but can simply because by a positive shift of the frontier. A bank whose value of change in TE is one has retained the same relative position with respect to the frontier.

The TFPCH was the result of EFFCH and techch between the two periods. TC is a measure of technical change in the production technology. It was an indicator of technological improvement between the periods. Technological change results may be greater, equal or less than one which means that there was an improving, constant and deteriorating change within the periods.

After defining the productivity of a firm as the ratio of outputs that it produces to the inputs used, the larger values of this ratio are associated with better performance. The MPI DEA result for year 2008 present on the table 4.4 below by assuming Productivity is a relative concept.

Table 4.4: Malmquist index summary of 2008

DMU	EFFCH	TECHCH	PECH	SECH	TFPCH
CBE	1.000	1.094	1.000	1.000	1.094
CBB	0.993	0.784	1.000	0.993	0.779
DB	1.000	0.823	1.000	1.000	0.823
AIB	0.973	0.829	1.000	0.973	0.806
BOA	1.080	0.826	1.059	1.020	0.891
WB	1.163	0.805	1.042	1.116	0.936
UB	0.983	0.810	1.000	0.983	0.797
NIB	1.000	0.832	1.000	1.000	0.832
Mean	**1.022**	**0.846**	**1.012**	**1.010**	**0.865**

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

The DEAP results in Table 4.4 represents that during the year 2008, all commercial banks of Ethiopia had tfpch are less than one except CBE. The TFPCH greater than one means there was productivity improvement unless it means constant or deterioration of productivity. The productivity of the banks is deterioration from what was in the year 2007. So, TFPCH was the result of the change in scale efficiency, management efficiency and technology. During the period two banks BOA (8%) &WB (16.3%) showed improvement on their efficiency. These change in overall efficiency result because of improvement in management performance & an increase in bank operation size.

The scale efficiency changes (SECH) for CBE, DB & NIB, are constant from the previous year except CBB, AIB and UB with a decrease in their scale with a value of 0.7%, 2.7% and 1.7% in the year 2008 in relative to 2007. The only bank that show improvement in their scale of operation were BOA (2%) & WB (11.6%). These improvements in the bank size may be due to change in deposit by 12.2% (from financial statement data), change in amount of loan granted to customer, opening new branches. The management efficiency changes (PECH) of the banks were also constant for CBE, CBB, DB, AIB, and UB & NIB with an exception of BOA and WB improvement with the value 5.9% and 4.2% respectively from previous year.

Regarding the TECHCH, only CBE with an amount of 9.4% improvement over its peers in the year 2008 than 2007. But the remaining banks showed a decline in adapting new technology.

The overall productivity (TFPCH) of the bank experienced a deterioration of productivity in the year 2008 from the previous year except CBE. The main reason improvement in overall productivity of CBE was because of improvement in technology, management efficiency and scale efficiency in the year 2008 than 2007. Improvement on the overall productivity of CBE results due to new technology adaptation. Application of machines (electronics devise) i.e., computer, cash counting machine, *etc* than manual system maybe the reason for improvement in productivity.

Table 4.5: Malmquist index summary of 2009

DMU	EFFCH	TECHCH	PECH	SECH	tfpch
CBE	1.000	1.195	1.000	1.000	1.195
CBB	1.007	0.911	1.000	1.007	0.918
DB	0.902	0.930	1.000	0.902	0.840
AIB	0.799	0.939	0.865	0.924	0.750
BOA	0.742	0.916	0.803	0.924	0.680
WB	0.762	0.917	0.823	0.927	0.700
UB	0.870	0.930	0.912	0.954	0.809
NIB	0.872	0.901	1.000	0.872	0.786
Mean	**0.864**	**0.951**	**0.922**	**0.938**	**0.822**

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

The DEA result on Table 4.5 above reveals that on 2009 all commercial banks have a tfpch score of less than one except CBE which had a score of greater than one which reveals that improvement in overall productivity. For banks that have TFPCH value of less than one represents there is deterioration in productivity. The deterioration or improvement of TFPCH is the result of change in technology, management efficiency and scale efficiency. For instance, for CBB there is a change in efficiency from previous period about 0.07%, but there is deterioration in productivity which resulted from change in technology, but the improvement in efficiency resulted from improvement in the scale efficiency in the amount of 0.07%.

The management efficiency (PECH) on the year 2009 were constant for CBE, CBB, DB and NIB, but there was a decrease in management efficiency of AIB (13.5%), BOA (19.7%), WB (17.7%) & UB (8.8%) from those previous years. This reveals that there are management inefficiencies in relation to utilization of inputs.

The scale efficiency (SECH) for the year 2009 shows that there is an improvement on the side of CBB (0.07%). This improvement in scale maybe resulted from either a change in deposit or opening a new branch or both a change in deposit and opening a new branch, sech is constant for CBE. But the remaining banks registered as follows, DB (9.8%), AIB (7.6%), BOA (7.6%), WB (7.3%), UB (4.6%) and NIB (12.8%).

Regarding technology change (TECHCH) the year 2009 revealed that there was improvement for only CBE (19.5%), which resulted improvement on overall in productivity. These show that CBE is better in using new technology than other banks during the year relative to previous years. But the remaining banks such as CBB (8.9%), DB (7%), AIB (6.1%), BOA (8.4%), WB (8.3%), UB (7%) and NIB (9.9%) were showed a decrease in adaptation of new technology.

The overall productivity (TFPCH) change in the year 2009 for CBE improvement of 19.5% was resulted due to technological change than previous years. But for the remaining banks, there was a decrease in productivity that results from technology, management and scale inefficiencies.

Table 4.6: Malmquist index summary of 2010

DMU	EFFCH	TECHCH	PECH	SECH	TFPCH
CBE	1.000	0.831	1.000	1.000	0.831
CBB	1.000	0.910	1.000	1.000	0.910
DB	1.013	0.934	0.927	1.093	0.946
AIB	1.013	0.980	0.937	1.081	0.993
BOA	1.270	0.940	1.179	1.077	1.195
WB	1.312	1.156	1.215	1.079	1.516
UB	1.001	0.931	0.952	1.051	0.931
NIB	0.943	1.022	0.908	1.039	0.964
Mean	**1.062**	**0.959**	**1.009**	**1.052**	**1.018**

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

The above Table 4.6 reveals that there is improvement in overall productivity in the year 2010 for BOA (19.5%) and WB (51.6%) and the remaining banks such as CBE (16.9%), CBB (9%), DB (5.4%), AIB (0.07%), UB (6.9%) and NIB (3.6%) were faced overall deterioration of productivity over the previous years. This result was due to change in technology, management and scale efficiency. For your surprise there is a change in efficiency for DB (1.3%), AIB (1.3%), BOA (27%), WB (31.2%) & UB (0.1%). This shows that there is a change in management and scale efficiency. For instance, the efficiency (EFFCH) change for DB, AIB and UB were occurred because of change in the scale or operation size of the banks.

In the year 2010, there were two banks who get advantage of adapting technology (TECHCH**)** with the amount of 15,6% for WB and 2.2% for NIB. These reveal that WB & NIB bank showed betterment in adapting new technology than the remaining banks during the period than those previous years. But the remaining banks showed a decrease in technology adaptation from those previous years.

Regarding the management (PECH) efficiency, only BOA (17.9%) and WB (21.5%) improvement in management of input (resource utilization) and CBE and CBB were remained constant. But the remaining commercial banks faced a decrease in management efficiency in management of inputs. In relation to a change in bank size operation (SECH) DB (9.3%), AIB (8.1%), BOA (7.7%), WB (7.9%), UB (5.1%) and NIB (3.9%) showed improvement on their size. But, the remaining CBE & CBB constant scale of operation than the previous year. This improvement in scale maybe resulted from either a change in deposit or opening new branches.

The overall productivity (TFPCH) change for BOA (19.5%) and WB (51.6%) improvement were resulted from a betterment in a management performance, technology adaptation for WB and change in bank operation size. Finally, CBE showed a decline on overall productivity in 16.9% from previous years. This deterioration in productivity resulted from a decline in technological adaptation in 2010 than previous year.

The Table below 4.7 DEA result showed that in the year 2011 there was an overall productivity improvement for CBE (2.3%), DB (1.2%), AIB (5.2%) and UB (3.8%) during the year over the previous year. The remaining banks CBB (15.5%), BOA (9.8%), WB (34.9%) and NIB (10.7%) showed deterioration in overall productivity during the year over the past years. The change in overall productivity on the banks was resulted due to change in technology adaptation, management performance and bank operation size (scale).

During the same year DB (9.4%), AIB (23.9%), BOA (2.6%), UB (16.8%) and NIB (18.2%) were banks that improved their overall efficiency. This change on efficiency (EFFCH) was resulted due to improvement on management performance in utilization of inputs and a change or increase in a bank operation size.

The scale (SECH) change for the same year shows improvement for DB, AIB, UB & UB with a an increase in bank operation size of 1.4%, 2.8%, 1.5% & 9.8% respectively. This ultimately resulted a change in overall efficiency and productivity of the banks during the year over the previous year. This improvement in scale maybe resulted from either a change in deposit or opening a new branch in another area.

Table 4.7: Malmquist index summary of 2011

DMU	EFFCH	TECHCH	PECH	SECH	TFPCH
CBE	1.000	1.023	1.000	1.000	1.023
CBB	1.000	0.844	1.000	1.000	0.844
DB	1.094	0.925	1.079	1.014	1.012
AIB	1.239	0.849	1.206	1.028	1.052
BOA	1.026	0.879	1.032	0.993	0.902
WB	0.903	0.721	0.906	0.997	0.651
UB	1.168	0.889	1.151	1.015	1.038
NIB	1.182	0.755	1.077	1.098	0.893
Mean	**1.071**	**0.856**	**1.053**	**1.018**	**0.917**

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

Among those banks which showed improvement on management performance (PECH) during the year were DB (7.9%), AIB (20.6%), BOA (3.2%), UB (15.1%) and NIB (7.7%). CBE & CBB were banks that showed a constant change and only WB which showed inefficiencies in management of input during the year relative to those previous years. In relation to technological change, (TECHCH) adaptation, only CBE showed improvement of 2.3% than the remaining banks.

The overall productivity (TFPCH) change during the year were 2011 from all banks only CBE (2.3%), DB (1.2%), AIB (5.2%) & UB (3.8%) showed improvement during such year. This improvement mainly resulted from improvement in technology, management performance and scale efficiency change during the year relative to those previous years. But the remaining banks such as CBB, BOA, WB & NIB were banks that faced deterioration in overall productivity during the year than previous year.

Table: 4.8 Malmquist index summaries of 2012

DMU	EFFCH	TECHCH	PECH	SECH	TFPCH
CBE	1.000	1.095	1.000	1.000	1.095
CBB	0.808	1.078	1.000	0.808	0.871
DB	0.994	1.085	1.000	0.994	1.079
AIB	1.005	1.146	1.021	0.984	1.151
BOA	1.002	1.076	1.028	0.975	1.078
WB	1.108	1.189	1.104	1.003	1.317
UB	0.985	1.105	1.000	0.985	1.089
NIB	1.028	1.169	1.023	1.005	1.202
Mean	**0.988**	**1.117**	**1.021**	**0.967**	**1.104**

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

The above DEA result presented on Table 4.8 shows that during the year 2012 All commercial banks CBE (9.5%), DB (7.9%), AIB (15.1%), BOA (7.8%), WB (31.7%), UB (8.9%) & NIB (20.2%) showed improvement on their overall productivity except CBB which faced deterioration in overall productivity during the year relative to previous year. These improvements in overall productivity was resulted from a change in technological adaptation, increase in management performance in utilizing input and increase in bank operation size than previous years.

In relation to change in efficiency (EFFCH) during the year that shows improvement was AIB (0.5%), BOA (0.2%), WB (10.8%) & NIB (2.8%). Improvement in efficiency resulted because of change in technology and improvement in management performance for AIB (14.6% & 2.1%), BOA (7.6% & 2.8%). And change in technology, management performance and change in bank operation size for WB (18.9%, 10.4% & 0.3%) and NIB (16.9%, 2.3% & 0.5%) respectively during the year relative to previous year. CBE was the only bank that remained constant and the remaining bank CBB, DB & UB showed a decrease in their efficiency during the year.

When we see a change resulted in 2012 relative to technology (TECHCH) adaptation all banks CBE (9.5%), CBB (7.8%), DB (8.5%), AIB (14.6%), BOA (7.6%), WB (18.9%), UB (10.5%) & NIB (16.9%) showed improvement in adaptation of new technology relative to previous years. This has a contribution for change in their overall productivity of the banks.

WB (0.3%) and NIB (0.5%) were banks that showed improvement in scale of bank operation that resulted proper betterment in efficiency and on overall productivity during the year 2012 relative to previous years. Only CBE remain on constant scale of operation but the remaining banks CBB, DB, AIB, BOA and UB showed a downsize in their scale of operation during the year than previous years.

For banks that show improvement on the overall productivity is resulted because of change in their technology, improvement in management performance in utilizing inputs. Surprisingly all commercial banks showed improvement in adaptation of new technology. These improvements resulted because of change in banking regulation by NBE which is a regulatory body which required all banks to implement the core banking system and most commercial banks also had adapted one window customer service which finally resulted a change in new technology adaptation like introduction of ATM, mobile banking and internet banking by the banks during the sated year.

The Table below 4.9 reveals that during the last year of the study only CBB (17.5%), BOA (2.9%) and NIB (4.7%) were banks that showed improvement on their overall productivity (TFPCH) during the year. The remaining banks CBE (11.4%), DB (7.7%), AIB (3.1%), WB (0.5%) and UB (5.4%) showed deterioration in their overall productivity during the year. This change in overall productivity was resulted due to a change in technology adaptation, improvement in management efficiency in utilizing inputs during the year relative to previous year.

Table: 4. 9 Malmquist index summary of 2013

DMU	EFFCH	TECHCH	PECH	SECH	TFPCH
CBE	1.000	0.886	1.000	1.000	0.886
CBB	1.187	0.990	1.000	1.187	1.175
DB	0.936	0.987	0.977	0.958	0.923
AIB	0.963	1.006	1.002	0.961	0.969
BOA	1.044	0.985	1.000	1.044	1.029
WB	0.998	0.996	1.000	0.998	0.995
UB	0.936	1.011	0.935	1.000	0.946
NIB	1.000	1.047	1.000	1.000	1.047
Mean	**1.005**	**0.987**	**0.989**	**1.016**	**0.993**

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

In the year 2013 CBB (18.7) & BOA (4.4%) were banks that improved their efficiency during the year and CBE and NIB remained unchanged during the year. But, DB (6.4%), AIB (3.7%), WB (0.2%) and UB (6.4%) were among banks that resulted a decrease on their efficiency during the year relative to previous year. The change in efficiency of CBB & BOA resulted because of improvement in bank operation size.

Relative to Scale efficiency (SECH) change, only CBB (18.7%) and BOA (4.4%) were banks that improve the scale of operation relative to other banks during the year 2013. This improvement in scale may result an improvement on overall productivity and efficiency of the banks. CBE, UB and NIB banks remain unchanged, but the remaining DB (4.2%), AIB (3.9%) and WB (0.2%) experienced a down size in their operation size.

Furthermore, during the year 2013 only AIB (0.6%), UB (1.1%) and NIB (4.7%) improvement in adaptation of new technology than other banks during the year relative to previous year. This change in efficiency maybe resulted from introduction of ATM, mobile banking and internet banking by the banks during the year.

In addition, during the year, the management performance in utilizing input for CBE, CBB, BOA, WB and NIB were banks remained constant. DB (2.3%) and UB (6.5%) deteriorated on management performance in utilizing inputs. Surprisingly, the only bank that showed improvement in management performance was AIB (0.02%).

In the overall productivity (TFPCH), CBB, BOA and NIB showed an improvement. These improvement in productivity resulted from due to change in scale efficiency for CBB and BOA. But for NIB the improvement in productivity resulted in a change in new technology adaptation during the year relative to previous year.

Table 4. 10: **Malmquist index summary firm means**

DMU	EFFCH	TECHCH	PECH	SECH	TFPCH
CBE	1.000	1.013	1.000	1.000	1.013
CBB	0.993	0.915	1.000	0.993	0.908
DB	0.988	0.944	0.996	0.992	0.933
AIB	0.991	0.952	1.000	0.991	0.943
BOA	1.015	0.934	1.011	1.004	0.948
WB	1.025	0.949	1.007	1.018	0.973
UB	0.986	0.941	0.989	0.998	0.929
NIB	1.000	0.944	1.000	1.000	0.944
Mean	**1.000**	**0.949**	**1.000**	**0.999**	**0.948**

Source: ***Researchers own computation from audited financial statement of selected commercial banks by using DEAP.***

The above table 4.10 shows the average score of TFPCH, SECH, PECH, TECHCH and EFFCH of all commercial banks for the period between 2007 up to 2013. The MPI result revealed that during the study period all commercial banks of Ethiopia showed a decline in overall productivity an average of 5.2%. These decrease in overall productivity of banks resulted because of an average 0.01% decrease in scale efficiency and average of 5.1% decrease in technology adaptation by the banks during the study periods.

CHAPTER FIVE

CONCULUSIONS AND RECOMMENDATIONS

This chapter comprises the last section of the paper. That is, conclusions extracted from the result and discussion and forwarded possible recommendations based on the conclusions.

5.1. Conclusions

Intermediation approach has been followed to select input and output variables for attainment of technical efficiency. The input variables included: i. salary expense ii. Capital related operating expense and iii. Total deposit, while output variables contain: i. investment and ii. total loan. The level of overall technical efficiencies of the banks during the year 2007 and 2008 indicated that for CBE, CBB and CBE, CBB, DB & NIB were 1.0000 respectively. But AIB, BOA, WB, UB were OTIE in both years. For instance, AIB overall technical efficiency score of 0.777 and 0.965 on 2007 & 2008 respectively. This implies that the bank was 77.7% and 96.5% efficient in these years as compared to its peers. To become efficient AIB must reduce their input by 4.255 to increase the output by 1.687. From this, it may be concluded that the overall technically inefficient banks should have made an adjustment efficient as their peers by reducing and adjusting their input and output mix to became on the efficient frontier. Generally, the bank with OTE score of less than 1.0000 is then to be relatively inefficient. Banks which have OTE score of 1.0000 are used as a best practice or efficient frontier and form the reference set for inefficient banks. The input utilization process in these efficient banks is functioning well. This means that the production process of these banks was characterizing relatively good input utilization.

Decomposing technical efficiency provides an insight about the source of inefficiency. Based on analysis made by decomposing technical efficiency into pure technical efficiency and scale efficiency, during the study period was due to poor input utilization (i.e. managerial inefficiency) and failure to operate at most productive scale size (i.e. scale inefficiency). The PTE and SE of inefficient bank were AIB, BOA, and WB with a score of 0.956, 0.941 and 0.938 (PTE) and 0.997, 0.965 and 0.914 (SE) during 2007 respectively and The PTE and SE of inefficient bank were AIB, BOA, and WB with a score of 0.999, 0.995 & 1.000 (PTE) and

0.966, 0.994 & 0.872 (SE) during 2008 respectively. But those remaining banks i.e. CBE, CBB, DB, UB and NIB were scored pure technical and scale efficient. This result shows that there was a good performance of management and has appropriate bank sizes operations during the year of 2007 and 2008.

The PTE and SE of inefficient bank in 2011 were AIB (0.972), BOA (0.973), WB (0.898), NIB (0.965) and AIB (0.996), BOA (0.978), WB (0.996), NIB (0.994), respectively. This result shows that there was not a good performance of management and has not appropriate bank sizes operations during the year of 2011. But the remaining banks i.e. CBE, CBB, DB and UB has no change. This result shows that there was a constant performance of management and has no increasing proportionate changed in bank sizes operations during the year 2011. .

The PTE and SE of inefficient bank in 2012 were only AIB (0.983), (0.998) and in 2013 the PTE and SE of inefficient bank were DB (0.993), (0.937) and UB (0.935), (0.985) respectively. This result shows that there was not a good performance of management and has not appropriate bank sizes operations during the year of 2012 and 2013.

In the year 2012 and 2013 the SE of inefficient bank were CBB (0.808), (DB), (0.994), BOA (0.958), UB (0.985) and CBB (0.959), AIB (0.920) and WB (0.998). From this it may be concluded that the major source of banks inefficiency in the year 2012 and 2013 were due to scale efficiency. This means that the banks were relatively efficient in management than their scale of operation.

To discover the most frequent reference set or peers for inefficient banks indicates to which of the efficient banks an inefficient bank is closest in its combination of inputs and outputs. Out of eight (8) banks only four (4) of them were of the one that appear more frequently as their peers (benchmark) were the following CBE, CBB, DB and NIB. This implies that, the peer count number can be considered as a measure of the extent to which the performance of an efficient bank can be a useful for the inefficient banks.

The slack characteristics of banks provide a conclusion about the excess input utilized (input slack) or the outputs under produced by the banks. Based on the discussion, the researcher found that AIB adjusted their salary expense by increasing their scale of operation by launching new branches and shuffling exiting employee to new branches.

The total factor productivity (Malmquist index) in the year 2007 the showed that two banks BOA (8%) &WB (16.3%) showed improvement on their efficiency. These change in overall efficiency resulted because of improvement in management performance & an increase in bank operation size. The scale efficiency (SECH) for 2009 showed there was an improvement for CBB (0.07%) and constant for CBE. But the remaining banks such as DB (9.8%), AIB (7.6%), BOA (7.6%), WB (7.3%), UB (4.6%) and NIB (12.8%). This improvement in scale maybe resulted either from a change in deposit or loan and opening a new branches. The CBE showed a decline on overall productivity in 16.9% from previous years. This deterioration in productivity resulted from a decline in technological adaptation in the year 2010 than previous year. The overall productivity (TFPCH) changes during the year 2011 from all banks were only CBE (2.3%), DB (1.2%), AIB (5.2%) & UB (3.8%) showed improvement during the year. This improvement mainly resulted from improvement in technology, management performance and scale efficiency change during the year relative to previous year. But the remaining banks such as CBB, BOA, WB & NIB were banks that faced deterioration in overall productivity during the year than previous year.

Surprisingly, in the year 2012 all commercial banks showed improvement in adaptation of new technology. These improvements resulted because of change in banking regulation by NBE which is a regulatory body which required all banks to implement the core banking system and most commercial banks also had adapted one window customer service which finally resulted a change in new technology adaptation like introduction of ATM, mobile banking and internet banking by the banks during the sated year.

All commercial banks for the period between 2007 up to 2013, the MPI result revealed that during the study period, all commercial banks of Ethiopia showed a decline in overall productivity with an average of 5.2%. These decrease in overall productivity of banks resulted because of an average 0.01% decrease in scale efficiency and average of 5.1% decrease in technology adaptation by the banks during the study periods.

5.2 Recommendations

In this part, based on findings and conclusions made in the above sections, the following possible recommendations are forwarded.

Managerial relevance of the research is quite important. It is widely accepted that for a company to succeed it should perform well. Moreover, the simplicity of the results, and the fact that they arise directly from observed input/output data that allowed for better acceptance of the results by the bank managers. The bank management officials should pay more attention to salary. Moreover expansion of branches business activities is done by keeping the existing input levels and control operating expenditure among the input variables. The excess amount of deposit balances should reinvest in different investment opportunities like (stock and bond) and proportionally disbursed the existing loans among the output variables. Furthermore, managers can use DEA to compare their business units with their peers.

Other important suggestion is implementing appropriate strategies to improve management inefficiency and technical efficiency of an inefficient bank. The management inefficiency can be eliminated by the following mechanisms: by delivering training courses for managers, establishing a gratifying system based on managers benefit, reviewing skilled human resources etc.

Regarding the return to scale, the researcher recommends that the bank management official should consider the type of return to scale of the banks. This may be done by allocating budget and resources. For instance, much of inefficient banks showed that IRS so the management give priorities while allocating budget and resource for IRS banks because it results in more output than those banks which commercial banks encounter CRS and DRS.

To become relatively efficient in their input consumptions, should adopt the practices of the efficient banks. From the peer results, the researcher might be said that the inefficient banks should adopt the practices of the peer banks in the utilizations of their inputs to be relatively efficient .The reason behind the inefficiency of banks during the study period was mis-adjustment of their inputs and outputs

Finally, the trends of efficiency in the commercial banks in this study were superior but their attitudes towards technological changes were declining (as a result of Malmquist index). In today‘s world the one which have a high technology in its system than others leads to dominate the competitors and accommodate more customers. As a result of this, it earns more incomes. To have this, the researcher recommends to those banks to have a technological improvement by taking a benchmark of foreign banks.

5.3 Directions for future research

As constraints, this study comes positive with various limitations which implies for further study on the subject matter. This study only used one approach (intermediation approach) to look at the inefficiencies of selected commercial banks. There is need to apply other approaches such as production and operating approaches and compares the results and possibly check if there are any deviations in the technical efficiency scores. The inputs and outputs used is not the only indicator of efficiency, there are also multiple inputs and outputs which are an indicator of efficiency, so in future other study may incorporate other additional outputs and inputs.

Additionally, the study focus only selected commercial banks; in future other study may deal with the remaining commercial banks of Ethiopia to see the strength of the result and for comparative analysis among commercial bank of Ethiopia.

Lastly, while measuring the efficiency of commercial bank of Ethiopia various factors i.e. inflation, regulatory, economic system of the country, management behavior etc which may affect the efficiency of the commercial banks are not considered in this study, therefore future researcher may incorporate these variables.

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Appendices

Appendix 1

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: CRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	te
1	1.000
2	1.000
3	0.902
4	0.777
5	0.734
6	0.762
7	0.855
8	0.872

mean 0.863

SUMMARY OF OUTPUT SLACKS:

firm output:	1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	1678.555
4	0.000	1.687
5	0.000	246.141
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	240.798

SUMMARY OF INPUT SLACKS:

firm input:	1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	8.874	0.000	0.000
4	4.255	0.000	0.000
5	5.569	0.000	0.000
6	18.832	3.421	0.000
7	7.961	6.570	0.000
8	5.457	5.225	0.000
mean	6.368	1.902	0.000

SUMMARY OF PEERS:

firm	peers:	
1	1	
2	2	
3	1	2
4	1	2
5	1	2
6	2	1
7	2	1
8	1	2

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:	
1	1.000	
2	1.000	
3	0.084	1.896
4	0.028	1.429
5	0.020	1.315
6	1.229	0.014
7	1.201	0.020
8	0.005	1.451

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	6
2	6
3	0
4	0
5	0
6	0
7	0
8	0

SUMMARY OF OUTPUT TARGETS:

firm output:	1	2
1	20275.000	26690.000
2	1391.000	59.000
3	4349.000	2365.555
4	2564.000	842.687
5	2242.000	621.141
6	1984.000	433.000
7	2086.000	617.000
8	2118.000	217.000

SUMMARY OF INPUT TARGETS:

firm input:	1	2	3
1	325.000	518.000	43489.000
2	27.000	74.000	1834.000
3	78.628	184.025	7149.006
4	47.821	120.473	3856.702
5	42.122	107.855	3297.288
6	37.585	97.976	2842.167
7	39.088	99.502	3093.212
8	40.774	109.916	2875.028

Appendix 2

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: VRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	1.000	1.000	1.000	-
2	1.000	1.000	1.000	-
3	1.000	1.000	1.000	-
4	1.000	1.000	1.000	-
5	0.916	0.939	0.975	drs
6	0.860	0.960	0.896	drs
7	1.000	1.000	1.000	-
8	1.000	1.000	1.000	-
mean	0.972	0.987	0.984	

Note: crste = technical efficiency from CRS DEA
vrste = technical efficiency from VRS DEA
scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

SUMMARY OF OUTPUT SLACKS:

firm output:	1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.000	0.000
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	0.000

SUMMARY OF INPUT SLACKS:

firm input:	1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	0.000	0.000	0.000
5	0.000	1.050	0.000
6	0.000	10.462	0.000
7	0.000	0.000	0.000
8	0.000	0.000	0.000
mean	0.000	1.439	0.000

SUMMARY OF PEERS:

firm peers:

1	1			
2	2			
3	3			
4	4			
5	3	7	2	8
6	3	1	2	7
7	7			
8	8			

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:			
1	1.000			
2	1.000			
3	1.000			
4	1.000			
5	0.335	0.066	0.402	0.198
6	0.283	0.009	0.375	0.333
7	1.000			
8	1.000			

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	1
2	2
3	2
4	0
5	0
6	0
7	2
8	1

SUMMARY OF OUTPUT TARGETS:

firm	output: 1	2
1	8370.000	23190.000
2	1142.000	382.000
3	3889.000	675.000
4	2403.000	429.000
5	2197.000	460.000
6	2060.000	702.000
7	1368.000	468.000
8	1755.000	252.000

SUMMARY OF INPUT TARGETS:

firm	input: 1	2	3
1	32873.000	218.000	732.000
2	1136.000	19.000	110.000
3	4861.000	53.000	134.000
4	3112.000	38.000	77.000
5	2555.652	31.823	105.194
6	2614.192	31.764	107.485
7	1541.000	23.000	65.000
8	1879.000	25.000	60.000

Appendix 3
results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: VRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	1.000	1.000	1.000	-
2	1.000	1.000	1.000	-
3	1.000	1.000	1.000	-
4	0.953	0.956	0.997	irs
5	0.908	0.941	0.965	drs
6	0.857	0.938	0.914	drs
7	1.000	1.000	1.000	-
8	1.000	1.000	1.000	-
mean	0.965	0.979	0.985	

Note: crste = technical efficiency from CRS DEA
vrste = technical efficiency from VRS DEA
scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

SUMMARY OF OUTPUT SLACKS:

firm	output: 1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.000	0.000
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	0.000

SUMMARY OF INPUT SLACKS:

firm	input: 1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	6.396	0.000	533.742
5	1.194	0.000	0.000
6	10.405	0.000	0.000
7	0.000	0.000	0.000
8	0.000	0.000	0.000
mean	2.249	0.000	66.718

SUMMARY OF PEERS:

firm	peers:			
1	1			
2	2			
3	3			
4	3	1	8	
5	1	2	3	8
6	1	2	3	8
7	7			
8	8			

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:			
1	1.000			
2	1.000			
3	1.000			
4	0.152	0.004	0.844	
5	0.001	0.417	0.325	0.258
6	0.009	0.426	0.237	0.328
7	1.000			
8	1.000			

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	3
2	2
3	3
4	0
5	0
6	0
7	0
8	3

SUMMARY OF OUTPUT TARGETS:

firm	output: 1	2
1	8370.000	32190.000
2	1142.000	382.000
3	3889.000	675.000
4	2103.000	429.000
5	2197.000	466.000
6	2060.000	702.000
7	1368.000	468.000
8	1755.000	252.000

SUMMARY OF INPUT TARGETS:

firm	input: 1	2	3
1	218.000	732.000	32873.000
2	19.000	110.000	1136.000

3	53.000	134.000	4861.000
4	29.941	73.629	2442.000
5	31.726	105.344	2559.290
6	30.852	105.016	2554.140
7	23.000	65.000	1541.000
8	25.000	60.000	1879.000

Appendix 4

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: CRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	te
1	1.000
2	1.000
3	1.000
4	0.965
5	0.989
6	0.872
7	0.967
8	1.000

mean 0.974

SUMMARY OF OUTPUT SLACKS:

firm output:	1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.000	93.144
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	11.643

SUMMARY OF INPUT SLACKS:

firm input:	1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	0.000	0.000	0.000
5	0.000	117.352	0.000
6	0.022	24.782	0.000
7	0.000	4.279	0.000
8	0.000	0.000	0.000
mean	0.003	18.302	0.000

SUMMARY OF PEERS:

firm	peers:			
1	1			
2	2			
3	3			
4	8	1	2	3
5	3	8		
6	1	2		
7	8	2	1	
8	8			

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:			
1	1.000			
2	1.000			
3	1.000			
4	0.004	0.009	0.268	0.498
5	0.337	0.553		
6	0.019	1.576		
7	0.703	0.158	0.012	
8	1.000			

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm peer count:

1	3
2	3
3	2
4	0
5	0
6	0
7	0
8	3

SUMMARY OF OUTPUT TARGETS:

firm	output: 1	2
1	16275.000	22156.000
2	1205.000	130.000
3	4280.000	857.000
4	2611.000	665.000
5	2566.000	388.144
6	2208.000	625.000
7	1810.000	406.000
8	2034.000	180.000

SUMMARY OF INPUT TARGETS:

firm	input: 1	2	3
1	285.000	570.000	37633.000
2	27.000	61.000	1189.000
3	73.000	175.000	6152.000
4	46.336	109.083	3735.841
5	44.489	112.014	3437.519
6	47.963	106.961	2587.732
7	32.895	83.763	2363.577
8	36.000	96.000	2470.000

Appendix 5
Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: VRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	1.000	1.000	1.000	-
2	1.000	1.000	1.000	-
3	1.000	1.000	1.000	-
4	0.965	0.999	0.966	irs
5	0.989	0.995	0.994	irs
6	0.872	1.000	0.872	drs
7	0.967	1.000	0.967	irs
8	1.000	1.000	1.000	-
mean	0.974	0.999	0.975	

Note: crste = technical efficiency from CRS DEA
vrste = technical efficiency from VRS DEA
scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

SUMMARY OF OUTPUT SLACKS:

firm	output: 1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	398.231
5	0.000	45.358
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	55.449

SUMMARY OF INPUT SLACKS:

firm	input: 1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	0.000	0.000	0.000
5	0.000	116.071	116.628
6	0.000	0.000	0.000

7	0.000	0.000	0.000
8	0.000	0.000	0.000
mean	0.000	14.509	14.579

SUMMARY OF PEERS:

firm	peers:			
1	1			
2	2			
3	3			
4	3	1	2	8
5	3	8		
6	6			
7	7			
8	8			

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:			
1	1.000			
2	1.000			
3	1.000			
4	0.187	0.035	0.418	0.360
5	0.237	0.763		
6	1.000			
7	1.000			
8	1.000			

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	1
2	1
3	2
4	0
5	0
6	0
7	0
8	2

SUMMARY OF OUTPUT TARGETS:

firm output:	1	2
1	16275.000	22156.000
2	1205.000	130.000
3	4280.000	857.000
4	2611.000	1063.231
5	2566.000	340.358
6	2208.000	625.000
7	1810.000	406.000
8	2034.000	180.000

SUMMARY OF INPUT TARGETS:

firm input:	1	2	3
1	285.000	570.000	37633.000
2	27.000	61.000	1189.000
3	73.000	175.000	6152.000
4	47.959	112.904	3866.714
5	44.764	114.712	3342.139
6	55.000	151.000	2966.000
7	34.000	91.000	2443.000
8	36.000	96.000	2470.000

Appendix 6

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: CRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	te
1	1.000
2	1.000
3	0.902
4	0.777
5	0.734
6	0.762
7	0.855
8	0.872

mean 0.863

SUMMARY OF OUTPUT SLACKS:

firm output:	1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	1678.555
4	0.000	1.687
5	0.000	246.141
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	240.798

SUMMARY OF INPUT SLACKS:

firm input:	1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	8.874	0.000	0.000
4	4.255	0.000	0.000
5	5.569	0.000	0.000
6	18.832	3.421	0.000
7	7.961	6.570	0.000
8	5.457	5.225	0.000
mean	6.368	1.902	0.000

SUMMARY OF PEERS:

firm	peers:	
1	1	
2	2	
3	1	2
4	1	2
5	1	2
6	2	1
7	2	1
8	1	2

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:	
1	1.000	
2	1.000	
3	0.084	1.896
4	0.028	1.429
5	0.020	1.315
6	1.229	0.014
7	1.201	0.020
8	0.005	1.451

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	6
2	6
3	0
4	0
5	0
6	0
7	0
8	0

SUMMARY OF OUTPUT TARGETS:

firm output:	1	2
1	20275.000	26690.000
2	1391.000	59.000
3	4349.000	2365.555
4	2564.000	842.687
5	2242.000	621.141
6	1984.000	433.000
7	2086.000	617.000
8	2118.000	217.000

SUMMARY OF INPUT TARGETS:

firm input:	1	2	3
1	325.000	518.000	43489.000
2	27.000	74.000	1834.000
3	78.628	184.025	7149.006
4	47.821	120.473	3856.702
5	42.122	107.855	3297.288
6	37.585	97.976	2842.167

7	39.088	99.502	3093.212
8	40.774	109.916	2875.028

Appendix 7
Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: VRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	1.000	1.000	1.000	-
2	1.000	1.000	1.000	-
3	0.902	1.000	0.902	drs
4	0.777	0.865	0.899	drs
5	0.734	0.799	0.918	drs
6	0.762	0.823	0.927	drs
7	0.855	0.912	0.938	drs
8	0.872	1.000	0.872	drs
mean	0.863	0.925	0.932	

Note: crste = technical efficiency from CRS DEA
vrste = technical efficiency from VRS DEA
scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

SUMMARY OF OUTPUT SLACKS:

firm output:	1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.000	0.000
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	0.000

SUMMARY OF INPUT SLACKS:

firm input:	1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	0.750	0.000	0.000
5	2.866	0.000	0.000
6	16.889	0.000	0.000
7	5.126	2.847	0.000
8	0.000	0.000	0.000
mean	3.204	0.356	0.000

SUMMARY OF PEERS:

firm	peers:			
1	1			
2	2			
3	3			
4	8	1	3	2
5	1	8	3	2
6	1	8	3	2
7	8	1	2	
8	8			

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:			
1	1.000			
2	1.000			
3	1.000			
4	0.673	0.023	0.081	0.222
5	0.006	0.321	0.171	0.502
6	0.011	0.520	0.003	0.466
7	0.487	0.018	0.495	
8	1.000			

PEER COUNT SUMMARY:

(i.e., no. times each firm is a peer for another)

firm	peer count:
1	4
2	4
3	3
4	0
5	0
6	0
7	0
8	4

SUMMARY OF OUTPUT TARGETS:

firm	output: 1	2
1	20275.000	26690.000
2	1391.000	59.000
3	4349.000	687.000
4	2564.000	841.000
5	2242.000	375.000
6	1984.000	433.000
7	2086.000	617.000
8	2118.000	217.000

SUMMARY OF INPUT TARGETS:

firm	input: 1	2	3
1	325.000	518.000	43489.000
2	27.000	74.000	1834.000
3	97.000	204.000	7925.000
4	57.187	134.033	4290.788
5	49.081	117.480	3591.525
6	43.990	109.418	3067.007
7	45.039	110.252	3298.114
8	53.000	132.000	3296.000

Appendix 8

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: CRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	te
1	1.000
2	1.000
3	0.914
4	0.788
5	0.932
6	1.000
7	0.856
8	0.823

mean 0.914

SUMMARY OF OUTPUT SLACKS:

firm	output: 1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.000	287.617
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	35.952

SUMMARY OF INPUT SLACKS:

firm	input: 1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	18.053	0.000
4	2.162	0.000	0.000
5	6.854	0.000	0.000
6	0.000	0.000	0.000
7	0.000	18.720	0.000
8	0.000	27.224	0.000
mean	1.127	8.000	0.000

SUMMARY OF PEERS:

firm peers:

1	1		
2	2		
3	6	1	2
4	2	1	6
5	1	2	
6	6		
7	2	6	1
8	2	6	1

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm peer weights:

1	1.000		
2	1.000		
3	0.013	0.096	1.694
4	0.481	0.037	0.418
5	0.020	1.573	
6	1.000		
7	1.404	0.007	0.013
8	0.312	0.513	0.012

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	5
2	5
3	0
4	0
5	0
6	4
7	0
8	0

SUMMARY OF OUTPUT TARGETS:

firm output:	1	2
1	23573.000	36188.000
2	1558.000	131.000
3	4939.000	3706.000
4	2997.000	1959.000
5	2920.000	925.617
6	3276.000	1307.000
7	2518.000	665.000
8	2447.000	1141.000

SUMMARY OF INPUT TARGETS:

firm input:	1	2	3
1	431.000	942.000	54646.000
2	37.000	74.000	2354.000
3	105.115	217.770	9272.965
4	71.879	142.568	4809.498
5	66.784	135.159	4790.210
6	91.000	172.000	3923.000
7	58.215	117.400	4045.076
8	63.360	122.536	3395.917

Appendix 9

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: VRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	1.000	1.000	1.000	-
2	1.000	1.000	1.000	-
3	0.914	0.927	0.986	drs
4	0.788	0.810	0.972	irs
5	0.932	0.943	0.989	drs
6	1.000	1.000	1.000	-
7	0.856	0.869	0.985	drs
8	0.823	0.908	0.906	irs
mean	0.914	0.932	0.980	

Note: crste = technical efficiency from CRS DEA
vrste = technical efficiency from VRS DEA
scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

SUMMARY OF OUTPUT SLACKS:

firm	output: 1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	1322.626
4	88.831	0.000
5	0.000	1237.892
6	0.000	0.000
7	0.000	693.306
8	258.879	0.000
mean	43.464	406.728

SUMMARY OF INPUT SLACKS:

firm	input: 1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	20.014	0.000
4	2.269	0.000	0.000
5	6.192	0.000	0.000
6	0.000	0.000	0.000
7	0.000	19.916	0.000
8	0.000	29.874	0.000
mean	1.058	8.725	0.000

SUMMARY OF PEERS:

firm	peers:		
1	1		
2	2		
3	2	6	1
4	1	6	2
5	6	1	2
6	6		
7	6	1	2
8	1	6	2

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:		
1	1.000		
2	1.000		
3	0.486	0.391	0.123
4	0.037	0.412	0.551
5	0.297	0.039	0.665
6	1.000		
7	0.211	0.027	0.762
8	0.011	0.531	0.458

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	5
2	5
3	0
4	0
5	0
6	5
7	0
8	0

SUMMARY OF OUTPUT TARGETS:

firm	output: 1	2
1	23573.000	36188.000
2	1558.000	131.000
3	4939.000	5028.626
4	3085.831	1959.000
5	2920.000	1875.892
6	3276.000	1307.000
7	2518.000	1358.306
8	2705.879	1141.000

SUMMARY OF INPUT TARGETS:

firm	input: 1	2	3
1	431.000	942.000	54646.000
2	37.000	74.000	2354.000
3	106.595	219.129	9403.495
4	73.918	146.699	4948.870
5	68.273	136.678	4844.052

6	91.000	172.000	3923.000
7	59.079	118.226	4105.156
8	69.896	135.335	3746.247

Appendix 10
Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: VRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	1.000	1.000	1.000	-
2	1.000	1.000	1.000	-
3	1.000	1.000	1.000	-
4	0.968	0.972	0.996	drs
5	0.952	0.973	0.978	drs
6	0.895	0.898	0.996	drs
7	1.000	1.000	1.000	-
8	0.965	0.971	0.994	drs
mean	0.972	0.977	0.996	

Note: crste = technical efficiency from CRS DEA
vrste = technical efficiency from VRS DEA
scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

SUMMARY OF OUTPUT SLACKS:

firm output:	1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.000	106.299
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	13.287

SUMMARY OF INPUT SLACKS:

firm input:	1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	26.880	0.000	0.000
5	4.834	9.202	0.000
6	40.534	76.219	0.000
7	0.000	0.000	0.000
8	27.965	37.684	0.000
mean	12.527	15.388	0.000

SUMMARY OF PEERS:

firm	peers:			
1	1			
2	2			
3	3			
4	1	2	3	7
5	3	2		
6	2	1	3	
7	7			
8	3	2	1	

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:			
1	1.000			
2	1.000			
3	1.000			
4	0.025	0.606	0.280	0.089
5	0.365	0.635		
6	0.911	0.028	0.061	
7	1.000			
8	0.090	0.890	0.020	

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	3
2	4
3	4
4	0
5	0
6	0
7	1
8	0

SUMMARY OF OUTPUT TARGETS:

firm	output: 1	2
1	36099.000	57676.000
2	1546.000	134.000
3	6094.000	3907.000
4	3842.000	2786.000
5	3205.000	1510.299
6	2778.000	1952.000
7	3186.000	1650.000
8	2652.000	1634.000

SUMMARY OF INPUT TARGETS:

firm	input: 1	2	3
1	562.000	1639.000	84799.000
2	47.000	98.000	2507.000
3	145.000	327.000	11841.000
4	90.704	206.987	7525.375
5	82.748	181.534	5911.817
6	67.220	154.554	5349.079
7	83.000	163.000	6066.000
8	66.202	149.679	5006.376

Appendix 11

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: CRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	te
1	1.000
2	1.000
3	1.000
4	0.968
5	0.952
6	0.895
7	1.000
8	0.965
mean	0.972

SUMMARY OF OUTPUT SLACKS:

firm	output: 1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.000	0.000
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	0.000

SUMMARY OF INPUT SLACKS:

firm	input: 1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	24.551	0.000	0.000
5	0.000	0.000	0.000
6	39.686	74.165	0.000
7	0.000	0.000	0.000
8	26.765	34.850	0.000
mean	11.375	13.627	0.000

SUMMARY OF PEERS:

firm	peers:			
1	1			
2	2			
3	3			
4	1	2	7	
5	3	7	1	2
6	1	2		
7	7			
8	1	2		

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:			
1	1.000			
2	1.000			
3	1.000			
4	0.036	0.905	0.360	
5	0.093	0.060	0.013	1.271
6	0.031	1.064		
7	1.000			
8	0.026	1.114		

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	4
2	4
3	1
4	0
5	0
6	0
7	2
8	0

SUMMARY OF OUTPUT TARGETS:

firm	output: 1	2
1	36099.000	57676.000
2	1546.000	134.000
3	6094.000	3907.000
4	3842.000	2786.000
5	3205.000	1404.000
6	2778.000	1952.000
7	3186.000	1650.000
8	2652.000	1634.000

SUMMARY OF INPUT TARGETS:

firm	input: 1	2	3
1	562.000	1639.000	84799.000
2	47.000	98.000	2507.000
3	145.000	327.000	11841.000
4	92.588	206.204	7496.905
5	85.698	186.630	5784.593
6	67.656	155.727	5328.650
7	83.000	163.000	6066.000
8	66.840	151.395	4976.490

Appendix 12
Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: CRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	te
1	1.000
2	0.808
3	0.994
4	0.981
5	0.958
6	1.000
7	0.985
8	1.000

mean 0.966

SUMMARY OF OUTPUT SLACKS:

firm output: 1 2

1	0.000	0.000
2	0.000	0.000
3	0.000	2289.822
4	0.000	175.070
5	0.000	888.453
6	0.000	0.000
7	0.000	661.763
8	0.000	0.000
mean	0.000	501.888

SUMMARY OF INPUT SLACKS:

firm input:	1	2	3
1	0.000	0.000	0.000
2	2.305	26.376	0.000
3	0.000	46.138	0.000
4	2.509	0.000	0.000
5	0.000	19.498	0.000
6	0.000	0.000	0.000
7	0.000	0.563	0.000
8	0.000	0.000	0.000
mean	0.602	11.572	0.000

SUMMARY OF PEERS:

firm	peers:	
1	1	
2	1	6
3	1	8
4	1	8
5	1	8
6	6	
7	1	8
8	8	

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:	
1	1.000	
2	0.009	0.303
3	0.062	1.151
4	0.020	1.147
5	0.019	0.733
6	1.000	
7	0.011	0.918
8	1.000	

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	5
2	0
3	0
4	0
5	0
6	1
7	0
8	4

SUMMARY OF OUTPUT TARGETS:

firm output:	1	2
1	60940.000	74259.000
2	1628.000	1519.000
3	7949.000	7387.822
4	5356.000	4236.070
5	3797.000	3163.453
6	3479.000	2705.000
7	3990.000	3027.763
8	3608.000	2399.000

SUMMARY OF INPUT TARGETS:

firm input:	1	2	3
1	873.000	1966.000	116584.000
2	51.847	94.861	2842.586
3	187.876	373.353	13982.380
4	150.474	289.294	9025.973
5	101.510	196.929	6484.206
6	144.000	252.000	5758.000
7	116.216	222.019	6655.806
8	116.000	218.000	5838.000

Appendix 13

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS

Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: VRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	1.000	1.000	1.000	-
2	0.808	1.000	0.808	irs
3	0.994	1.000	0.994	drs
4	0.981	0.998	0.983	drs
5	0.958	1.000	0.958	irs
6	1.000	1.000	1.000	-
7	0.985	1.000	0.985	irs
8	1.000	1.000	1.000	-
mean	0.966	1.000	0.966	

Note: crste = technical efficiency from CRS DEA
vrste = technical efficiency from VRS DEA
scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

SUMMARY OF OUTPUT SLACKS:

firm	output: 1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.000	0.000
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	0.000

SUMMARY OF INPUT SLACKS:

firm	input: 1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	13.559	9.249	0.000
5	0.000	0.000	0.000
6	0.000	0.000	0.000
7	0.000	0.000	0.000
8	0.000	0.000	0.000
mean	1.695	1.156	0.000

SUMMARY OF PEERS:

firm	peers:		
1	1		
2	2		
3	3		
4	1	3	8
5	5		
6	6		
7	7		
8	8		

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:		
1	1.000		
2	1.000		
3	1.000		
4	0.016	0.193	0.791
5	1.000		
6	1.000		
7	1.000		
8	1.000		

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	1
2	0
3	1
4	0

5	0
6	0
7	0
8	1

SUMMARY OF OUTPUT TARGETS:

firm output:	1	2
1	60940.000	74259.000
2	1628.000	1519.000
3	7949.000	5098.000
4	5356.000	4061.000
5	3797.000	2275.000
6	3479.000	2705.000
7	3990.000	2366.000
8	3608.000	2399.000

SUMMARY OF INPUT TARGETS:

firm input:	1	2	3
1	873.000	1966.000	116584.000
2	67.000	150.000	3517.000
3	189.000	422.000	14066.000
4	142.105	285.116	9184.192
5	106.000	226.000	6771.000
6	144.000	252.000	5758.000
7	118.000	226.000	6758.000
8	116.000	218.000	5838.000

Appendix 14

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: CRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	te
1	1.000
2	0.959
3	0.930
4	0.920
5	1.000
6	0.998
7	0.922
8	1.000

mean 0.966

SUMMARY OF OUTPUT SLACKS:

firm output:	1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.000	0.000
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	0.000

SUMMARY OF INPUT SLACKS:

firm input:	1	2	3
1	0.000	0.000	0.000
2	51.872	86.850	0.000
3	0.000	0.367	0.000
4	9.483	0.000	0.000
5	0.000	0.000	0.000
6	50.564	61.660	0.000
7	1.771	53.744	0.000
8	0.000	0.000	0.000
mean	14.211	25.328	0.000

SUMMARY OF PEERS:

firm	peers:		
1	1		
2	1	8	
3	5	8	1
4	1	8	5
5	5		

6	1	8
7	1	8
8	8	

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:		
1	1.000		
2	0.023	0.059	
3	0.468	1.142	0.021
4	0.003	1.360	0.235
5	1.000		
6	0.014	0.822	
7	0.010	0.885	
8	1.000		

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	5
2	0
3	0
4	0
5	2
6	0
7	0
8	5

SUMMARY OF OUTPUT TARGETS:

firm	output: 1	2
1	69675.000	101839.000
2	1878.000	2509.000
3	8663.000	6272.000
4	7332.000	4366.000
5	4609.000	2827.000
6	4585.000	3420.000
7	4623.000	3223.000
8	4429.000	2481.000

SUMMARY OF INPUT TARGETS:

firm	input: 1	2	3
1	1334.000	2789.000	152386.000
2	39.218	80.948	3928.391
3	237.224	477.802	14746.013
4	219.639	436.161	11543.550
5	106.000	226.000	8496.000
6	133.156	263.844	7538.524
7	137.376	271.546	7430.061
8	140.000	275.000	6658.000

Appendix 15
Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated DEA

Scale assumption: VRS

Slacks calculated using multi-stage method

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	1.000	1.000	1.000	-
2	0.959	1.000	0.959	irs
3	0.930	0.993	0.937	drs
4	0.920	1.000	0.920	drs
5	1.000	1.000	1.000	-
6	0.998	1.000	0.998	irs
7	0.922	0.935	0.985	irs
8	1.000	1.000	1.000	-
mean	0.966	0.991	0.975	

Note: crste = technical efficiency from CRS DEA
vrste = technical efficiency from VRS DEA
scale = scale efficiency = crste/vrste

Note also that all subsequent tables refer to VRS results

SUMMARY OF OUTPUT SLACKS:

firm	output: 1	2
1	0.000	0.000
2	0.000	0.000
3	0.000	1039.378
4	0.000	0.000
5	0.000	0.000
6	0.000	0.000
7	0.000	0.000
8	0.000	0.000
mean	0.000	129.922

SUMMARY OF INPUT SLACKS:

firm	input: 1	2	3
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	0.000	16.487	0.000
4	0.000	0.000	0.000
5	0.000	0.000	0.000
6	0.000	0.000	0.000
7	0.000	51.650	0.000
8	0.000	0.000	0.000
mean	0.000	8.517	0.000

SUMMARY OF PEERS:

firm	peers:			
1	1			
2	2			
3	1	4	8	
4	4			
5	5			
6	6			
7	8	2	1	5
8	8			

SUMMARY OF PEER WEIGHTS:
(in same order as above)

firm	peer weights:			
1	1.000			
2	1.000			
3	0.037	0.638	0.326	
4	1.000			
5	1.000			
6	1.000			
7	0.813	0.113	0.007	0.067
8	1.000			

PEER COUNT SUMMARY:
(i.e., no. times each firm is a peer for another)

firm	peer count:
1	2
2	1
3	0
4	1
5	1
6	0
7	0
8	2

SUMMARY OF OUTPUT TARGETS:

firm	output: 1	2
1	69675.000	101839.000
2	1878.000	2509.000
3	8663.000	7311.378
4	7332.000	4366.000
5	4609.000	2827.000
6	4585.000	3420.000
7	4623.000	3223.000
8	4429.000	2481.000

SUMMARY OF INPUT TARGETS:

firm	input: 1	2	3
1	1334.000	2789.000	152386.000
2	95.000	175.000	4097.000
3	253.118	493.719	15734.019
4	249.000	474.000	12545.000
5	106.000	226.000	8496.000
6	184.000	326.000	7550.000
7	141.239	278.530	7541.764
8	140.000	275.000	6658.000

Appendix 16

Results from DEAP Version 2.1

Instruction file = $$TEMP$$.INS
Data file = $$TEMP$$.DTA

Input orientated Malmquist DEA

DISTANCES SUMMARY

year = 1

firm no.	crs te rel to tech in yr t-1	t	t+1	vrs te
1	0.000	1.000	1.368	1.000
2	0.000	1.000	1.403	1.000
3	0.000	1.000	1.252	1.000
4	0.000	1.000	1.241	1.000
5	0.000	0.916	1.097	0.939
6	0.000	0.860	1.066	0.960
7	0.000	1.000	1.256	1.000
8	0.000	1.000	1.265	1.000
mean	0.000	0.972	1.243	0.987

year = 2

firm no.	crs te rel to tech in yr t-1	t	t+1	vrs te
1	1.637	1.000	0.959	1.000
2	0.857	0.993	1.101	1.000
3	0.849	1.000	1.094	1.000
4	0.829	0.973	1.048	1.000
5	0.808	0.989	1.075	0.995
6	0.804	1.000	1.098	1.000
7	0.811	0.983	1.064	1.000
8	0.875	1.000	1.110	1.000
mean	0.934	0.992	1.069	0.999

year = 3

firm no.	crs te rel to tech in yr t-1	t	t+1	vrs te
1	1.370	1.000	1.563	1.000
2	0.921	1.000	1.199	1.000
3	0.855	0.902	0.981	1.000
4	0.738	0.777	0.866	0.865
5	0.670	0.734	0.798	0.799
6	0.705	0.762	0.738	0.823
7	0.801	0.856	0.899	0.912
8	0.786	0.872	0.959	1.000
mean	0.856	0.863	1.000	0.925

year = 4

firm no.	crs te rel to tech in yr t-1	t	t+1	vrs te
1	1.079	1.000	1.169	1.000
2	0.993	1.000	1.183	1.000
3	0.866	0.914	0.986	0.927
4	0.842	0.788	0.940	0.810
5	0.897	0.932	1.061	0.943
6	1.294	1.000	1.487	1.000
7	0.779	0.856	0.972	0.869
8	0.945	0.823	1.076	0.908
mean	0.962	0.914	1.109	0.932

year = 5

firm no.	crs te rel to tech in yr t-1	t	t+1	vrs te
1	1.222	1.000	1.206	1.000
2	0.842	1.000	1.012	1.000
3	0.923	1.000	0.920	1.000
4	0.840	0.976	0.867	0.977
5	0.841	0.956	0.911	0.973
6	0.698	0.903	0.762	0.906
7	0.896	1.000	0.923	1.000
8	0.726	0.973	0.843	0.977
mean	0.874	0.976	0.931	0.979

year = 6

firm no.	crs te rel to tech in yr t-1	t	t+1	vrs te
1	1.447	1.000	1.336	1.000
2	0.951	0.808	0.827	1.000
3	1.077	0.994	1.019	1.000
4	1.143	0.981	0.997	0.998
5	1.056	0.958	0.954	1.000
6	1.193	1.000	1.008	1.000
7	1.110	0.985	0.985	1.000
8	1.185	1.000	0.982	1.000
mean	1.145	0.966	1.013	1.000

year = 7

firm no.	crs te rel to tech in yr t-1	t	t+1	vrs te
1	1.049	1.000	0.000	1.000
2	0.961	0.959	0.000	1.000
3	0.928	0.930	0.000	0.977
4	0.972	0.945	0.000	1.000
5	0.967	1.000	0.000	1.000
6	0.999	0.998	0.000	1.000
7	0.941	0.922	0.000	0.935
8	1.076	1.000	0.000	1.000
mean	0.987	0.969	0.000	0.989

[Note that t-1 in year 1 and t+1 in the final year are not defined]

MALMQUIST INDEX SUMMARY

year = 2

firm	effch	techch	pech	sech	tfpch
1	1.000	1.094	1.000	1.000	1.094
2	0.993	0.784	1.000	0.993	0.779
3	1.000	0.823	1.000	1.000	0.823
4	0.973	0.829	1.000	0.973	0.806
5	1.080	0.826	1.059	1.020	0.891
6	1.163	0.805	1.042	1.116	0.936
7	0.983	0.810	1.000	0.983	0.797
8	1.000	0.832	1.000	1.000	0.832
mean	1.022	0.846	1.012	1.010	0.865

year = 3

firm	effch	techch	pech	sech	tfpch
1	1.000	1.195	1.000	1.000	1.195
2	1.007	0.911	1.000	1.007	0.918
3	0.902	0.930	1.000	0.902	0.840
4	0.799	0.939	0.865	0.924	0.750
5	0.742	0.916	0.803	0.924	0.680
6	0.762	0.917	0.823	0.927	0.700
7	0.870	0.930	0.912	0.954	0.809
8	0.872	0.901	1.000	0.872	0.786
mean	0.864	0.951	0.922	0.938	0.822

year = 4

firm	effch	techch	pech	sech	tfpch
1	1.000	0.831	1.000	1.000	0.831
2	1.000	0.910	1.000	1.000	0.910
3	1.013	0.934	0.927	1.093	0.946
4	1.013	0.980	0.937	1.081	0.993
5	1.270	0.940	1.179	1.077	1.195
6	1.312	1.156	1.215	1.079	1.516
7	1.001	0.931	0.952	1.051	0.931
8	0.943	1.022	0.908	1.039	0.964
mean	1.062	0.959	1.009	1.052	1.018

year = 5

firm	effch	techch	pech	sech	tfpch
1	1.000	1.023	1.000	1.000	1.023
2	1.000	0.844	1.000	1.000	0.844
3	1.094	0.925	1.079	1.014	1.012
4	1.239	0.849	1.206	1.028	1.052
5	1.026	0.879	1.032	0.993	0.902
6	0.903	0.721	0.906	0.997	0.651
7	1.168	0.889	1.151	1.015	1.038
8	1.182	0.755	1.077	1.098	0.893
mean	1.071	0.856	1.053	1.018	0.917

year = 6

firm	effch	techch	pech	sech	tfpch
1	1.000	1.095	1.000	1.000	1.095
2	0.808	1.078	1.000	0.808	0.871
3	0.994	1.085	1.000	0.994	1.079
4	1.005	1.146	1.021	0.984	1.151
5	1.002	1.076	1.028	0.975	1.078
6	1.108	1.189	1.104	1.003	1.317
7	0.985	1.105	1.000	0.985	1.089
8	1.028	1.169	1.023	1.005	1.202
mean	0.988	1.117	1.021	0.967	1.104

year = 7

firm	effch	techch	pech	sech	tfpch
1	1.000	0.886	1.000	1.000	0.886
2	1.187	0.990	1.000	1.187	1.175
3	0.936	0.987	0.977	0.958	0.923
4	0.963	1.006	1.002	0.961	0.969
5	1.044	0.985	1.000	1.044	1.029
6	0.998	0.996	1.000	0.998	0.995
7	0.936	1.011	0.935	1.000	0.946
8	1.000	1.047	1.000	1.000	1.047
mean	1.005	0.987	0.989	1.016	0.993

MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

year	effch	techch	pech	sech	tfpch
2	1.022	0.846	1.012	1.010	0.865
3	0.864	0.951	0.922	0.938	0.822
4	1.062	0.959	1.009	1.052	1.018
5	1.071	0.856	1.053	1.018	0.917
6	0.988	1.117	1.021	0.967	1.104
7	1.005	0.987	0.989	1.016	0.993
mean	1.000	0.949	1.000	0.999	0.948