A NOVEL APPLICATION OF DATA ENVELOPMENT ANALYSIS AND PRODUCTION TRADE-OFFS FOR EFFICIENCY EVALUATION OF BANKING INSTITUTIONS – THE CASE FOR PAKISTAN

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Declarations

I declare that:

- I am the author of this thesis and responsible for the work submitted.
- The work in the thesis has not been previously submitted within a degree programme at this or any other institution.
- This thesis does not contain any information formerly published without incorporating due references and acknowledgements.

During the PhD studies, the following conference presentations were made.

Ishaq, S. "Improving Data Envelopment Analysis with the Trade-Off Approach-A Case of Banking Sector Firms", 56th Annual OR Conference, Royal Holloway University of London, UK, 9-11 September, 2014.

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Abstract

A growing body of empirical literature has attempted to measure the efficiency of banking sector using Data Envelopment Analysis (DEA) by focusing on different aspects of banking services. However, standard DEA models often fail to sufficiently discriminate between efficiency scores of banks particularly with small sample size. Moreover, sometimes knowledge about different banking operations is available that needs to be incorporated in the evaluation method to assess their impact on the performance of banks.

This research deals with the efficiency evaluation of banking sector through DEA based on additional information about multiple banking operations without which efficiency is generally overestimated. The main objective of this thesis is to develop a better informed DEA model that is capable of incorporating additional information about different bank specific characteristics by overcoming the problem of poor discrimination. For this purpose, the current study has proposed a novel methodological integration of DEA with production trade-offs in banking context and named it “DEATOB Framework”. This framework is universal in nature and can be applied to banking sectors of other countries.

The study also aims to provide the empirical application of DEATOB Framework for which a sample of 29 commercial banks of Pakistan is selected. The results indicate that this framework evaluates banks on the basis of additional characteristics and provides better discrimination between good and bad performers as compared to the standard DEA model. The final objective is to extend the proposed framework to other banking models. For this purpose, the profitability model is chosen considering the profit maximization goal of banks and a separate PDEATOB Framework is developed. An empirical application of this framework is also provided to demonstrate its workability. This thesis also provides an insight on scale efficiency and relationship of efficiency with the banks size and ownership after application of the proposed frameworks.

List of Acronyms

ADB: Asian Development Bank

ADR: Advances to Deposit Ratio

AKFED: Aga Khan Fund for Economic Development

AI: Artificial Intelligence

BCC: Banker, Charnes and Cooper Model

BLP: Branch Licencing Policy

BSC: Banking Services Corporation

BSS: Banking Sector Strategy

CAR: Capital Adequacy Ratio

CCR: Charnes Cooper and Rhodes Model

CDC: Central Depository Company

CES: Constant Elasticity of Substitution

CLA: Corporate Law Authority

CRR: Cash Reserve Requirement

CRS: Constant Returns to Scale

DEA: Data Envelopment Analysis

DEATOB: Data Envelopment Analysis with Trade-Offs in Banking Sector

DFA: Distribution Free Approach

DFID: Department for International Development

DFIs: Development Financial Institutions

DMU: Decision Making Unit

DRS: Decreasing Returns to Scale

EMG: Employee Management Group

EPS: Earnings per Share

ESOP: Employees Stock Ownership Plan

FDH: Free Disposal Hull

FSAL: Financial Sector Adjustment Loan

GDP: Gross Domestic Product

GMM: Generalized Method of Moments

ICP: Investment Corporation of Pakistan

IDR: Investments to Deposit Ratio

IMF: International Monitory Fund

IRS: Increasing Returns to Scale

MCR: Minimum Capital Requirement

MFIs: Microfinance Institutions

MI: Malmquist Index

MOF: Ministry of Finance

NBFIs: Non-Bank Financial Institutions

NCBs: Nationalized Commercial Banks

NDRS: Non-Decreasing Returns to Scale

NIBAF: National Institute of Banking and Finance

NIRS: Non-Increasing Returns to Scale

NIT: National Investment Trust

NPLs: Non-Performing Loans

NSS: National Saving Schemes

OBS: Off-Balance Sheet

OLS: Ordinary Least Squares

OR: Operations Research

OTE: Overall Technical Efficiency

PBC: Pakistan Banking Council

PDEATOB: Data Envelopment Analysis with Trade-Offs in Banking Sector with Profitability Model

PIB: Pakistan Investment Bonds

PPS: Production Possibility Set

PTC: Participation Term Certificates

PTE: Pure Technical Efficiency

RA: Regression analysis

ROA: Return on Assets

ROE: Return on Equity

ROI: Return on Investment

RTS: Returns to Scale

SAP: Structural Adjustment Programme

SBP: State Bank of Pakistan

SE: Scale Efficiency

SECP: Securities and Exchange Commission of Pakistan

SFA: Stochastic Frontier Approach

SLR: Statutory Liquidity Requirement

TFA: Thick Frontier Approach

TFC: Term Finance Certificates

TO: Trade-Off

VRS: Variable Returns to Scale

WB: World Bank

CHAPTER 1

INTRODUCTION

1.1. Background

A well-established financial system is considered an important prerequisite for increasing the pace and sustenance of economic growth (Levine, 1998, State Bank of Pakistan, 2003, Paradi et al., 2011b). Banking industry is the leading player of the financial sector that plays the important economic role in providing intermediation and economic acceleration through profitable channelling of savings and allocation of credit in the economy (Staub et al., 2010).

From the beginning of 1990's till 2007, banking industry all over the world has gone through substantial structural changes due to the twin forces of deregulation and technological changes (Wilson et al., 2010). Deregulation removed the entry barriers on the penetration of foreign banks in the domestic markets (Jeon and Menicucci, 2011). Technological changes revolutionized the processing and analysis of the financial data, and the delivery system of banks. All these revolutionary features not only improved the variety and quality of products and services but also reduced their costs and increased the overall lending capacity of banks. Hence, deregulation coupled with technological change enhanced the competition and internationalization of the domestic banking markets.

Competitive environment serves as catalyst for improving the banks' efficiency by reducing the services' prices as well as operational cost (Berger and Hannan, 1997, Casu and Girardone, 2010), enhancing the efficient organization of production and introducing innovation in products and services (Sahoo and Tone, 2009b). In contrast, sometimes competitive environment may increase the likelihood of accepting more risky ventures by banks to maintain their market share. This risk taking behaviour may lead to the insolvencies of banks and ultimately to the systematic risk which may cripple the whole economy (Fethi and Pasiouras, 2010).

The economic significance and increasing market competition emphasize the need to evaluate the financial performance of banks. This performance evaluation is essential for continuous improvement of their operations and monitoring of their financial sustenance. Moreover, different stakeholders such as owners, potential investors, depositors, managers and regulators are interested in the evaluation of financial performance and overall efficiency of banks (Zhu, 2009).

Identification of the best and worst performers, is the first task in the performance evaluation of financial sector (Berger and Humphrey, 1997). For this purpose, often frontier techniques are applied that also require the development of different banking behaviour modelling approaches to appropriately capture the banks' activities and objectives. These modelling approaches are important for the selection of variables in the efficiency analysis. However, an important limitation of these approaches is their inability to include all the banking aspects in the form of input/output variables in the banking model.

Literature review on banking efficiency highlighted the important fact that except risk other bank specific endogenous and exogenous factors are normally not included into the input/output set of the banking behaviour models used for efficiency evaluation through Data Envelopment Analysis (DEA). Even risk variable is included in the input/output set of only a handful of DEA based efficiency studies (such as Charnes et al. (1990), Leightner and Lovell (1998), Drake et al. (2006), Pasiouras (2008a)). Moreover, in spite of using risk variables, these studies have not ensured their inclusion in the efficiency evaluation because these could be ignored in the analysis by assigning zero weight to them due to the complete weight flexibility allowed in DEA. Furthermore, there is some additional information available regarding the bank specific characteristics which need to be added to the transformation process of banks. To deal with these issues, the current study has applied a novel concept of production trade-offs[1] which is somewhat similar to the traditional method of weight restrictions but provides a different way of incorporating additional information in the transformation process by preserving the technological meanings of efficiency.

The main aim of this study is to contribute to both DEA and banking efficiency literature by proposing a novel combination of DEA and production trade-offs in the banking context in the form of a framework that is capable of adding additional information about different banking aspects into the DEA based banking behaviour models. This framework provides a way to incorporate risk and bank specific exogenous and endogenous factors into the efficiency evaluation to create a better informed DEA banking model. Moreover, this framework handles the problem of insufficient discrimination encountered in case of small data set. This study does not capture all the bank specific endogenous and exogenous factors that may impact efficiency. Instead this study provides the first illustration of the innovative method of production trade-offs to capture the impact of these factors on the efficiency estimation.

This study also aims to investigate scale efficiencies and efficiency estimates in relation to the ownership type and the asset size with application of the proposed framework. Finally, the study aims to extend the proposed framework to other banking behaviour models. For the empirical application of the proposed framework, the current study has selected the data set from the banking sector of a developing

[1] Production trade-offs is a methodological approach proposed by Podinovski (2004). Production trade-offs states that simultaneous changes in inputs and/or outputs that are possible in technology under consideration. This concept is explained in detail in Chapter 4 section 4.7.3.

emerging Asian economy "Pakistan". It should be noted here that the current study is not a straight forward application of the DEA in banking sector rather this provides a framework that addresses the universal issues which are not limited to the banking sector of Pakistan.

1.2. Problem Statement and Motivations

Data Envelopment Analysis (DEA) is an optimization technique used to assess the relative efficiency of homogenous organizational units, called decision making units[2] (DMUs). Since its first application on the banking sector by Sherman and Gold (1985), it has been used in a variety of ways by researchers in various countries to evaluate the efficiency of different aspects of banking operations. Efficiency of financial institutions has attained a considerable attention of researchers all over the world because it is generally argued in the banking literature that banks, as financial intermediaries, play an important role in the process of economic growth (Levine, 1998). However, instability and insolvency of banks may lead to the systematic crisis that can affect the whole economy adversely (Fethi and Pasiouras, 2010).

Financial instability of banks is mainly caused by misallocation of credit that gives rise to the poor quality loan/non-performing loans[3] (NPLs), which ultimately end up in loan losses. Hence, a large amount of NPLs symbolize that greater risk factor is attached to the assets of banks in the form of loan default. Accumulation of such NPLs may lead to the bank failure (Demirguc-Kunt, 1989, Barr and Siems, 1994, Wahlen, 1994) and ultimately the banking crisis (Reinhart and Rogoff, 2011).

Although the last two decades have witnessed a significant proliferation of research on banking efficiency studies using DEA, the banking studies that have accounted for

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[2] Decision making unit (DMU) is a name given to the entity under evaluation in DEA terminology. DMU can be university, hospital, financial institution, cities, manufacturing unit etc.

[3] Non-performing loans (NPLs) represent all loans in the portfolio overdue on interest and loan payment for more than 90 days.

risk factor in the banking models are quite limited. The literature on banking studies with respect to risk can be divided into three distinct strands.

The first strand has completely ignored the risk factor attached to the total amount of loans in the form of poor quality loans (i.e NPLs) (for reference see (Thompson et al., 1997, Chen et al., 2005, Das and Ghosh, 2006, Sahoo and Tone, 2009a, Fethi et al., 2011). Such ignorance of risk factor can lead to incorrect relative efficiency scores.

The second strand of studies has incorporated risk into the efficiency studies as exogenous factor by using multistage evaluation methods (Isik and Hassan, 2003, Ariff and Can, 2008, Sufian, 2009, Staub et al., 2010). These studies used different frontier techniques at the first stage for measuring efficiency of banks without risk. Then at the second stage, the efficiency scores obtained at the first stage were regressed against a number of variables including risk to study their impact on the efficiency scores.

Unlike the first two strands, the third strand has explicitly considered risk factor in DEA models at the first stage by using different variables as proxy for risk. Among those some studies have considered loan loss provision[4] as a proxy for poor loan quality (Leightner and Lovell, 1998, Drake and Hall, 2003, Drake et al., 2009) while others have used multiple variables such as loan loss provisions, actual loan losses or NPLs for risk measurement in the model (Charnes et al., 1990, Chang, 1999, Paradi et al., 2011b). However, in spite of including risk variables there is still a possibility to ignore risk variables in the analysis through the allocation of zero weight to them due to the complete weight flexibility allowed by DEA models. The current study has addressed this problem by ensuring the inclusion of risk variable in the DEA based appraisal.

[4] Loan loss provision reflects the current period increase in the expected level of future loan losses and is represented as accrued expense on the income statement.

Apart from the risk, study of different bank specific endogenous (for example, liquidity, capitalization, ownership, management, size, profitability) and exogenous factors (such as GDP, GDP growth rate, inflation and regulations etc.) influencing the efficiency of banks, is a popular research dimension in DEA based banking efficiency literature (Isik and Hassan, 2003, Hauner, 2005, Ataullah and Le, 2006, Das and Ghosh, 2006, Ariff and Can, 2008, Pasiouras, 2008a). Despite the fact that such factors are not subject to the management control still their inclusion in the efficiency analysis is very important to study their particular impact on banks' performance (Charnes and Cooper, 1985). There are two main approaches to deal with such endogenous and exogenous factors. First, these factors have been introduced in the studies as non-discretionary variables (Lozano-Vivas et al., 2002) and second, as independent variables in regression model at the second stage analysis (Bhattacharyya et al., 1997, Resti, 1997, Hauner, 2005, Das and Ghosh, 2006, Drake et al., 2006, Sufian, 2009). In addition to these exogenous and endogenous factors, there are many aspects of banking operations that influence the production process and ultimately the profitability of banks. Such aspects are very obvious in the operational practices of banks and in many cases are even quantifiable, but due to the limitations of analysis techniques, information about such aspects cannot be added to the efficiency evaluation of banks. For example, it is a known fact that banks act as financial intermediaries that accept deposits and advance loans to individuals and corporate customers. According to the intermediation process, every increase in the deposits brings about an increase in the amount of loans and investments. Such an increase in loans and investments as a result of increase in deposits can be anticipated keeping in view the market conditions, past experience and regulations governing this intermediation process. However, standard DEA models do not allow incorporating this information into the evaluation process. This limitation of the standard DEA models indicates that there is a need of a reliable method that is capable of incorporating this information of bank specific exogenous and endogenous factors into standard DEA models.

Another significant problem, often faced with the application of standard DEA models, is the lack of discrimination in efficiency scores of DMUs where most of the units obtain maximum or near maximum efficiency scores. Insufficient discrimination problem is observed more frequently in studies involving the small number of DMUs as compared to the number of input and output variables required to adequately represent various activities undertaken by the DMUs. Sometimes, despite the presence of sufficient number of DMUs, the problem of poor discrimination is still observed when the production technology is considered to exhibit variable returns to scale and a subset of units have very different scale sizes as compared to the rest of the units (Podinovski, 2007b).

In the current study, efficiency scores of Pakistani banks obtained through running standard output oriented DEA model with VRS assumption also encountered the problem of poor discrimination. This is due to the fact that both of the above mentioned reasons of poor discrimination are prevalent in the banking sector of Pakistan that is, the existence of small data set (as series of mergers and acquisitions during the last 10 years has reduced the number of banks drastically) and the variation in the scale of operations (as one public and four privatised banks are very large in size as compared to the rest of the banks working in Pakistan).

Weight restrictions have long been recognized as an important tool to add additional information and deal with the problem of poor discrimination in standard DEA models. Weight restrictions are constructed according to the value judgments based on management's perceived view regarding the relative importance of inputs and outputs or monetary considerations. However, a major drawback of such weight restrictions is that the resulting efficiency estimate can no longer be interpreted as a realistic improvement factor (Allen et al., 1997, Thanassoulis and Allen, 1998). In other words, efficient radial target of an inefficient unit is not feasible or producible technologically (Podinovski, 2004).

Based on the above mentioned facts, the key motivation of the current thesis is to propose a better informed DEA framework in the banking context that is capable of incorporating additional information regarding the production process, exogenous and endogenous factors and banks specific operating characteristics directly into the DEA based efficiency estimation. For incorporating additional information into the DEA model, the current study has applied a novel methodological approach known as "*the trade-off approach*", originally proposed by Podinovski (2004). The trade-off approach is based on the idea of "*production trade-offs"* that represent "*simultaneous changes in inputs and/or outputs that are possible in technology under consideration*". The trade-off approach is an outcome of the technological thinking based on technological realities and not a result of value thinking based on managerial value judgments. With the trade-off approach, technological meanings of efficiency as a realistic radial improvement are preserved and the resulting model provides better discrimination between efficient and inefficient DMUs. We have named this combination of DEA and production trade-offs in the banking context as the *"DEATOB Framework*" which is the first application of production trade-offs in the banking sector.

This thesis is also motivated by the need to expand the existing banking efficiency literature to a developing Asian economy "Pakistan" as banking efficiency literature is dominated by the studies conducted on the developed economies. The proposed DEATOB Framework designed for the banking sector of Pakistan is not only suitable for Pakistani and Asian banking sector but have the potential of worldwide applicability.

Moreover, there is no recent work available on efficiency of the banking sector of Pakistan. Credible studies on the banking sector of Pakistan have covered 1990's and few early years of 21st century when the major banking reforms were introduced as a result of deregulation and liberalization and mostly used parametric approaches for efficiency evaluation. Therefore, another motivation of the study is, the need to investigate the Pakistani banking sector using DEA in the recent years when most of the banking reforms have shaped up the banking system.

This thesis investigates the efficiency of banking sector of Pakistan with different operational dimensions (intermediation and profitability) in recent years with a completely new framework that is a novel application of DEA with production trade-offs.

1.3. Research Aims and Objectives

Based on the above discussion, this study has three main objectives.

The *primary objective* of the study is, to develop a novel DEA based framework using productions trade-offs in the banking context. The aim is to construct a better informed model of technology that can tell DEA how to evaluate efficiency based on the additional information. The novelty of the study lies in the way additional information is incorporated directly into the DEA model through the production trade-offs that otherwise is not possible to add in the DEA model. Sub objectives under this main objective are:

1. To clarify the meaning of production trade-offs in the banking context.

2. To elaborate the development process of the DEATOB Framework by identification, evaluation and incorporation of production trade-offs in DEA.
3. To ensure the workability of trade-offs.

The proposed DEATOB Framework is the first methodological application of the theoretical concept of production trade-offs for the efficiency evaluation in the banking set up. This framework provides an innovative way of identification, justification and incorporation of production trade-offs in the banking context. To accomplish this objective, we have chosen the intermediation approach from among the banking behaviour modelling approaches and selected the input and output variables accordingly. Our proposed DEATOB Framework has a number of constituent production trade-offs developed in the form of relationships between inputs and/or outputs.

The main task in developing trade-offs is, to assess the particular trade-off at the first place and make sure that it is technologically plausible which means that all the banks in the sample should agree on the use of that trade-off. This ensures that the expansion in the production possibility set (PPS) is technologically meaningful. Therefore, our core concern in assessing the trade-offs, is their technological realism and general approval by the banks because it is possible to formulate a more demanding trade-off that improves the discrimination even better but may not be acceptable by all the banks.

We have conducted a detailed literature review of the banking efficiency studies and identified that not much attention had been paid to the incorporation of bank specific factors including risk into standard DEA models. This review in conjunction with the review on banking sector of Pakistan identified different features of banking operations (such as risk, regulations, intermediation process, profit generation process and shift in asset mix) in the domain of bank specific exogenous and endogenous factors.

After identification, the quantification of trade-off relationships between inputs and outputs is a crucial step that requires the detailed information on banking operations and regulations. Moreover, opinions and feedback of the banking professionals are essential for the evaluation and refinement of trade-offs to make them acceptable for all the banks involved in the study. The workability of identified trade-offs requires their right application into the DEA model in order to ensure that they are technologically feasible. For this purpose, we have formulated simple and realistic trade-offs in the current study that are technologically feasible and work well with the operational requirements of all banks.

The *second objective* of the thesis is to analyse the impact of trade-offs through the application of the proposed DEATOB Framework. This objective is further divided into the following sub objectives:

1. To examine the impact of different trade-offs developed for the DEATOB Framework on the technical efficiency of banks.
2. To improve the discrimination of DEA model.
3. To use the DEATOB Framework for investigating the relationship of efficiency with the bank size and ownership type.
4. To demonstrate that the idea of production trade-offs is equally applicable and useful with the existing standard methods of calculations used for the determination of scale efficiency (SE) and returns to scale (such as IRS, DRS, CRS).

To put the proposed framework into practice, we have empirically applied it on the data set from the banking sector of Pakistan. The impact of trade-offs on technical efficiency scores is analysed after applying each constituent trade-off of the DEATOB Framework in the standard DEA model. By compensating for the small quantities of data, production trade-offs designed for the DEATOB Framework have the ability to reduce the chances of obtaining uniform efficiency scores by banks with non-uniform performance. However, an important feature of this framework is that all its trade-offs are not formulated arbitrarily just to improve the discrimination. Rather, these trade-offs serve the dual purpose. First, they develop the better informed model to evaluate banking efficiency and second, they improve the discrimination of the model.

Moreover, the efficiency estimates obtained after application of the DEATOB Framework are analysed to investigate the relationship of efficiency estimates with the bank size and ownership type. For the calculation of scale efficiency and returns to scale (RTS), we have used the existing standard method of calculating RTS without modifying them for the application of the DEATOB Framework. This practice indicates that trade-offs characterize the technology, not the way of measuring the scale efficiency and RTS characteristics.

The *third objective* of this thesis is to extend the idea of production trade-offs to various banking behaviour models.

The main purpose of this objective is to provide empirical evidence that the idea of production trade-offs is equally applicable to various banking behaviour models and their applicability is not just confined to one banking model (intermediation approach) for which the DEATOB Framework is developed initially. To extend the idea of production trade-offs on other banking models, we have selected the profitability model considering the fact that banks are profit oriented organizations who strive to maximize their profits. Profitability model has different set of input and output variables therefore; we have developed a separate framework for this model termed as "PDEATOB Framework" with different set of trade-offs.

1.4. Research Questions

This thesis addresses different research questions based on the objectives delineated in the previous section. Each objective has its separate set of questions. The research questions related to the first objective are:

1. How can bank specific knowledge of different operational aspects of banking activities be accounted for into the DEA model?
   1.1. How are trade-offs identified in actual banking operations?
   1.2. How is it assessed that certain trade-offs exist or not?
   1.3. How can trade-offs be used to handle bank specific exogenous and endogenous factors (such as risk, regulations, intermediation process, profit generation process and shift in asset mix of banks)?
   1.4. How are simple and complex trade-offs developed and what is the impact of their application on the efficiency scores?

The research questions related to the second objective are:

2. What is the impact of trade-offs of the DEATOB Framework on the technical efficiency of banks?
3. Does the discrimination of the standard VRS model improve with the DEATOB Framework?
4. Does the ownership type influence the efficiency of banks?
5. Is there any relationship between bank size and efficiency scores?
6. What are the scale efficiencies and RTS of Pakistani banks with the DEATOB Framework?

The research question related to the third objective is:

7. How can the idea of production trade-offs be extended to other banking models?

Question 1 and its sub questions are answered in Chapter 6 by proposing a DEA based DEATOB Framework that integrates the production trade-offs with banking operations. The outcome of this question is the methodological proposition that leads to a new application of production trade-offs in the banking context that incorporates bank specific characteristics such as risk, intermediation process and asset mix in the intermediation banking behaviour model under DEA approach. Sub questions stated under the first question basically address the general issues arising in the course of developing trade-offs for the DEATOB Framework. These questions are answered through a detailed description of the development process of each trade-off. The effect of defined trade-offs on the efficiency scores is elaborated with the help of a practical example using the sub set of original data from the banking sector of Pakistan.

To answer all the questions formulated for the second objective, we have performed the empirical analysis that is presented in Chapter 7. For this purpose, first the efficiency scores are calculated with the standard VRS model. For answering *Question 2*, the efficiency scores are calculated by incorporating each individual trade-off independently and compared with the efficiency scores obtained with the standard VRS model. *Question 3* is answered by comparing the efficiency scores before and after application of the complete DEATOB Framework. Based on the evidence in the form of differences in the relative efficiency scores before and after application of the DEATOB Framework, it could be determined whether the discrimination of efficiency scores of banks improved or not.

Questions 4 and 5 are answered by running the intermediation models with the DEATOB Framework under output oriented VRS technology and calculating the individual as well as average efficiency scores across different groups of banks in terms of size and ownership (as separate group are designed for size and ownership). This is interesting in a way that it provides a meaningful comparison of; individual efficiency scores within each subgroup and average efficiency scores across different banking subgroups. This comparison in turn helps to highlight the causes of gaps between efficiency scores of different banking subgroups.

For answering *Question 6*, in addition to running the DEATOB Framework under the intermediation model with output oriented VRS technology, we need to calculate output oriented efficiency scores with constant returns to scale (CRS) and non-increasing returns to scale (NIRS) technology. CRS and VRS efficiency scores are required to calculate the scale efficiency whereas CRS, VRS and NIRS efficiency scores are needed for investigating the returns to scale characteristics of all the banks according to the method proposed by Färe et al. (1985).

For answering *Question 7*, we have selected the profitability model from different banking behaviour models. Profitability model has different set of input and output variables than the intermediation approach therefore we have developed the PDEATOB Framework for this model with different set of trade-offs. The trade-offs development process for the PDEATOB Framework along with its empirical application on the banking sector is provided in Chapter 8.

1.5. Thesis Contribution

1.5.1. Methodological Contributions

The major contribution of this research is towards the methodology of performance evaluation of banks. This contribution is the development of a framework with Data Envelopment Analysis using production trade-offs in the banking sector (called the DEATOB Framework), which is a novel application of theoretical concept of production trade-offs in DEA for efficiency evaluation of banking sector firms.

Production trade-offs provide a different way of data assessment by developing relationships between input and output variables that are technologically feasible. In ***methodological*** terms, there are three main ***contributions*** of the thesis.

The first contribution of the study is related to the development of a non-parametric banking efficiency framework that is capable of evaluating banks' efficiency on the basis of quantity as well as quality of assets. The DEATOB Framework contributes through the development of the nexus between bank efficiency and risk by incorporating risk variable in the banking model and linking it with the related risk free variable. This framework not only incorporates risk factor into DEA model but also ensures that risk factor is not ignored in the performance evaluation due to weight flexibility allowed in standard DEA model.

The second contribution of our study relates to the incorporation of bank regulation (exogenous) and bank specific (endogenous) characteristics (such as loan generating capability, profit generating capability, and asset management) into standard DEA model through the application of the trade-off approach without introducing any special variable. This contribution aims to ensure the improvement of existing DEA models of banks performance evaluation by incorporating the additional information regarding banks' specific operational characteristics, regulatory requirement and expert opinion through the production trade-offs.

The third contribution is in the form of improved discriminatory power of standard DEA assessment. It is theoretically clear that the use of production trade-offs leads to the improvement in the discrimination but the extent of discrimination depends on the data set and other factors. In this study we provide an empirical evidence of such improvement in discrimination which is achieved through the development and incorporation of feasible and reliable technological judgements in the standard DEA model through the production trade-offs.

1.5.2. Generalizability of the DEATOB Framework

The DEATOB Framework formulated for the banking system of a developing country like Pakistan is equally applicable to the banking environment of developed countries. Although rules and regulations governing banking activities and the financial environment vary from country to country, the transferable set of trade-offs developed in the study can be used in a variety of ways:

1. The same set of trade-offs, developed in the DEATOB Framework, can be applied to the banking sector of other countries with minor changes in values of trade-offs, if required.
2. The DEATOB Framework can also provide guidelines for developing new trade-offs in the banking sector.
3. This idea of the DEATOB Framework is easily extendable to various banking behaviour modelling approaches. As a confirmation of this claim, the current study has considered the intermediation and profitability models and developed a separate set of trade-offs for each model and applied that on data from the banking sector of Pakistan.
4. This framework can help other sectors to develop the logic for the formulation of production trade-offs in their production process.

1.5.3. Extending the Empirical Context of DEA Application

This piece of research is an empirical contribution to the existing DEA literature that has broadened its application context in two ways. First, it contributes to DEA literature on the banking sector and second, to the DEA literature on the developing economies. In terms of DEA banking literature, the DEATOB Frameworks developed for banking intermediation and profitability approaches separately, has incorporated risk, bank specific characteristics and banking regulation in the intermediation and profit maximization goals of banks. Moreover, this framework is the first application of theoretical concept of production trade-offs on the banking sector that provides a better informed model of technology accounting for asset quality/risk, banking regulations and bank specific operational characteristics. In this way, the DEATOB Framework enriches the DEA banking behaviour models by incorporating the required information regarding the banking system, operational needs, and policies that otherwise cannot be considered in DEA appraisal. Moreover, this model ensures better discrimination of DEA efficiency scores.

Regarding the DEA literature in the developing economies, this study has considered the banking sector of Pakistan which is a developing Asian economy. In Pakistan, the literature on banking sector is quite limited and among the available studies, the notable studies have used parametric estimation methods for efficiency calculation. The only few studies with the application of DEA for efficiency estimation have addressed the efficiency of banks with reference to banking deregulation, liberalization and financial reforms introduced in 1990's and early years of 21st century. Moreover, none of the study has considered the risk factor explicitly in the DEA based banking model.

Therefore, this research contributes to the DEA application in the developing economies of Asia and particularly Pakistan by considering a novel DEATOB Framework that covers both risk and profitability of the intermediation activities across different types of banks in Pakistan. In addition, this study analyses the banking efficiency in the year 2012 that provides the information about the current state of the banking system of Pakistan after disappearance of a large number of banks particularly foreign banks from banking arena as a result of mergers and acquisitions. This investigation also has profound implications at the policy level. This study will help management of commercial banks to identify efficient and inefficient areas of operations and will assist them to design future strategies for improving their efficiency. Methodology developed in our study can also provide useful guideline to central bank to evaluate performance of banking sector as well as performance of sub groups of banks working in Pakistan, which in turn can be helpful for effective policy recommendations.

1.6. Thesis Structure

This thesis is organized into nine chapters. Chapter 1 have provided general overview of the performance evaluation of banks and highlighted the dimensions in banking efficiency studies that inspired the current thesis. The chapter also sets out the motivations underlying the study and delineate different research objectives from which research questions are derived. It has introduced DEA as the key analysis tool and its novel application with production trade-offs in the banking context. It has provided brief overview of the scheme of work to answer the questions formulated under each objective. It has also described research contributions attempting to contribute to DEA as well as banking literature by considering the data set of commercial banks from Pakistan.

Chapter 2 reviews different performance evaluation techniques used in the banking sector. Based on the choice of DEA as the main research technique of the thesis, this chapter provides a detailed review of the banking studies that have used DEA for the assessment of banking efficiency. This chapter also provides a brief overview of different issues addressed in the banking studies using DEA. A detailed description of various banking behaviour modelling techniques, adopted in different banking studies for the selection of input-output variables, is also provided in this chapter. Finally, different issues addressed in the current study are outlined in this chapter considering the limitations of the existing banking efficiency literature.

Chapter 3 introduces the financial system of Pakistan. This chapter starts with a brief overview of the regulatory structure of Pakistan and moves on to the evolution of banking system in Pakistan since independence. Next, it outlines the distinguishing features of the banking sector of Pakistan that help in selecting the banking behaviour models and developing the DEATOB Framework.

Chapter 4 provides a comprehensive review of the theory of DEA. This chapter offers different basic theoretical concepts and preliminary information on the basic DEA models along with their mathematical formulations. It also introduces the concept of weight flexibility in DEA and describes weight restrictions as a traditional approach used to restrict the weight flexibility. It also provides theoretical underpinning of the concept of production trade-offs which is the core subject of the current research.

Chapter 5 details the major methodological considerations in relation to developing a DEA model for the estimation of banking efficiency. It starts with the selection of appropriate banking techniques and describes the input-output specifications under different banking models used in the current study. The choice of returns to scale and orientation of the study is also detailed herein. Moreover, it explains the data used in the current study along with their different sources.

Chapter 6 unfolds the conceptual framework named "DEATOB Framework" build around the motivations of the current study. It describes the development process of the DEATOB Framework and covers all the stages in the identification, validation, evaluation, incorporation and review of each constituent trade-off of the framework. It also provides the mathematical formulation of different components of framework. An empirical example has been used to elaborate the impact of each trade-off on the efficiency estimates. In short, this chapter covers all the aspects of primary objective and answers all the questions formulated under this objective.

Chapter 7 provides the empirical application of the DEATOB Framework on the banking sector of Pakistan. It first explains the impact of each individual trade-off on the efficiency estimates and then analyses variations observed in the efficiency scores as a result of sequential addition of all the trade-offs of the DEATOB Framework. It investigates the average efficiency and best-practice differences across different identified subgroups based on bank ownership, and size. In the final section, the scale efficiency of banking sector of Pakistan is determined. This section also performs returns to scale investigation of all the banks included in sample with the DEATOB Framework using the method described by Färe et al. (1985). In general, this chapter discusses the findings from the empirical analysis with regards to the questions set out under the second objective of the study.

Chapter 8 aims to achieve the third objective set in the study. It extends the scope of our proposed framework to another banking behaviour model known as profitability model in the form of the PDEATOB Framework. It first describes the development process of the PDEATOB Framework given that this model uses a different set of inputs and outputs. This chapter also reports the empirical findings obtained with the application of this framework on the banking sector of Pakistan. The last section of this chapter provides a comparative analysis of the results obtained with the two frameworks developed in the current study.

Finally, in Chapter 9, we summarize the major findings of the current research and the key conclusions derived. This chapter also offers directions for future research.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

This chapter introduces different performance evaluation techniques used in the banking sector. A brief introduction of these techniques is given with their merits, demerits and uses in different banking studies. Based on the brief literature of different techniques, justification for the selection of DEA as the main research technique of the thesis is provided in this chapter. The chapter includes the review of banking studies at institutional level that used DEA for the efficiency estimation. This chapter also provides the overview of different banking behaviour modelling techniques applied in the banking literature. Finally, the chapter describes the main issues that are addressed by the current thesis through the proposed framework considering the limitations of the existing banking efficiency literature.

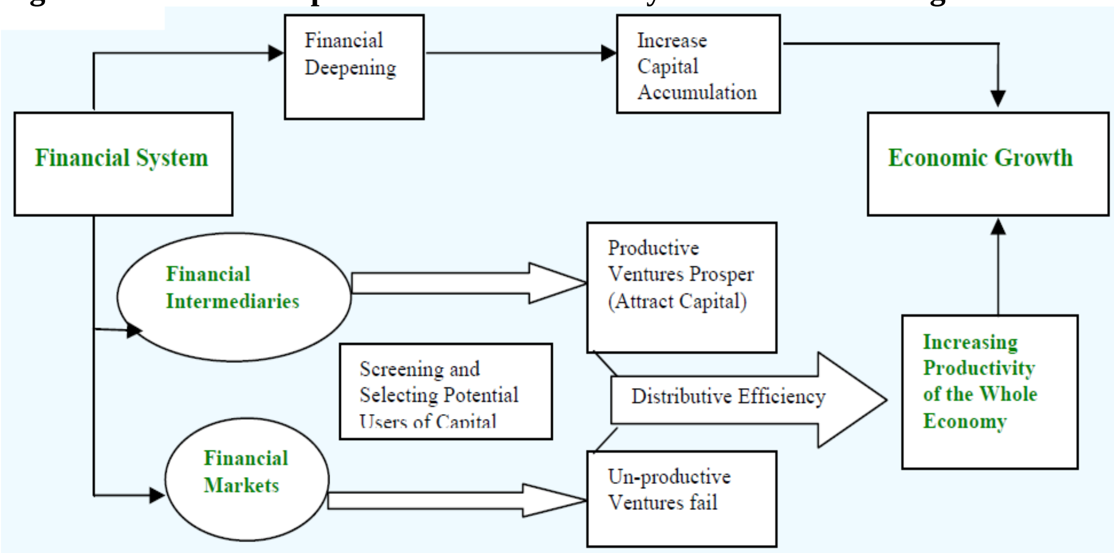
2.2. Performance Evaluation in Banking

Performance refers to the accomplishment that hosts to a wide range of systems, processes and mechanisms (Conaty, 2012) while evaluation focuses on the determination of results and objectives of the performance and its main purpose is not to prove but to improve (Guerra-López, 2008). Therefore, performance evaluation means to determine the worth of processes, mechanisms and systems to find whether they have delivered the desired results or not. Generally, performance evaluation compares the achieved results with the expected performance and is essentially concerned how to improve the performance (Guerra-López, 2008).

Performance evaluation and benchmarking plays a positive role for the constant progression and improvement of a business unit so that it can survive and flourish in the present competitive business environment (Zhu, 2009). Performance evaluation not only reveals strengths and weaknesses of business operations and activities but also helps to identify opportunities to improve current processes, operations and services in order to meet the ever-increasing demands of customers (Paradi et al., 2011a).

Performance evaluation becomes much more important in the banking context because a well-established financial system is considered to be an important prerequisite for increasing the pace and sustenance of the economic growth (State Bank of Pakistan, 2003). Specialized services provided by the banks and their increased financial deepening and outreach serve as an important linkage between the financial development and economic growth. This linkage between the financial sector and economic growth can be demonstrated with the help of the following diagram (State Bank of Pakistan, 2003).

Figure 2. 1 Relationship between the financial system and economic growth



Source: (State Bank of Pakistan, 2003)

It is argued in the banking literature that banks increase the level of economic activities and stimulate the process of economic growth in different ways. First, as financial intermediaries, these mobilize the financial resources of economy by channelling them from where they are in excess to where they are needed (Fama, 1980). Hence, they optimize the allocation of resources available in the economy.

Second, the volume of total deposits in all the banks reflects the bulk of money stocks held by a country (Yue, 1992) that represents the level of capital accumulation in the economy. Third, banks provide transaction and payment services (Paradi et al., 2011a). Finally financial sector manages risks by pooling and diversifying constituents' risks (State Bank of Pakistan, 2003).

Performance evaluation of banks also becomes important in the wake of increasing competition in the market in order to monitor their financial condition and improve their functions. There are many stakeholders who are concerned about the financial performance of banks such as regulators, management and potential investors (Paradi et al., 2011a). Regulators are interested in the performance analysis to determine the response of industry as a result of introduction of new regulations, worldwide competition, non-traditional entrants and future government policies as well as to work out appropriate and timely interventions to prevent the systematic failures. Management and owners of banks use such analysis to judge the effectiveness of their resource allocation, the impact of on-going structural changes and their ability to realign business operations with recent and more profitable trends. Moreover, efficiency studies highlight the inefficient areas of operations that help management to improve such inefficiencies by formulating suitable remedial strategies. An important use of this analysis is for potential investors and depositors who want the security of their money along with the attractive return.

Initially, financial institutions used to enjoy large spread between deposit and loan rate due to market fragmentation and local oligopolies. However, these benefits started to shrink with the wave of deregulation and liberalization of financial sector that increased the competitive pressure amongst financial institutions (Resti, 1997). The competitive environment serves as catalyst for improving performance of banks, by reducing services' prices and operational costs (Berger and Hannan, 1997, Casu and Girardone, 2010). But this intense competition led banks to behave less carefully while assessing the creditworthiness of their clients that initiated the profitability problem. Such a situation emphasized the need for financial institutions to assess their productivity level through quantitative techniques.

2.3. Performance Evaluation Techniques in Banking

Performance evaluation of banks was a common phenomenon even long before the introduction of DEA. Traditionally banks performance was evaluated through comparatively simple techniques such as financial ratios and regression analysis. In recent years, the focus of academic research on performance evaluation of financial institutions has shifted towards the operations research (OR) based efficient production frontier models which evaluate how well a bank performs relative to the best banks provided they are doing business in the same economic environment. Major advantage of frontier techniques over other performance evaluation methods is that they provide an objectively determined quantitative measure by eliminating the effect of differences in prices and other market based exogenous factors (Bauer et al., 1998). A brief introduction of these techniques is provided in the following sub sections.

2.3.1. Ratio Analysis

Ratios analysis is a traditional method that has been frequently used by the regulators, business analysts and management to measure the performance of banks. A ratio measures the relationship between two variables selected to provide insight into multiple dimensions of banking operations such as liquidity, leverage, risk management, asset quality, and profitability. Ratio analysis involved a number of key performance indicators[5] commonly used by financial institutions and investors to

[5] Performance indicator refers to the ratio of input to output or output to input.

assess the financial position and business performance. Return on Assets (ROA), Return on Equity (ROE), Return on Investment (ROI), Earnings per Share (EPS), and dividend per share are the most commonly used key performance indicators amongst financial ratios. Financial ratios provide a lot of information about the financial performance of individual banks, not only compared to previous years but also in comparison to the performance of other banks (Sherman and Gold, 1985). Ratios also allow the comparison between different sized banks. Moreover, ratios are used as a tool to control for sector characteristics allowing the comparison of individual bank's ratios with some benchmarks of that sector (Halkos and Salamouris, 2004).

Although, ratio analysis is attractive to analysts due to its simplicity and ease of understanding still there are some methodological problems and limitations attached to its use as an overall performance indicator. The major weakness is that each ratio only provides a partial picture of bank's performance due to its limited evaluation perspective constraint to one input and one output context failing to reflect multidimensional nature of bank's complex operations (Avkiran, 2011). This one dimensional nature of ratio analysis may also lead to contradictory and confusing results in case where different ratios provide varying levels of performance (Greenberg and Nunamaker, 1987, Barrow and Wagstaff, 1989, Thanassoulis et al., 1996, Thanassoulis, 2003). In some cases, a bank that appears profitable among its peers on the basis of ratio higher than the industry benchmark, is not actually efficient in applying its resources to generate various outputs (Avkiran, 2011). Another problem encountered in ratio analysis is that one ratio can only be compared with one benchmark ratio at a time considering that other ratios are fixed and the chosen benchmark ratio is suitable for comparison (Yeh, 1996). In addition, ratio analysis does not provide any clear indication about the precise target setting in terms of amounts of inputs and/or outputs required to improve the performance because it can derive performance target only with reference to one input and one output level at a time without considering the rest of the input and output variables. Although, poor value of any ratio for an organization indicates the need to improve that area but the required improvement level cannot be estimated with confidence (Thanassoulis et al., 1996). One common argument in favour of using ratio analysis is its ability to control for the size effect of financial variables that facilitates the comparison of a specific firm with other firms and with the industry averages. However, this control for size assumes a proportional relationship between numerator and denominator that implies constant returns to scale (Smith, 1990), which may not be true in many cases. Therefore, failure to account for multidimensional input and output processes coupled with inability to identify the best performing peer and input output targets, makes ratio analysis an inadequate technique for the performance evaluation of banks (Paradi et al., 2011a).

In spite of all its limitations, ratio analysis is still used for the performance evaluation of banks all over the world. Banks report their financial performance in terms of ratios in their annual reports. Market analysts use different groups of ratios such as solvency, credit quality, liquidity and profitability to make investment recommendations. Banking regulators also use various financial ratios to monitor the performance of banks such as ratios for the CAMELS[6] rating and compliance with the Basel Accord I, II and III[7].

[6] An international bank-rating system where bank supervisory authorities rate institutions according to six factors capital adequacy, asset quality, management quality, earnings, liquidity and sensitivity to market risk.

[7] A set of agreements introduced by Basel Committee on Bank Supervision (BCBS) that provides banking supervisory regulations and recommendations with regards to capital risk, operating risk and market risk. Basel Accord I was introduced in 1988 and focused on the capital adequacy. Basel Accord II published in 2004 and introduced standards for credit risk, market risk and operational risk. Basel Accord III agreed upon in 2010-11 to strengthen the liquidity position of banks in response to the deficiencies appeared in the form of financial crises of 2008.

There are many studies in banking literature, which intended to show that accounting ratios analysis could be used in complement to other performance assessment techniques such as frontier techniques to bridge the gap between academia and business world. Bauer et al. (1998) studied consistency condition of different frontier efficiency techniques for regulatory analysis of financial institutions and observed that if efficiency scores are related to standard performance measures such as cost and profitability ratios then regulators are more confident that these scores are accurate performance indicators and not just artificial measures based on some specific assumptions. Weill (2004) also examined consistency of different frontier efficiency methods on a sample of banks from five European nations. He investigated correlation between cost efficiency and four standard performance ratios and found significant correlations.

Yeh (1996), Bauer et al. (1998), Halkos and Salamouris (2004), Avkiran (2011) have used financial ratios with DEA for the performance assessment of banks. Some of the studies have used financial ratios at the second stage analysis[8] in the efficiency studies (Thoraneenitiyan and Avkiran, 2009).

2.3.2. Regression Analysis (RA)

Regression analysis is another common methodology used in the previous studies for the performance evaluation of banking sector based on inputs and outputs (Berger et al., 1993a, Boufounou, 1995, Avkiran, 1997, Hensel, 2003, Iannotta et al., 2007). It is a parametric method and is capable of handling either multiple inputs and single output or reverse – multiple outputs and single input. It provides the average performance of all banks/bank branches in the sample and can be used to estimate the performance of a new bank/bank branch. Being a central tendency method, it is less

[8] Second stage analysis is explained in section 2.9.2

susceptible to extreme inefficiencies. Comparing with the ratio analysis, one major advantage is its ability to evaluate the influence of multiple independent variables on one dependent variable. Another major advantage of regression analysis is that it provides statistical inference and measurement errors.

In spite of being effective in many situations, regression analysis suffers with some inherent problems and limitations that make it unsuitable for reflecting the complex nature of banking operations. First, being a parametric method it requires general specification of the production function. Second, it is only suitable to model single input-multiple outputs or single output-multiple inputs scenario. However, in case of multiple inputs and multiple outputs, dependent variables have to be artificially combined into a single indicator to fit the regression equation. Third, it is a central tendency method which predicts values based on the average or the expected level of outcome given certain inputs instead of maximum achievable output (Ray, 1991). It is possible to calculate random noise in RA, it requires strong assumptions about the nature of the error distribution.

2.3.3. Frontier Evaluation Techniques

The problems associated with the ratio and regression analysis led researchers to develop more advanced tools for the performance assessment of firms that could overcome the limitations associated with these techniques. Main task in performance evaluation of financial institutions is to identify, by some standard, good performing units and poorly performing units, which is well performed by the frontier based techniques. In the last three decades, researchers have extensively used frontier techniques for the performance evaluation of financial institutions. Frontier techniques estimate, how well an institution is performing relative to the best performing institution involved in the similar business activities under the same operating environment. Best firms are identified from within the data set, which form an efficient/best practice frontier against which the rest of the firms in the data set are compared hence provide a sophisticated way to benchmark the relative efficiency of production units. Main advantage of frontier techniques over other benchmarking techniques is that they provide a numerical efficiency score with powerful optimization mechanism for complicated operational environment (Berger and Humphrey, 1997). These techniques also provide a framework that helps management in decision making, planning, and controlling processes within the complex operations of the firm. These techniques, by highlighting areas of good and bad practices, broadly identify sources and magnitude of inefficiency in inputs/outputs that may lead to the reduction in the cost of operations and improvement in service quality. It is also possible to calculate the achievable targets for inefficient units that provide further insight to improve the production system.

The information obtained through frontier analysis techniques can be used (Paradi et al., 2011a):

- To address the research issues by assessing efficiency of a firm and ranking it in comparison to its industry or by comparing the results of different efficiency techniques.
- To improve managerial performance by identifying best and worst practices related to high and low efficiency scores.
- To inform the government for policy making by assessing the impact of different factors (such as mergers, deregulation etc.) on efficiency.

Five frontier analysis techniques have been applied in the literature for the performance evaluation of financial institutions that can be categorized into two major groups: parametric and non-parametric. Three of them are parametric econometric techniques named: Stochastic Frontier Approach (SFA), Distribution Free Approach (DFA) and Thick Frontier Approach (TFA). Other two are non-parametric linear programming based approaches: Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH). All these approaches differ in terms of assumptions regarding the functional form of the efficient frontier (more restrictive for parametric versus less restrictive for non-parametric approaches), the existence of random error and the probability distribution assumed for inefficiencies used to separate inefficiency from the random error (Berger and Humphrey, 1997, Bauer et al., 1998).

2.3.3.1. Parametric Frontier Approaches

Parametric econometric approaches require *a priori* specification regarding the functional form of the efficient frontier (production, cost, revenue and profit function that defines the production possibility set[9]) whose estimation is accompanied by two error components; the first represents the error term that captures the inefficiency and the second accounts for the noise in the data or random error. Numerous different specifications of the functional forms can be Cobb-Douglas, constant elasticity of substitution (CES), translog, normalised quadratic, generalised Leontief or fourier flexible form (Kumbhakar and Lovell, 2000). These techniques assume probability distribution for inefficiency in the form of half normal, truncated normal, exponential normal and gamma distribution (Coelli et al., 2005). Main advantages of parametric approaches are the econometric interpretation of the parameters (due to their ability to differentiate the effect of noise from inefficiency) and their statistical properties. Three main parametric approaches used in the literature include: Stochastic Frontier Approach (SFA), Distribution Free Approach (DFA) and Thick Frontier Approach (TFA).

[9] PPS represents all the observed input-output correspondences of a sample of DMUs which are assumed producible. It is explained in detail in Chapter 4 section 4.3.2.

Stochastic Frontier Approach (SFA), proposed by Aigner et al. (1977) and Meeusen and Broeck (1977), (also known as the econometric frontier approach), is the most commonly used parametric approach (Berger and Humphrey, 1997). It specifies the functional form for production, cost, revenue or profit relationship among inputs, outputs and environmental variables and allows for the random error. SFA provides a composed error model where random error follows a symmetric distribution usually standard normal while inefficiencies are assumed to follow asymmetric distribution usually the half normal (Aigner et al., 1977). By using different distribution methods, random error and inefficiency can be disentangled and then measured. The assumption of half normal distribution for the inefficiencies is relatively inflexible and presumes that most of the firms are clustered around full efficiency. Therefore, some of the studies have used truncated normal (Stevenson, 1980, Berger and Deyoung, 1997) or exponential or gamma distribution (Greene, 1990, Yuengert, 1993) instead of half normal arguing that these provide additional flexibility in the assumed distribution of inefficiencies. However, this flexibility in the assumed distribution of inefficiencies may create difficulty in the separation of inefficiency from random error as truncated normal and gamma distributions assumed for inefficiency may be close to symmetric distribution assumed for random error (Berger and Humphrey, 1997). This approach has been used in many studies such as; Berger and Deyoung (1997), Altunbaş et al. (2001), Bonin et al. (2005), Williams and Nguyen (2005), Margono et al. (2010).

***Distribution Free Approach (DFA)*,** proposed by Berger (1993)**,** is similar to SFA as it also specifies the functional form for the frontier. The difference between the two lies in how DFA separates inefficiency from random error. DFA assumes that efficiency of each firm is constant over time whereas the random error term has the tendency to average out to zero over time. Inefficiency for each firm is estimated by the difference between its average residual and the average residual of the firm on the efficient frontier with some adjustments to consider the random error not averaging out to zero. Since, in DFA, efficiency of a firm is not changing over time therefore, if any change in efficiency is observed as a result of external factors (such as regulatory reforms, the interest rate cycle or other influences) then it is referred to the average deviation of each firm from the best average practice frontier instead of the efficiency at any point in time (Berger and Humphrey, 1997).

One advantage of DFA is that unlike SFA, it does not make a strong assumption regarding the specific distribution of random errors and inefficiencies. Inefficiencies can follow any distribution, even one that is very close to symmetric as long as the inefficiencies remain non-negative. This approach has been used in banking studies conducted by Berger and Hannan (1997), Berger and Mester (1997), Deyoung (1997), and Patti and Hardy (2005).

Thick Frontier Approach (TFA) introduced by Berger and Humphrey (1991) specifies a functional form which assumes that deviations from predicted performance values within the highest and lowest performance quartiles of observation characterize random error, whereas deviations in the predicted performance between the highest and lowest quartiles symbolise inefficiencies (Berger and Humphrey, 1997). Since TFA examines the average production, it does not consider efficient firms. Moreover, large efficient firms tend to be removed in case of decreasing returns to scale. Key advantage of TFA is that it does not impose any distributional assumption on either random error or inefficiency. It also reduces the effect of extreme points in the data. Drawback of TFA is that it does not provide point estimates of efficiency ratings for individual firms, instead it tends to provide the estimate of general level of overall efficiency of entire industry. TFA has been used for determining the banking efficiency in Germany (Lang and Welzel, 1996), Norway (Berg and Kim, 1998) and Spain (Lozano-Vivas, 1997).

Major *drawbacks of parametric approaches* are the specification of the explicit functional form of the efficient frontier and the distribution of inefficiency term (Seiford and Thrall, 1990). Parametric approaches also face the issue of misspecification of error term (Berger and Humphrey, 1997) that can lead to inconsistent results. Misspecification may arise due to the use of an unsuitable functional form for the production frontier, measurement errors on the production factors and the presence of serial correlation between technical efficiency and inputs (Giannakas et al., 2003). Moreover, parametric models have difficulty in handling the multiple inputs and multiple outputs – a situation that is very common in banking industry.

2.3.3.2. Non-Parametric Frontier Approaches

Unlike parametric techniques, mathematical non-parametric techniques do not require *a priori* assumption regarding the functional form of efficient frontier but allow the observed data to speak for itself. This characteristic of non-parametric approaches enables them to avoid the problem of misspecification of functional form that may lead to inaccurate efficiency estimates. The major advantage of these approaches is their ability to handle multiple inputs and multiple outputs. DEA and FDH are two non-parametric approaches. Among these DEA is the most commonly used technique in empirical studies.

Data Envelopment Analysis (DEA) (Charnes et al., 1978, Banker et al., 1984) is a linear programming based tool for measuring the relative efficiencies of decision making units (DMU) with respect to multiple inputs and multiple outputs which are similar for all the DMUs. Instead of pre-specifying a functional form DEA establishes a convex shaped frontier formed as piecewise linear combination of a set of best practice units. A detailed discussion of DEA is provided in Chapter 4.

Free Disposal Hull (FDH) proposed by Deprins et al. (1984) is a subset of DEA that employs a smaller set of DMUs while defining efficiency frontier. DEA satisfies free disposability of inputs and outputs and the convexity of the production possibility set (PPS) while FDH only relies on free disposability assumption (Fried et al., 2008). Therefore, instead of DEA's piecewise linear frontier, FDH uses a stepwise (staircase) frontier that ensures that efficiency estimates are only effected by the observed performance. The production possibility set is made up of the DEA vertices only and the FDH points interior to those vertices excluding the points which are the convex combination of the DEA vertices representing the hypothetical performance (Berger and Humphrey, 1997). Since FDH frontier is either congruent with or interior to DEA, the FDH normally provides larger estimates of average efficiency as compared to DEA (Tulkens, 1993).

However, there are few *drawbacks of non-parametric techniques* argued in literature. The first and key limitation of these approaches is that they attribute all deviation from the efficient frontier to inefficiency ignoring the random error. The occurrence of a random error in the data of a unit may alter its efficiency scores. However, the presence of such error is more problematic if it exists in the data of one of the unit on the efficient frontier as it may alter the efficiency estimates of all the units compared against it or a linear combination involving it. The second drawback of these approaches is that they are sensitive to outliers. The reason is that efficient frontier is derived from the sample observations that are actually the extreme points and envelop all other data points. Third, it is very difficult to interpret the efficiency result of these approaches in terms of sensitivity of production of output to particular inputs (elasticity , shape of production function etc.) and to perform inference of the measure of interest (confidence intervals, hypothesis tests) (Simar and Wilson, 2008). Final drawback of these approaches is the so called “curse of dimensionality”[10].

2.3.4. Other Performance Evaluation Methods

There are many other performance evaluation methods that have been used by different studies to evaluate the performance of banks and include: Balanced Score Card (Kim and Davidson, 2004, Wu et al., 2009), Analytic Hierarchy Process (Frei and Harker, 1999, Seçme et al., 2009) , Artificial Intelligence (Chen and Shih, 2006) , Multivariate Statistical Analysis (Canbas et al., 2005) and Grey Relations Analysis (Ho and Wu, 2006). These techniques have mostly addressed issues like prediction of bank failure and performance of banks. For a detailed description of these methods reader is referred to the references mentioned against each technique and the review of banking studies by Fethi and Pasiouras (2010).

2.4. Selection of Performance Evaluation Technique

Among the wide spectrum of performance evaluation techniques, the current study has selected Data Envelopment Analysis (DEA) to estimate the efficiency of banking sector of Pakistan. DEA is one of the most successfully used operations research technique for the performance assessment of banking sector. Its powerful optimizing ability enables management and researchers to objectively identify the best performers and the areas of potential improvement in the complex banking operations.

There are a number of reasons to choose this particular frontier technique for the current study. First, unlike parametric techniques, DEA can capture the interaction

[10] The curse of dimensionality refers to an issue that arises in the form of high efficiency scores and poor discrimination among efficiency scores mainly due to the multiple dimensions (inputs and outputs) of firms (Coelli et al., 2005). The curse of dimensionality implies that when data set consists of a number of input and output variables (referred as multiple dimensions), the analysis requires sufficiently large sample size in order to obtain a reasonable estimation precision (Daraio and Simar, 2007).

between multiple inputs and multiple outputs (Charnes et al., 1978) that enables it to account for all the aspects of a decision making unit (DMU) simultaneously which may render that DMU a good performer, even if its performance is not outstanding on any individual aspect (inputs and output) (Thanassoulis et al., 1996). As production process in banking employs multiple inputs including financial and physical capital, employees, borrowings, deposits and interest expenses to produce multiple outputs such as investments, loans, interest income and non-interest income therefore, it may be difficult to use parametric techniques because they only deal with single output technologies at a time.

Second, DEA does not require *a priori* assumption to be made regarding the relationship between inputs and outputs as reflected by production function. Instead it derives the best practice production function solely on the basis of observations eliminating the chances of misspecification of production function. DEA also avoids the need to specify the distributional form for the inefficiency term. If functional form is misspecified, the estimated efficiency may be confounded with specification error and significant bias (Berger and Humphrey, 1997). Hence, DEA is quite a flexible technique as compared to parametric frontier techniques.

Third, a well-known advantage of using DEA, which is particularly relevant to our study of banking sector in Pakistani context, is that it works well with small data sample. Maudos (2002) described this fact as: "of all the techniques for measuring efficiency, the one that requires the smallest number of observations is the non-parametric and deterministic DEA, as parametric techniques specify a large number of parameters, making it necessary to have available a large number of observations." (p. 511).

Fourth, DEA works exclusively with quantity information and does not require price or restrictive behavioural assumption in its estimation. Finally, DEA can easily decompose cost, profit and revenue efficiencies into technical, pure technical and scale efficiencies in order to determine the sources of efficiencies/inefficiencies in a particular industry for instance banking industry.

The current study employs DEA as the main research technique with the novel idea of production trade-offs to estimate the technical efficiency of the banking sector of Pakistan.

2.5. Banking Efficiency and Productivity Studies Using DEA

The idea of evaluating the banking efficiency is very old and started with the work of Benston (1965). However, banking efficiency literature using DEA grew drastically since eighties after the first published paper of Sherman and Gold (1985) on the efficiency of 14 U.S. bank branches. In recent years, DEA has become a most widely used operational research technique among a range of modelling techniques for the performance evaluation of banks (Fethi and Pasiouras, 2010). The first frontier techniques based review of 130 banking efficiency studies was performed by Berger and Humphrey (1997). They found that DEA is the most popular frontier technique applied in 62 papers whereas there were 60 applications of parametric techniques consisting of 24 SFA, 20 DFA and 16 TFA. Paradi and Zhu (2013) surveyed 275 banking efficiency studies that used DEA as a tool for performance assessment in banking sector. They reported that 80 studies examined efficiency at the bank branch level while the rest of the studies (195) focused on banking sector at the institutional level reflecting that evaluation of banking sector at institutional level is the most popular area in the banking studies.

A large body of banking efficiency literature, conducted at the institutional level, has focused on the developed economies (for reference see surveys conducted by Berger et al. (1993b), Berger and Humphrey (1997), and Berger (2007)). For example, banking efficiency studies in developed economies have been conducted for U.S. (Miller and Noulas, 1996, Thompson et al., 1997, Seiford and Zhu, 1999b, Mukherjee et al., 2001), UK (Ashton, 2001, Drake, 2001), Australia (Avkiran, 2000, Sturm and Williams, 2004, 2008, Avkiran, 2009b, Sturm and Williams, 2010), New Zealand (Avkiran, 2009b), Canada (Asmild et al., 2004, Paradi et al., 2011a) and European countries such as Spain (Tortosa-Ausina, 2002b, Tortosa-Ausina et al., 2012), Italy (Resti, 1997), Greece (Tsionas et al., 2003, Pasiouras, 2008a) and Poland (Havrylchyk, 2006). Some of the banking studies have investigated banking sectors of multiple European countries. For example, Hauner (2005) studied the banking sectors of Austria and Germany while Casu and Girardone (2004) and Casu et al. (2004) studied the largest banks of France, Germany, Italy, Spain and UK.

Compared with the developed economies, fewer but a growing number of banking efficiency studies are on emerging economies such as India (Bhattacharyya et al., 1997, Kumbhakar and Sarkar, 2003, Sathye, 2003, Ataullah and Le, 2006, Das and Ghosh, 2006, Ray and Das, 2010), Malaysia (Sufian, 2009), Taiwan (Chiu and Chen, 2009), Singapore (Sufian and Majid, 2007), Brazil (Staub et al., 2010, Wanke and Barros, 2014), Turkey (Isik and Hassan, 2002, Fukuyama and Matousek, 2011), Thailand (Leightner and Lovell, 1998), Indonesia (Harada, 2005, Margono et al., 2010, Sufian and Habibullah, 2012), Egypt (Fethi et al., 2011) and China (Chen et al., 2005, Avkiran, 2011, Asmild and Matthews, 2012).

Many researchers have conducted cross-country studies such as Oliveira and Tabak (2005) studied 41 economies, and Pasiouras (2008b) studied a sample of 915 banks across 95 countries. Similarly, Mostafa (2009) has studied 85 top Arab banks and Sun and Chang (2011) have studied the banking sector of 8 emerging economies that include: China, India, Indonesia, Korea, Malaysia, Philippine, Taiwan, and Thailand.

2.5.1. Banking Efficiency Studies in Asia

A large body of literature exists on banking efficiency in the developed countries, while relatively few studies have been conducted on banking efficiency in the developing countries particularly in Asia. Burger and Humphrey (1997) conducted the first comprehensive survey of 130 studies out of which 122 reviewed efficiency of depository financial institutions and eight measured efficiency of insurance companies. This survey covered studies from 21 countries and included 62 DEA applications. Almost all the studies were on the developed economies dominated by U.S. (66 studies) and European nations (55 studies). In this survey there were only 4 studies from Asia and only one from south Asia (India). Burger and Humphrey (1997) suggested the need for more studies from different economies for making cross-country comparisons.

However, an increase in efficiency studies in this continent has been observed after deregulation and liberalization of the financial markets and the Asian financial crisis of 1997 in order to study their impact on the productivity and performance of financial institutions. Most of the efficiency studies in this continent have focused on the emerging economies (most of the Southeast Asian countries, China, and India) in individual as well as multiple economies context.

Asia can be broadly divided into four major regions: Southeast Asia, East Asia, West Asia, and South Asia. In Southeast Asia, studies have been conducted for individual countries such as Indonesia (Harada, 2005, Margono et al., 2010), Malaysia (Sufian, 2009, 2011), Korea (Gilbert and Wilson, 1998, Hao et al., 2001, Sufian and

Habibullah, 2009), Singapore (Sufian and Majid, 2007), Thailand (Leightner and Lovell, 1998) and for multiple countries such as Indonesia, Malaysia, Korea, Thailand and Philippine (Thoraneenitiyan and Avkiran, 2009).

In East Asian countries comparatively more literature on banking efficiency is available for Japan (Drake and Hall, 2003, Liu and Tone, 2008, Drake et al., 2009), China (Ariff and Can, 2008, Avkiran, 2011, Asmild and Matthews, 2012, Wang et al., 2014) and Taiwan (Chang, 1999, Kao and Liu, 2004, Chiu and Chen, 2009) whereas few studies have been conducted in Hong Kong (Drake et al., 2006).

Banking efficiency studies for West Asian countries are comparatively rare. Some studies have considered individual countries such as Saudi Arabia (Akhtar, 2010a, Assaf et al., 2011), UAE (Avkiran, 2009a), Iran (Tayebeh and Khansoz, 2014), Jordan (Al-Shammari and Salimi, 1998) while a study by Mostafa (2009) has considered multiple Arab banks.

In South Asia, most of the banking studies have been conducted on the emerging economy India (Bhattacharyya et al., 1997, Sathye, 2003, Ataullah and Le, 2006, Das and Ghosh, 2006, 2009, Ray and Das, 2010). In comparison to India, there are few studies on the banking sector of Pakistan that has applied DEA for efficiency evaluation of banking sector (Rizvi, 2001, Akhtar, 2002, 2010b). Some studies have compared the banking sector of India and Pakistan (Ataullah, 2004, Ataullah et al., 2004, Jaffry et al., 2013) while others have covered multiple countries in this region such as India, Pakistan and Bangladesh (Jaffry et al., 2007). The current study has considered the data set of Pakistan to evaluate the banking efficiency by applying DEA technique. A review of banking efficiency studies in Asia is provided in Appendix A.1.

2.5.2. Banking Efficiency Studies in Pakistan

Above mentioned literature on banking efficiency in Asia indicates the growing interest of researchers towards the efficiency evaluation of banking sector in Asian economies. However, the efficiency literature on the banking sector of Pakistan is still quite limited as compared to other emerging economies of Asia. This dearth of studies on Pakistani banking sector was also reflected in banking survey conducted by Berger (2007) that provided international comparisons of bank efficiency. This survey included 11 more countries (two developed and 9 developing nations) than the survey conducted by Burger and Humphrey (1997) due to inclusion of some new countries in efficiency studies of banks. This survey also included five new Asian countries including; China, Pakistan, Malaysia, South Korea, and Thailand. Among these Asian studies, only one study was from Pakistan performed by Patti and Hardy (2005) which was not a DEA based study. It rather used distribution free approach (DFA) to analyse the banking efficiency.

Similarly, Fethi and Pasiouras (2010) provided a comprehensive review of 196 studies, published between 1998-2009, that employed operational research (OR) and artificial intelligence (AI) techniques for performance evaluation of banks. In this survey, 181 studies used DEA and DEA like techniques whereas the rest of the fifteen studies used different classification techniques such as neural networks, multi-criteria decision aid, support vector machines and decision trees. Most of the studies included in the survey also focused on the developed economies. However, this survey included 12 Asian economies in comparison to 5 Asian countries included in Berger (2007) survey. These 12 Asian countries include: China, Hong Kong, India, Japan, Korea, Malaysia, Pakistan, Philippine, Singapore, Thailand, Taiwan, and Turkey which are mostly the emerging economies. In this survey, four studies have discussed banking sector of

Pakistan where two studies had comparative analysis of banking sector of India and Pakistan (Ataullah, 2004, Ataullah et al., 2004) whereas the rest of the two had solely considered the banking sector of Pakistan (Rizvi, 2001, Akhtar, 2002).

Banking efficiency studies in Pakistan have mostly addressed the impact of banking sector reforms introduced in Pakistan from time to time as a result of deregulation and liberalization. In addition to liberalization and reforms these papers have also considered the efficiency comparison of domestic and foreign banks. In terms of analytical techniques mostly parametric approaches have been used for efficiency evaluation (Iimi, 2004, Patti and Hardy, 2005, Burki and Ahmad, 2010).

In comparison to parametric studies, only a handful of studies have used non parametric techniques particularly DEA for efficiency evaluation of Pakistani banking sector. Such as Rizvi (2001) studied the post liberalization efficiency of 37 scheduled banks of Pakistan for six years from 1993 to 1998 using DEA. Technical efficiency and scale efficiency estimates revealed that domestic banks marginally outperformed the foreign banks. Overall inefficiency of the sample over the period of six years was 20%.

Akhtar (2002) studied the X-efficiency of 40 commercial banks for the year 1998 to study the impact of on-going process of liberalisation. He found that private banks are the most efficient banks in terms of technical and allocative efficiency. Akhtar (2010b) has considered the X-efficiency analysis of commercial banks for the period 2001 to 2006. In contrast to Rizvi (2001) and Akhtar (2002), this study found that foreign banks are the most efficient banks as compared to their domestic counterparts.

In cross country studies Ataullah et al. (2004) have studied the impact of financial liberalization on the banking sector efficiency of India and Pakistan from 1990 to 1998 using DEA. They found the evidence of efficiency improvement as a result of financial liberalization. In Pakistan efficiency improvement was observed due to improvement in scale efficiency whereas in India efficiency improved as a result of improvement in both pure technical and scale efficiency. They also found that public sector banks were relatively slow in improving their efficiency in comparison to private banks in both India and Pakistan.

Jaffry et al. (2013) have also studied the trends in efficiency of banks in response to the regulatory reforms. They studied a sample of 114 banks (73 in India and 41 in Pakistan) by using DEA and bootstrap approach for a period of nineteen years from 1985 to 2003. They found that regulatory reforms introduced in 1992 could not achieve their desirable effects initially on the efficiency of both Indian and Pakistani banks. However, banks slowly adjusted to the competitive environment in the final years of 90's and showed improvement in their efficiency in all the early years of 21st century. A detailed review of banking efficiency studies in Pakistan is provided in Appendix A.2.

It is clear from the above mentioned banking efficiency literature that despite the abundance of studies on efficiency and productivity of financial institutions using frontier analysis conducted primarily in developed economies there are still far fewer studies on banking sector of Pakistan. Moreover, among those only few have used DEA estimator for efficiency evaluation.

2.6. Major Themes in Banking Efficiency Studies

Apart from focusing on different countries, banking efficiency studies have also addressed various banking issues. Major issues that have been discussed through the application of DEA include; benchmarking for banking performance improvement (Rizvi, 2001, Akhtar, 2010b), the impact of off-balance sheet activities on bank efficiency (Rogers, 1998, Tortosa-Ausina, 2003, Casu and Girardone, 2005, Sufian and Ibrahim, 2005, Lozano-Vivas and Pasiouras, 2010), efficiency and stock performance (Chu and Lim, 1998, Beccalli et al., 2006, Pasiouras, 2008a), economic environment and market structures changes (Seiford and Zhu, 1999b, Isik and Hassan, 2003), the impact of mergers on bank performance (Avkiran, 1999, Seiford and Zhu, 1999b, Sherman and Rupert, 2006, Sufian and Majid, 2007, Al-Sharkas et al., 2008), international comparisons (Lozano-Vivas et al., 2002, Oliveira and Tabak, 2005, Pasiouras, 2008b, Mostafa, 2009, Thoraneenitiyan and Avkiran, 2009), cost and/or profit efficiency (Maudos and Pastor, 2003, Ariff and Can, 2008, Ray and Das, 2010), the impact of risk on bank performance (Drake et al., 2006, 2009), the comparison of parametric and non-parametric frontier techniques (Huang and Wang, 2002, Casu et al., 2004, Weill, 2004, Delis et al., 2009), the impact of Asian financial crisis on banking efficiency (Sufian and Habibullah, 2009, Thoraneenitiyan and Avkiran, 2009), efficiency change over time as a result of deregulation, liberalization and financial reforms (Leightner and Lovell, 1998, Ataullah et al., 2004, Chen et al., 2005, Das and Ghosh, 2006, Fethi et al., 2011), and the relationship of efficiency with bank size (Miller and Noulas, 1996, Ataullah et al., 2004, Chen et al., 2005, Das and Ghosh, 2006) and bank age (Isik and Hassan, 2003). In addition, bank type and ownership is extensively studied particularly in relation to comparison of efficiency between domestic and foreign banks (Bhattacharyya et al., 1997, Isik and Hassan, 2003, Sturm and Williams, 2004, Hauner, 2005, Ataullah and Le, 2006, Havrylchyk, 2006, Sufian, 2011).

2.7. Approaches Underlying the Selection of Banking Efficiency Model

Banking is one of the most complex industries in the world that offers a wide range of products and services ranging from simple handling of accounts to consumer financing, home mortgages, and many others (Paradi et al., 2011b). It is very difficult to measure and price their services because disagreement exists over what kind of services banks produce and how to measure those services. One of the reasons is that banks do not always provide services which are directly paid for because many financial services are bundled in one package hence, priced jointly (Fraser and Fraser, 1990). Moreover, complex government regulations may affect the way in which products and services are offered and priced. Despite all these problems, it is important to measure the efficiency of banking sector because banks act as financial pillars for the economy, stronger are these stable is the economy.

Application of DEA in the banking sector starts with a bank behaviour model used for the conceptualization of production possibilities in order to provide management an insight regarding potential financial and operational improvements (Avkiran, 2011).

However, modelling of commercial banks operations requires clear understanding of the objectives of banking system. Such an understanding provides a guideline for the selection of appropriate input and output variables to be used in the measurement of banking efficiency (Bhattacharyya et al., 1997) because, it is generally accepted that the choice of variables in efficiency studies influence results significantly (Tortosa-Ausina, 2002a, Tortosa-Ausina, 2002b, Das and Ghosh, 2006).

Different philosophical approaches have been mentioned in DEA banking efficiency literature to model input and output variables that are used to measure the efficiency of banks. Unlike other industries where outputs are easily specified, there is still a debate about the specification of banking outputs, particularly regarding the classification of deposits as input or output. This disagreement in the classification of deposits forms the basis for two commonly used approaches, which are the production approach and intermediation approach. Production approach treats deposits as output whereas intermediation approach considers deposits as input. These two approaches are described in detail in the following sections along with other approaches mentioned in literature.

2.7.1. Production Approach

Production approach was originally introduced by Benston (1965) and primarily been used for measuring the efficiency of bank branches. This model emphasizes the operational activity of financial institutions. According to this approach primary function of financial institutions is to provide services to the account holders. Common services include performing transactions and processing various documents such as checks or other payment instruments, loan applications, credit reports, counselling and advisory services. Inputs, which are used to produce all these services, include physical variables (e.g. capital, labour, floor space, and information system) or their associated costs. These associated costs include all the operating expenses except interest expenses on deposits due to their non-relevance to the operational process which requires only physical inputs (Camanho and Dyson, 2005). Outputs under this approach represent different services provided to the customers and include the type and number of transactions handled, specialized services provided or documents processed over a given period of time. As the transaction flow data are proprietary in nature and generally un-available, data on the number or stock of deposits and loans accounts are used instead as a proxy for services provided.

2.7.2. Intermediation Approach

According to the intermediation approach primary function of financial institutions is the intermediation of funds between the savers and investors (Fama, 1980). Banks provide intermediation services by transforming risk and maturity profile of funds collected from depositors to investments and loan portfolio of a different risk and maturity profile (Sengupta and Sahoo, 2006).

Inputs of this approach include both funds and their interest costs because these available funds are the main raw material, which is transformed to outputs in the financial intermediation process. Outputs of the financial institutions comprise of loans and other earning assets. However, a longstanding controversy in the literature regarding the treatment of deposits as input or output has led to the development of different trends and debates on the identification of outputs in the banking sector, which formed the basis for the intermediation and production approaches on one hand, and resulted in the establishment of three further approaches namely: asset approach, value added approach and user cost approach on the other hand. These three approaches are considered the ***variants of the intermediation approach*** because these also focus on the intermediation activities of the financial institutions.

2.7.2.1. Asset Approach

Generally, liabilities of banks have some characteristics of inputs, because these provide investable funds that act as the raw material for financial institutions. Similarly, assets of banks possess some characteristics of output as these represent the actual uses of funds that are responsible for generating the main banking revenue. In the intermediation process, balance sheet liabilities are transformed into balance sheet assets. However, Interest paid and received in this process covers the time value of money (Berger and Humphrey, 1992b).

Asset approach is a reduced modelling form of banking intermediation activities, which mainly focuses on the role of banks as financial intermediaries between depositors and the receivers of loans. Input set of this approach consists of deposits, other liabilities and real resources such as labour and capital which are utilized to produce loans and other assets in the intermediation process (Sealey and Lindley, 1977).

It is appropriate to use asset approach in a situation where cost and different methods of raising funds are considered exogenous as this approach excludes the important differences in service output that arises when funds are raised through deposits versus purchased funds (Berger et al., 1987, Berger and Humphrey, 1992b).

2.7.2.2. User Cost Approach

User cost approach was pioneered by Donovan (1978) and Barnett (1980) in developing money supply index. User cost approach suggests a method to decide whether a financial product is input or output based on its net contribution to the banks revenue. According to this method, if the financial return of an asset exceeds the opportunity cost of funds or if financial costs of a liability are less than its opportunity cost, the financial instrument is treated as financial output otherwise, it is considered financial input (Hancock, 1985a, b).

The user cost approach finds out whether an asset/liability contributes towards the bank's financial revenue or not. Operating costs does not include the costs incurred for rendering the non-financial services associated with assets and liabilities. How accurately user cost approach measures the financial revenue and opportunity cost is largely dependent on the allocation of excluded operating costs. However, due to the measurement error and sensitivity to changes in data over time, it is very difficult to estimate financial revenues and opportunity costs accurately which, in turn, make it hard to distinguish between inputs and outputs under user cost approach (Berger and Humphrey, 1992b).

2.7.2.3. Value Added Approach

This approach was first applied by Berger et al. (1987) and assumes that a bank will only offer a loan or accept deposit if it will make a strategic or financial contribution in its business. According to the value added approach the balance sheet items (assets or liabilities) that contribute to the bank's value added (such as business associated with the consumption of real resources) are considered output. Major categories of deposits (term, demand and saving deposits) and loans (commercial and consumer loans and mortgages) are main outputs under this approach because these are responsible for most of the value added in banking business. Financial inputs of this approach are purchased funds, foreign deposits, large cash deposits and other liabilities for borrowed money because they need very small amount of labour and capital. Government securities and other non-loan investments are viewed as unimportant outputs because their value added contribution is very low (Berger and Humphrey, 1992b). This approach has been used by Pastor et al. (1997) for international efficiency comparison of European and U.S. banking systems.

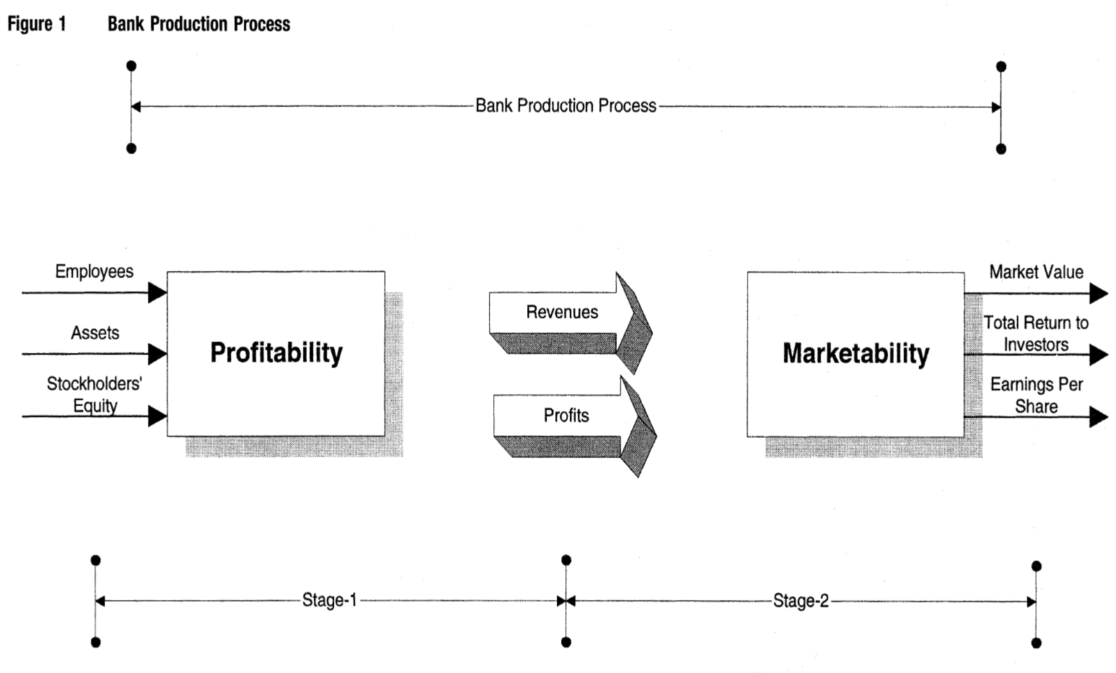
2.7.3. Operating/Profitability /Income Based Approach

Profitability approach, introduced by Leightner and Lovell (1998), is based on the profit-oriented objective of the financial institutions, which assumes that these institutions try to maximize the profit arising from their different financial activities. This approach uses income-based outputs in contrast to the quantity-based outputs. According to this approach, two outputs are net interest income (interest from loans minus interest on deposits) and non-interest income which represent fees generated by deposits without including deposits themselves. Input set of this approach includes personnel expenses, and operating expenses. Drake et al. (2006) modified this profit oriented approach by specifying revenue components as outputs and cost elements as input. However, Avkiran (2009a) further added that intermediation process can be captured by proxy cost and revenue variables which effectively measure the profit efficiency of banks. These proxy input variables include interest and non-interest expense while output variables are interest income and non-interest income. Here we can say that by using proxy variables, asset based intermediation process can be converted to profitability based intermediation process. In other words, profitability approach is profitability version of intermediation approach.

2.7.4. Marketability Approach

The marketability approach was proposed by Seiford and Zhu (1999b) in a study of top 55 U.S. commercial banks to measure both profitability and marketability of commercial banks. They defined a two-stage production process in which the first stage measured profitability and the second stage measured marketability. Eight factors have been expressed as inputs and outputs in these two stages. At the first stage assets, labour and capital stock are used as input to generate revenues and profit. Revenues and profits generated in the first stage are the intermediate factors that serve as input for the second stage and generate market value, earnings per share and total return to investor as outputs.

Figure 2. 2 Graphical representation of the marketability approach



Source: Seiford and Zhu (1999b)

2.7.5. Modern Approach

The modern approach introduced by Freixas and Rochet (1997) attempts to integrate quality of bank services, agency cost and some of the risk measures. The most innovative aspect of this approach is the introduction of the probability of bank failure in the estimation of costs and quality of banking assets (Das and Ghosh, 2006). This approach is similar to the risk based CAMEL approach where individual elements of CAMEL have been derived from the financial tables of banks and employed as variables in the performance analysis.

2.7.6. Portfolio Approach

Fama (1980) described banks as financial intermediaries that accept deposits and use that money to purchase the securities. So in competitive banking environment banks not only manage the transactions but also undertake the portfolio management activities. Portfolio approach views balance sheet as a mix of both short (right hand side) and long (left hand side) positions generating different components of net income (Clement, 2007). This intermediation function of banks under portfolio approach is different from intermediation philosophy of Sealey and Lindley (1977) which considers production and other costs as input along with the balance sheet items.

2.7.7. Risk-Return Approach

Hughes and Moon (1995) developed a structural model of production that allowed the managers to trade profit for other managerial objectives particularly, the objective of reducing risk. According to this approach, managers' preferences of different production plans are measured by a managerial utility function. The authors used the parameters of this model to estimate a best practice stochastic risk-return frontier, the predicted rate of return on equity (ROE), and the standard error of the prediction for the sample of banks. This risk-return model has also been used in Hughes et al. (1996), Hughes et al. (2000), Hughes et al. (2001), Hughes et al. (2003).

2.8. Selection of an Appropriate Banking Model

The previous section has provided a review of different banking behaviour modelling approaches used in the banking literature, but the production approach and intermediation approach are considered two major approaches on the basis of flow of services provided by the financial institutions. According to Berger and Humphrey (1997) neither of these approaches is perfect because neither of these wholly covers the dual function of financial institutions as (i) processing transactions or documents of customers and (ii) providing intermediation between lenders and borrowers. However, they pointed out that production approach is appropriate for evaluating the branch level efficiency of the financial institutions because branches process customer documents on behalf of the whole institution and branch managers have very little influence on the overall funding and investment decisions of the financial institution.

On the other hand, intermediation approach is a better choice for evaluating the efficiency of an entire financial institution because it takes into account interest expenses which comprise about one-half to one-third of the total costs of the financial institutions. Pursuing the profit orientation goal, banks' managers aim to reduce both interest and non-interest costs for the profit maximization of the financial firms.

However, there exists a controversy even in the intermediation approach regarding the role of deposits that divide it into three subcategories i.e. asset approach, user cost approach and value added approach. These approaches differ in the role that each approach attaches to different categories of assets and liabilities in the form of inputs or outputs (Tortosa-Ausina, 2002a). Some studies use only earning assets as output which is in line with the asset approach of Sealey and Lindley (1977). It treats banks as only the financial intermediaries between depositors and borrowers while regarding deposits an input that contribute to the creation of loans. Under user cost approach (Hancock, 1985a, b) assets and liabilities are classified as input or output on the basis of their net contribution to bank's revenue. However, in both these approaches inputs and outputs are mutually exclusive. On the contrary, under value added approach (Berger et al., 1987) liabilities may be treated as both input and output simultaneously. Choice of each approach is context dependent (Camanho and Dyson, 2005).

Ferrier and Lovell (1990) remarked that if the goal of study is to evaluate the cost efficiency then production approach is appropriate choice as it considers just operating costs of the financial institution. On the other hand, intermediation approach is suitable to choose when the goal of study is to evaluate the economic viability of financial institution because this approach takes into account the overall costs of the financial institution.

The literature survey performed by Berger and Humphrey (1997) concluded that little attention was given to the implications of using different approaches and consequently to the definition of inputs and outputs in the efficiency assessment. However, in the later years studies started to consider different banking models simultaneously to evaluate the banking efficiency and found that efficiency results are significantly influenced by the selection of inputs and outputs according to a particular banking model (Tortosa-Ausina, 2002a, Tortosa-Ausina, 2002b, Avkiran, 2006, Das and Ghosh, 2006, Drake et al., 2009, Sufian, 2009).

2.9. Issues Addressed in the Current Study

This section provides the brief literature review of the major issues that serve as foundation for the development of different productions trade-offs of the DEATOB Framework, added in the standard DEA model to transform it to a better informed model.

2.9.1. Asset Quality/Risk

Risk is an essential element in the banking industry because banks produce their outputs by taking different kinds of risks. For instance banks deal with loans, investments and other financial services that correspond to credit, market and operation risk. Among all these risks, credit risk is vitally important for the profitable and sustainable growth of banking sector. Credit risk refers to the risk of loan default that originates initially in the form of accumulation of poor quality assets known as non-performing loans (NPLs) and results in the loan losses. It is well recognized in the banking literature that omitting the credit risk factor in performance appraisal model, would not only result in inaccurate conclusion regarding the inefficiency level (Hughes and Mester, 1993, Mester, 1996, Hughes et al., 2001) but might also lead to subsequent financial crisis in future. Thus, for a sound financial system it is necessary that financial institutions should be efficient and secure.

There is proliferation of banking efficiency studies. However, the banking literature that has considered the risk factor in efficiency evaluation is relatively limited. With respect to risk, banking efficiency literature can be distinguished into three distinct strands. The first strand has completely ignored risk factor and handled the issue of banks' performance evaluation by exploring the information embedded in physical inputs and outputs of banks. The aim of such studies is either refine/extend the existing estimation approach (Thompson et al., 1990, Berger et al., 1993a, Thompson et al., 1996, Seiford and Zhu, 2002, Sahoo and Tone, 2009a, Avkiran, 2011), studying the impact of regulations and reforms (Bauer et al., 1998, Ataullah et al., 2004, Chen et al., 2005, Das and Ghosh, 2006, Fethi et al., 2011) or discussing different other factors such as the impact of merger (Seiford and Zhu, 1999b, Al-Sharkas et al., 2008), ownership type (Sturm and Williams, 2004), and size (Das and Ghosh, 2006) etc.

This strand of literature presents an interesting point of view in terms of methodological inductions, explanation of economic phenomenon and elaboration of banking operational mechanisms. Nonetheless, mere utilization of conventional inputs and outputs in the standard models of production may undermine their usefulness particularly in the banking context where risk has an important economic role (Hughes, 1995) and the conviction of conclusion derived from such research may be constrained and misleading (Mester, 1996).

This shortcoming has been addressed by the second strand of studies that has recognized the importance of credit risk. This strand of studies has explicitly accounted for credit risk/loan quality through a one-step approach by incorporating risk measures into the production model as either input or output vector while appraising banks' efficiency. These studies can be divided into three distinct groups.

The first group of studies has considered non-performing loans (NPLs) as an indicator of risk. For example Hughes and Mester (1993) and Mester (1996) used NPLs in stochastic cost function as a control for loan quality and considered them endogenous or bank specific factor. Being endogenous factor, NPLs reflect the negligence of management in the initial evaluation and monitoring of loans (Mester, 1996). Berger and Mester (1997) have also used NPLs in stochastic cost and profit function to control for external shocks while considering it as an exogenous/environmental variable. In addition to NPLs, all these studies have also treated financial equity capital as an input in the production models as a representative of insolvency risk.

In contrast, Berger and Deyoung (1997) considered NPLs both exogenous and endogenous factors. They used Granger Causality Model to empirically test the relationship between NPLs and cost efficiency of 600 U.S. commercial banks during 1985-1994 by developing four hypothesis that are; "bad luck" (exogenous), "bad management", "skimping" and "moral hazard" (endogenous). They concluded that all four hypotheses have their own argumentation basis while having a negative relationship between NPLs and cost efficiency. Some studies have also considered the actual amount of loan losses (Berg et al., 1992, Paradi et al., 2011b) and NPLs to loans ratio in the production model to reflect risk (Altunbas et al., 2000).

There are few studies which have used NPLs as an input in the DEA and DEA like models for the efficiency evaluation of banks. However, these studies are silent regarding their inclusion of NPLs in the efficiency model implying that these studies have considered NPLs just as undesirable output without any explicit intention to account for risk factor (Lotfi et al., 2010, Asmild and Matthews, 2012).

The second group of studies has also adopted a one-step approach. However, this group of studies, instead of using actual amount of loans at risk (NPLs), have considered the risk coverage or cost of risk-taking in lending termed as loan loss provision as input vector in deriving the production frontier in the DEA efficiency model using intermediation or profitability approach of banking behaviour model. The underlying assumption for using this variable is that despite being a cost for risk coverage, it signals a safer environment for the depositors (Brockett et al., 1997, Leightner and Lovell, 1998, Drake and Hall, 2003, Drake et al., 2006, Pasiouras, 2008a, Drake et al., 2009).

The third group of studies have considered multiple indicators for risk in the performance evaluation model. For example Charnes et al. (1990) have used loan loss provisions and loan losses as indicators of risk in their polyhedral cone ratio DEA model. Chang (1999) has used NPLs, loan loss provision and weighted risky assets as input in the DEA based production model. Paradi et al. (2011b) have used NPLs and loan loss provision in the input set of intermediation banking approach whereas included loan losses in the inputs of profitability approach in DEA based bank branches study of big five Canadian banks.

In contrast to the second strand, the third strand has incorporated risk in the efficiency studies as an exogenous variable by following the multistage evaluation method. Most of the studies have used frontier techniques (parametric or non-parametric) at the first stage to calculate the efficiency scores without risk. At the second stage these efficiency scores are regressed on or tested for correlation with a set of variables describing different characteristics being investigated including risk. However, there is huge diversity in the variables selected to represent risk. For example, risk has been incorporated in the form of NPLs (Staub et al., 2010), ratio of NPLs to total loans (Isik and Hassan, 2003), loan loss provision to total loans (Kwan, 2003, Havrylchyk, 2006, Sufian, 2009), and loans to total assets (Maudos et al., 2002, Ariff and Can, 2008).

This literature discussion indicates that importance of credit risk in efficiency studies is well established. This literature on risk also clearly represents that there are only few studies that have addressed the issue of risk in DEA studies by incorporating risk measure in the efficiency model. Moreover, in spite of explicitly dealing with the credit risk through incorporation of risk measures, as done in the studies mentioned above, there is still a possibility that risk variable can be ignored in the final analysis due to the allocation of zero weight to that variable.

However, there is not a single study that has dealt with the risk element of poor quality assets and relevant additional information in the DEA based model. The current study has incorporated credit risk explicitly at the first stage and used the theoretical concept of production trade-offs[11] to incorporate additional information regarding credit risk in the model. In this study, we are considering credit risk (the total amount of NPLs and loan loss provisions) in the model irrespective of their determinants. This is so, because in our opinion, macroeconomic factors are exogenous to the banking industry and similar for all banks. On the other hand, NPLs in all banks not only reflect poor quality asset but also capture the management's ability to control the exposure of risk.

The purpose of incorporating credit risk factor in the study through production trade-offs is to investigate whether a banks technical efficiency is significantly different when risk is specified as compared to when risk is not specified.

2.9.2. Regulations and Bank Specific Factors

A number of studies have examined the impact of regulations and bank specific endogenous and exogenous factors on the efficiency and productivity of banks.

[11] Production Trade-offs are explained in detail in Chapter 4 section 4.7.3.

However, these studies mostly focused on the regulations related to the deregulation and liberalization of banking sector and related reforms (Leightner and Lovell, 1998, Ataullah et al., 2004, Chen et al., 2005, Das and Ghosh, 2006, Fethi et al., 2011). In such studies, the banks are studied over a number of years in which these reforms were introduced to see their impact on the efficiency of banks. These studies have considered two different ways to study the influence of financial reforms. The first way is to calculate the relative efficiencies of all banks for each year independently over the sample period using DEA and then compare the efficiency results to see the impact of financial reforms (Ataullah et al., 2004, Chen et al., 2005). The second way is to analyse the productivity of banks over the sample period using Malmquist Index (MI) and then observe the changes in the productivity to see the impact of regulations (Howcroft and Ataullah, 2006). However, some of the studies have used both methods in the study simultaneously (Leightner and Lovell, 1998, Rizvi, 2001).

To study the impact of bank specific exogenous and endogenous factors in DEA context, a two stage approach is commonly used in banking literature. In two stage approach DEA is used at the first stage to obtain efficiency estimates. Then at the second stage DEA scores are regressed on a number of explanatory variables (such as liquidity, capitalization, ownership, management, size, risk, profitability, GDP, inflation and regulations etc.) using SFA (Bhattacharyya et al., 1997, Thoraneenitiyan and Avkiran, 2009), Tobit Regression (Sufian, 2009, Jaffry et al., 2013), Ordinary Least Squares (OLS) (Resti, 1997, Hauner, 2005, Ataullah and Le, 2006), and Generalized Method of Moments (GMM) (Ataullah and Le, 2006). Similarly, some of the studies have used three stage approach (Pastor, 2002, Chiu and Chen, 2009) or four stage analysis (Fried et al., 1999, Avkiran, 2009b) for studying the impact of exogenous variables particularly environmental variables.

Similar to this trend, the current study also attempts to incorporate a regulation regarding the liquidity requirement termed as statutory liquidity requirement (SLR). In addition to this, we consider bank specific characteristics such as credit expansion capability and shift in the asset mix of banks in the form of inter convertibility of banking assets. In contrast to the two, three and four stage approaches, the current study proposes the DEATOB Framework to incorporate liquidity regulation and bank specific characteristics directly into DEA estimator. This framework enables the standard DEA model to incorporate the information about bank specific exogenous and endogenous factor into the efficiency analysis on one hand, and ensures the process of intermediation on the other hand, by using that information for the inclusion of major variables involved in the intermediation process.

2.10. Limitations of the Existing Literature

The discussion presented in section 2.9 highlights a few limitations of the existing literature on banking indicating the need for the current study so that the gaps existing in the banking literature can be filled.

First, there are few studies that have addressed poor asset quality or credit risk by introducing risk variables directly in the DEA banking model. Moreover, these studies have not ensured the inclusion of risk variables in the performance evaluation that may lead to overestimated efficiency scores of banks.

The second limitation is that the existing studies have not considered the additional information about different bank specific characteristics in the banking models selected for estimating efficiency. This additional information, if added to the banking models, can complement the existing information about the production process and provides efficiency estimates close to reality.

Third, the existing studies have investigated the impact of regulations using a multistage analysis process. There is no study to the best of our knowledge that has incorporated banking regulations in the banking behaviour models in the form of relationship between standard input and output variables of the model without introducing any additional variable.

Considering these limitations of the existing literature, the current study has proposed the DEATOB Framework that has the capability to handle all these issues simultaneously in the efficiency evaluation of banks.

2.11. Conclusion

The studies on bank efficiency date back to 1960's but still they remain an attractive area of interest for researchers around the world. This chapter has examined the traditional methods (ratio and regression analysis) and operational research based frontier (parametric and non-parametric) techniques used for the performance evaluation of banking sector. A non-parametric frontier method, DEA has been selected as the main research technique of the thesis due to its ability to handle multiple inputs-outputs about which a comprehensive review is provided in Chapter 4. This chapter also reviewed DEA based banking efficiency literature in different parts of the world especially in Asia and particularly in Pakistan. The review of DEA applications in banking sector revealed that there is very limited literature on the banking sector of Pakistan. Most of these studies have either performed cross country comparison while addressing the impact of deregulation and liberalization on the banking sectors or used parametric techniques for evaluating Pakistani banking sector. A brief overview of various banking issues, addressed through the application of DEA, is also provided in the chapter.

This chapter has also provided a review of different banking behaviour modelling approaches used in the banking efficiency studies. This review is important for the selection of the appropriate banking modelling technique for the current thesis that has been described in detail in Chapter 5. Based on the banking literature with DEA application, this study has also found out some issues that need to be addressed in the banking context. Keeping in view these issues, the current study is suggesting a different way of their treatment through the proposed DEATOB Framework explained in Chapter 6.

CHAPTER 3

BANKING SYSTEM OF PAKISTAN

3.1. Introduction

This chapter aims to provide a brief introduction to the financial system of Pakistan since the current study has considered the data set of Pakistani commercial banks for the development and empirical application of the proposed DEATOB Framework. The chapter provides an overview of different institutions comprising the regulatory structure of financial system along with their operational jurisdictions. This chapter also discusses the key financial developments that have shaped the role of banking sector in Pakistan. After providing historical characteristics, this chapter also highlights some important features related to the banking sector of Pakistan that serve as the building blocks of the DEATOB Framework.

3.2. Regulatory Structure of the Financial System of Pakistan

Pakistan is a South Asian economy that gained independence from British Rule on August 14, 1947. In 1947, Pakistan was an agricultural economy and 53% of its gross domestic product (GDP) was contributed by agriculture sector. However, over a period of 77 years, a number of structural changes occurred in the economy of Pakistan. The most prominent change among those was the replacement of agriculture sector with the services sector that became the dominating sector of the economy with a contribution of about 57.7% to the total GDP in 2012 (Economic Survey 2012). Financial sector is the part of the services sector with 5.2% share and contributes 3.0% to the GDP. Financial sector plays an important role of intermediation by mobilizing savings and providing optimal allocation of funds in the economy. Financial system in Pakistan consist of; regulators, banks, microfinance institutions (MFIs), non-bank financial institutions (NBFIs), insurance companies and the stock market. Banking sector is the leading player in the financial sector that contributes 73 % in the total assets of the financial sector (Economic Survey 2012).

In broader terms, bank is a business organization engaged in the business of borrowing and lending money that earns income by borrowing at a lower rate and lending at a relatively higher rate. In Pakistan, banks are the companies that operate in accordance with the provisions of the Banking Companies Ordinance 1962, Section 5(b) that says: "banking means accepting, for the purpose of lending or investment, of deposits of money from the public, repayable on demand or otherwise and withdrawable by cheques, drafts, orders or otherwise". According to section 8 of the Ordinance, it is obligatory for any banking company or its subsidiary to use the word "bank" or any of its derivatives as a part of its name.

Formerly, the financial system of Pakistan was regulated and supervised by three authorities: State Bank of Pakistan (SBP), Pakistan Banking Council (PBC) and Corporate Law Authority (CLA). SBP was established in 1948 and dispensed its function as the central bank under the constitution, laid down in the State Bank of Pakistan Order, 1948. PBC was established as a holding company under Banks Nationalization Act, 1974 to monitor the performance of nationalized banks. It was also responsible to perform different banking related functions in line with the nationalization objectives. CLA was established in 1948, to regulate the capital market under the Ministry of Finance (MOF).

Under State Bank of Pakistan Order 1948, SBP was vested with the role of central banking and was responsible for securing stability of monetary and credit system of Pakistan. Later on, State Bank of Pakistan Order 1948 was replaced with the State Bank Act 1956, according to which basic objectives of SBP were the maintenance of monetary as well as credit system stability and the promotion of economic growth.

SBP had substantial overlapping of regulatory functions with PBC and CLA that caused considerable distortion in the supervisory role of SBP. With PBC this overlapping occurred in matters regarding public sector banks and development financial institutions (DFIs), and with CLA this was related to non-bank financial institutions (NBFIs).

In 1997, restructuring process was introduced to streamline the regulatory and supervisory role in the banking sector. As a result, regulatory functions of PBC and SBP were consolidated. SBP was vested with the sole authority to supervise and regulate all banks and financial institutions whereas PBC was dissolved.

A new regulatory organization, Securities and Exchange Commission of Pakistan (SECP), was set up under Securities and Exchange Commission of Pakistan Act 1997, to regulate the capital market, leasing and investment banks. SECP became operational from January 1, 1999 and replaced CLA by taking over all its operations. The main difference between CLA and SECP was that former was an attached department of Ministry of Finance (MOF) whereas the latter was established as an autonomous body within the framework of SECP Act, 1997. Initially, SECP was concerned with the regulations of the capital market, Central Depository Company (CDC), credit rating institution and corporate sector. Overtime, its area of operations expanded and it had been assigned the supervision and regulation of insurance companies, non-bank finance companies (NBFC), and private pensions.

With a view to strengthen the SBP’s role as an independent and efficient regulator, SBP was organized into three distinct entities in 2001 as a part of the reform and restructuring process. These entities are:

1. The SBP – the central bank,
2. Banking Services Corporation (BSC) – the retail arm of SBP

3. National Institute of Banking and Finance (NIBAF) – delivery arm of SBP for all the training needs.

Currently, SBP and SECP are the two financial regulators operating in Pakistan. SBP is responsible for the supervision and regulation of banks, microfinance banks and DFIs whereas NBFIs, insurance companies and the stock markets are under the control of SECP. The term “bank” is normally used for the scheduled banks operating in Pakistan. According to section 37(2) of State Bank of Pakistan Act 1956, banks having a paid up capital and reserve not less than Rupees 0.5 million and fulfilling certain other requirements are declared as scheduled banks. Scheduled banks cover two broad categories of banks: commercial banks and specialized banks. Commercial banks are categorized into public sector banks, private banks and foreign banks. The current study has only selected the data set of commercial banks therefore the use of word ‘bank’ in this dissertation only refers to commercial banks instead of scheduled banks. The structure of financial system of Pakistan is depicted in the following diagram.

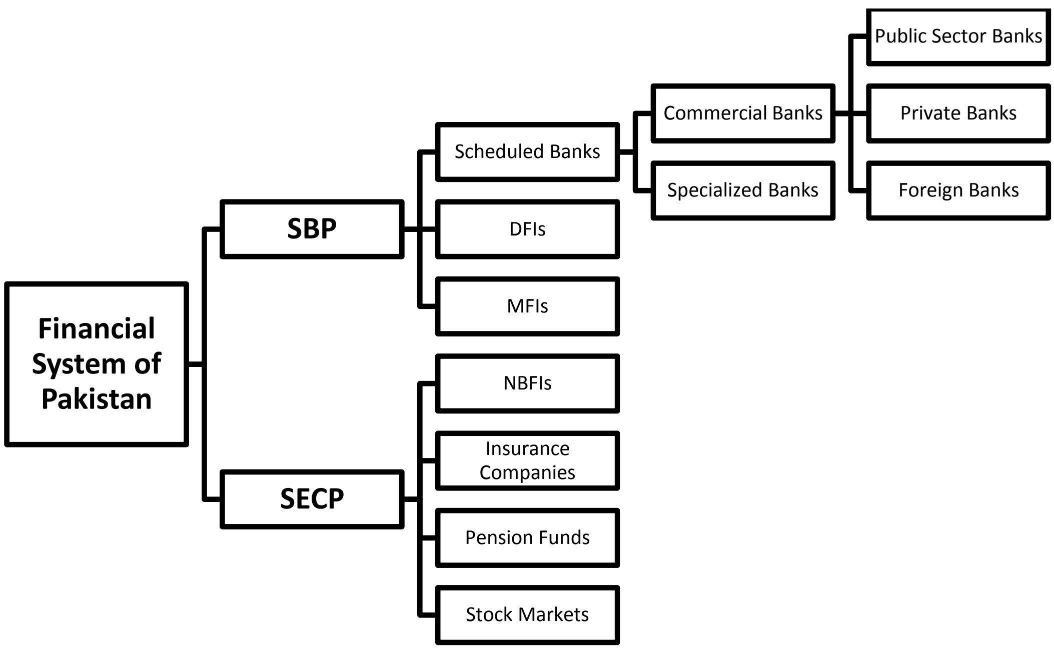


Figure 3. 1 The structure of the financial system of Pakistan

3.3. Evolution of the Banking System in Pakistan

Like other developing countries, banking sector in Pakistan is the major source of financing for the non-financial sector. However, banking sector in Pakistan evolved very differently from the banking sectors of the developed world. In March 1947, there were ninety nine scheduled banks listed on the Reserve Bank of India having 3,496 offices of banks in Indo-Pak subcontinent out of which 631 were located in the areas that were to become Pakistan (East and West Pakistan together where East Pakistan is now Bangladesh) and 487 were located in the territories currently constituting Pakistan (Zaidi, 2005). Reserve Bank of India was the central bank of India before partition. The partition plan was announced on June 3, 1947 and August 15 was decided as the day of partition. According to the Indian Partition Act 1947, an expert committee was set up to deal with the problems of coinage, currency exchange, division of the assets and liabilities of reserve bank of India and the membership of world bank and International Monitory Fund (IMF). This committee recommended that Reserve Bank of India would continue its operations in Pakistan till September 30, 1948 and Indian notes would also continue to act as legal tender till that date. On October 1, 1948 Pakistan would take over the management of public debt and exchange control from the Reserve Bank of India.

Pakistan inherited a weak banking structure after partition. Starting from the scratch in 1947, financial sector of Pakistan has passed through a lot of challenging phases to come to the present state. These phases are described in the following subsections.

3.3.1. Banking Growth from 1947 to 1970

The first phase of evolution after partition was the hardest phase in the whole evolution process of the banking sector. At the time of independence plan there were 25 Indian banks (Siddiqi, 2007). Following the announcement of independence plan, most of the Indian banks closed their branches in Pakistan and shifted their registered offices from Pakistan to India. The few offices that stayed were in the process of winding up their operations. As a result, the number of offices declined from 487 to 195 till June 30, 1948 (Meenai, 2010).

There were 19 non-Indian foreign banks with the status of small branch offices, involved merely in the export of agricultural crops from Pakistan. There were only two Muslim Institutions: Habib Bank and Australasia Bank that were operating in Pakistan. Habib Bank, established in 1941 in Bombay (now called Mumbai), was the only bank shifted its head office from India to Pakistan and served as the first commercial bank. Australasia bank was founded in December 1942, at Lahore and was the only bank among ninety nine scheduled banks that had its head office in Pakistan at the time of partition (Zaidi, 2005).

The third Muslim bank, named The Muslim Commercial Bank, was established on July 19, 1947 with head office at Calcutta (India). Its head office was moved to Dhaka (former Pakistan and now Bangladesh) in 1948, where it commenced its business with five branches. In 1956, it shifted its head office to Karachi (Pakistan).

On July 1, 1948, State Bank of Pakistan (SBP) was established as the central bank under the quasi-government ownership. The first important task that SBP had to perform was the issuance of currency notes and the withdrawal of Reserve Bank of India notes. The first Pakistan notes were issued on October 1, 1948 and all the Reserve Bank of India notes were withdrawn by August 1949. Initially, SBP was vested with the regulatory and supervisory responsibility aimed to develop commercial banking and strengthen the financial sector of the country. Australasia Bank was appointed to perform the treasury services for the SBP in 1948.

To pursue the SBP's objectives, in 1949, National Bank of Pakistan was established as government owned entity. In 1952, it was assigned the role to act as trustee of public funds as well as agent of SBP at places where SBP does not have its own branches. SBP also provided every possible help and encouragement to Habib Bank for expanding its branch network in Pakistan.

Since its inception, SBP encouraged the private sector to establish banks and financial institutions as a result of which an expansion in the branch network of commercial banks was observed in 1950's. SBP also sponsored the establishment of specialized credit institutions to promote agriculture and industry on one hand, and to broaden the institutional framework of financial sector on the other hand.

In 1958, banking and monetary sector observed significant expansion as a result of formation of new institutions, expansion and consolidation of banking sector all over the country. In 1960's there were 29 scheduled banks consisting of 10 domestic and 19 foreign banks. After ten years, the number of scheduled banks increased to 36 out of which 17 were domestic banks. The total number of bank branches reached to 3,133 in June 1970 (Meenai, 2010). This expansion in branch network, not only reduced the number of persons allocated to one bank branch from 176,000 in 1960, to 29,000 per branch, but also facilitated the entry of middle and lower middle income groups in the banking network. Resultantly, the volume of bank deposits increased five folds and the number of bank accounts observed an increase of eleven times during this decade. Domestic banks' share of deposits and advances increased up to 90% as a result of fierce competition in commercial banking (Zaidi, 2005).

3.3.2. Banking Growth from 1970 to 1988

Commercial banking made tremendous progress and phenomenal growth since independence. By December 31, 1973 there were 14 scheduled Pakistani commercial banks with 3,323 offices in Pakistan and 74 offices in the foreign countries (Meenai, 2010). These scheduled commercial banks were:

1. National Bank of Pakistan
2. Habib Bank Limited
3. Habib Bank (Overseas) Limited
4. United Bank limited
5. Muslim Commercial Bank Limited
6. Commercial Bank Limited
7. Standard Bank Limited
8. Australasia Bank Limited
9. Bank of Bahawalpur Limited
10. Premier Bank Limited
11. Pak Bank Limited
12. Sarhad Bank Limited
13. Lahore Commercial Bank Limited
14. Punjab Provincial Co-operative Bank Limited

All commercial banks played a vital role in mobilizing people's savings to provide financing to individuals and corporate sector of the economy. However, it was realised that these banks failed to mobilize savings to the sectors catering goods and services needs of the large number of people in the economy. Moreover, SBP was concerned about the concentration of credit in small class of big borrowers. A report issued by the SBP in 1970, revealed that only eighty eight account holders in banks had access to 25% of the total credit expanded by banks and majority of these account holders were the directors of banks themselves. Given the role of private sector in the industry and banking, SBP was not legally empowered to change the ownership structure of commercial banks. Of the four largest banks of that time, only one bank was in the public sector while the rest of the three were in the private ownership of three big families such as Habib, Adamjees and Saigols. These four banks hold 75% share of the total deposits and two third of the total earning assets. There were 4 other private banks which were also owned by four big families such as Dawood, Sheikhs, Haji Habib and Fancys. All seven private banks owned by big business families, altogether account for 92% of deposits held by all the local banks. Therefore, it was also not a surprising fact that these family owned banks promoted their own companies in the provision of credit. In the light of this background and other contemporary issues, banking reforms were introduced in 1972 (Zaidi, 2005). The Banking Reforms Ordinance 1973, was promulgated to correct the situation but some political circles believed that the existing anomalies and injustices could not be removed through this legislation. Therefore, Government of Pakistan nationalized all the banks in 1974 under the Banks Nationalization Act, 1974. The main objectives of this nationalization were to reduce the concentration of credit in the hands of few rich bankers by enabling government to use that capital for economic development of the country and to make credit availability to high priority sectors of the economy. Under the Nationalization Act, Pakistan Banking Council notified Banking Amalgamation Scheme 1974, which directed smaller banks to amalgamate with bigger banks to form the following five big national banks in three phases:

1. National Bank of Pakistan
2. Habib Bank Limited
3. Muslim Commercial Bank Limited
4. United Bank Limited
5. Allied Bank of Pakistan Limited

The first phase was completed on June 30, 1974 when Habib Bank (Overseas) Limited was merged with Habib Bank Limited, Premier Bank Limited with Muslim Commercial Bank Limited, Bank of Bahawalpur Limited with National Bank of Pakistan, and Australasia Bank Limited was merged with Pak Bank Limited, Lahore Commercial Bank Limited and Sarhad Bank Limited to form Allied Bank of Pakistan Limited. The second phase was completed on December 31, 1974 with the merger of Commercial Bank Limited and United Bank Limited (Zaidi, 2005). The last phase was completed on June 30, 1975 when Standard Bank Limited and Habib Bank Limited merged together (Siddiqi, 2007). In this way, all the private banks were completely wiped away from the financial structure of Pakistan.

After nationalization, banks were ordered to open their branches in every township of the country having a population of 2,000 inhabitants. This step played a positive role in shifting a non-monetized economy into a more formal banking economy, but its major drawback was observed in the form of overcrowded and overstaffed branches. Even branches of national banks were located next to each other in some localities regardless of their deposit potential. Moreover, the government ownership of commercial banks contaminated the credit allocation and loan recovery process with the political intervention besides other inefficiencies. Consequently, non-performing loans (NPLs) increased sharply, quality of financial services deteriorated and financial sector suffered losses. Although, some of the socio-economic objectives of nationalization were met but the powerful and lucrative banking sector was now open to political pressure and misuse (Zaidi, 2005).

Another development of this period was the introduction of the interest free banking in the form of Islamic banking in February 1979. Islamic banking was originally started by eliminating interest from NBFIs such as House Building Finance Corporation, National Investment Trust (NIT) and mutual funds of the Investment Corporation of Pakistan (ICP). Few months later, government ordered the nationalized commercial banks to provide interest free loans to the small farmers to meet their seasonal agricultural financial needs. In the next one year, this scheme was expanded to fishermen and co-operatives societies. All the five nationalized commercial banks set up their non-interest based profit and loss sharing deposit accounts in 1981 that replaced the interest bearing deposit accounts completely by 1985.

3.3.3. Banking Growth from 1988-1997

Economic system of Pakistan transformed radically in 1988, as a result of Structural Adjustment Programme (SAP)[12]. Financial system of Pakistan was among the priority sectors selected for the structural adjustments and became a target for reforms since. The era of financial liberalization, started in Pakistan in 1988, was an important benchmark in the financial history of Pakistan because it opened up the financial sector to international pressure and increased the country's vulnerability to the external shocks. In 1988, there were 8 scheduled Pakistani banks and 18 foreign banks working in Pakistan.

In order to promote women participation in the economic development of country, First Women Bank Limited was established in the public sector. It started its operations on December 2, 1989 with an authorized capital of Rupees. 100 million where 57.75% shares were held by public sector banks comprising United Bank Limited, Habib Bank Limited, National Bank of Pakistan and Ministry of Women Development while the rest of the 42.25% share-holding was with Allied Bank of Pakistan Limited and Muslim Commercial Bank Limited (Siddiqi, 2007).

[12] SAP refers to a set of measures that countries need to implement in order to qualify for loans from donor agencies such as World Bank and IMF.

After observing the performance of nationalized banks for many years, the Government of Pakistan decided to revise its nationalization policy to encourage the participation of private sector. This participation was planned in the form of transferring management and control of NCBs to private sector and permitting to open new banks and NBFI, in order to enhance the level of efficiency and competition in the financial sector.

Banks Nationalization Act, 1974 was amended in 1991, and the process of privatization of nationalized commercial banks (NCB) was started. At the first stage, two state owned banks: Muslim Commercial Bank and Allied Bank Limited, were privatized. The privatization of these two banks completed in two years. In 1991, 26% shares of Muslim Commercial Bank and Allied Bank were transferred to the general public. Additional 49% shares of Muslim Commercial Bank were floated in 1993 and subsequently, the control and management of Muslim Commercial Bank was transferred to the new buyer. For Allied Bank, 25% shares were transferred to private sector under Employees Stock Ownership Plan (ESOP) and consequently management and control was transferred to Employee Management Group (EMG).

Another important development of 1991 was, the decision permitting private sector commercial banks to operate in the country. Consequently, twenty three new banks were allowed to commence banking operations out of which ten were private domestic banks and remaining 13 were foreign banks (Meenai, 2010). In 1994, two provincial banks: the Bank of Khyber and the Bank of Punjab were declared scheduled banks in the public sector. Considering the mushroom growth of banks, a moratorium was imposed in 1995 and no new bank was allowed to open afterwards (Zaidi, 2005). However, branch policy was liberalized for both private and foreign banks in order to provide them the opportunity to grow. Conversely, nationalized banks were not only prohibited to open new branches from December 1996, but also instructed to close down their unprofitable branches in 1997. Moreover, NCBs were asked to formulate a restructuring plan to rationalize their size and workforce. In response to this, three NCBs, two specialized banks and two privatized banks introduced a golden handshake scheme for their employees and reduced the number of employees from 99,954 to 81,079 by December 1999 (State Bank of Pakistan, 2001-2002). In terms of branch closure strategy, the initial criterion of branch expansion was retained ensuring no area would be under banked[13].

3.3.4. Banking Growth from 1997-Present

Banking system of Pakistan witnessed significant structural changes subsequent to the implementation of the first financial liberalization programme, initiated in 1989. Another set of reforms was introduced in 1997, to supplement the existing liberalization programme. In consonance with these reforms, SBP was provided full legal autonomy and a risk based inspection system, in line with the Basel Capital Accord, was adopted in the financial sector.

In 1999, the total number of banks was 46 with 25 domestic and 21 foreign banks. Most of the newly formed foreign and domestic banks were small in size and had small branch network that only concentrated their business in the top ends of the market. However, in 1999, the new governor of SBP (who came from the World Bank) accelerated the pace of financial sector liberalization and institutional changes demanded by the IMF. As a result, the large number of foreign banks merged with the private banks gradually.

[13] A place/area is called under banked if no branch of any other bank is operating within the radius of 5 km. For reference see Banking Surveillance Department Circular No. 11, dated 17th March 2001 titled Branch Licensing Policy.

Considering rapidly changing operating environment and future direction of reforms, minimum paid up capital requirement (MCR) for banks was increased in December 2000 from Rupees. 500 million to 1000 million. This was done to strengthen the capital base of scheduled banks. Banks were required to meet this increased capital requirement in two phases by the end of December 2002 (State Bank of Pakistan, 2001-2002). Besides strengthening the capital base, this requirement greatly affected the structure of banking system through the initiation of mergers and acquisitions in banking sector. In pursuance of the privatization policy, two more nationalized banks, named United Bank and Habib Bank, were privatised. United Bank was sold in 2003 to a businessman from Middle East whereas Habib Bank (the biggest commercial bank) was privatised in 2004 by selling 51% shares to Aga Khan Fund for Economic Development (AKFED).

The continuous privatization coupled with on-going process of mergers and acquisitions changed the ownership structure and concentration of banking sector in Pakistan. A number of weak banks merged their operations with other banks to avail the economies of scale and scope. Most of the mergers or acquisitions activity was observed among the private banks, non-bank finance institutions (NBFI) and foreign banks. The former two groups merged or acquired the operations of the latter group to form domestic private banks. As a result, the number of scheduled banks reduced to 40 in 2003 and the share of public sector banks (both commercial and specialized) in the total assets of scheduled banks dropped sharply from 55.3 % in 1997 to 25.3% in 2004 (State Bank of Pakistan, 2003). On the other hand, the private sector banks owned the majority share of 56.6% in the total assets of banks in 2004 that first time exceeded the public sector share after nationalization in 1974. Another provincial bank, Sindh Bank Limited was founded on December 24, 2010 with the head office in

Karachi, Pakistan that increased the count of provincial banks to three. A summary of the number of commercial banks under different ownership groups is provided in Table 3.1.

Table 3. 1 Statistics about different ownership types of banks in Pakistan at different time periods

Type of Bank	1951	1960	1970	1980	1990	2000	2005	2010	2012
Public Banks	1	1	1	5	6	6	4	5	5
Private Banks	4	9	16	0	0	14	20	25	22
Foreign Banks	27	19	19	24	17	19	11	12	7
Total	32	29	36	29	23	39	35	42	34

Source: (State Bank of Pakistan, 2003-2012)

Summarily, there have been many structural changes in the banking sector of Pakistan since independence. The number of foreign banks has reduced markedly from 27 in 1951 to 7 currently. Compared to five NCBs in 1990's, at present National Bank of Pakistan is the only large and fully owned government bank. The three provincial banks currently operating in the public sector include: The Bank of Punjab, The Bank of Khyber and Sindh Bank Limited. First Women Bank is the only female oriented bank operating in the public sector since 1989. Currently, there are 22 private banks out of which 5 are Islamic banks. The list of all scheduled banks along with the number of their branches is provided in the following Table.

Table 3. 2 Different banks operating in Pakistan and the number of their branches

Reporting Scheduled Banks and Their Branches As on 31st December 2012					
Sr No.	Name of Bank	Number of Branches	Sr No.	Name of Bank	Number of Branches
	Public Banks	**1868**		**Private Banks**	**7862**
1	Bank of Punjab Ltd.	302	1	Al Baraka Bank Pakistan Ltd.	90
2	Bank of Khyber Ltd.	78	2	Allied Bank of Pakistan Ltd.	873
3	Sindh Bank Ltd.	150	3	Askari Commercial Bank Ltd.	236
4	First Women Bank Ltd.	42	4	Bank Al Falah Ltd.	453
5	National Bank of Pakistan Ltd.	1296	5	Bank Al Habib Ltd.	307
	Foreign Banks	33	6	Bank Islami Pakistan Ltd.	83
1	Barclays Bank PLC Pakistan	7	7	Burj Bank Ltd	67
2	Citi Bank	7	8	Dubai Islamic Bank Ltd.	100
3	Deutsche Bank AG	3	9	Faysal Bank Ltd.	265
4	HSBC Bank Middle East Ltd	10	10	Habib Bank Ltd.	1496
5	HSBC Bank Oman S.A.O.G	3	11	Habib Metropolitan Bank Ltd.	143
6	Industrial and Commercial Bank of China	2	12	JS Bank Ltd.	77
7	The Bank of Tokyo Mitsubishi UFJ Ltd.	1	13	KASB Bank Ltd.	70
	Specialized Banks	532	14	Muslim Commercial Bank Ltd.	1179
1	Industrial Development Bank Ltd.	7	15	Meezan Bank Ltd	310
2	SME Bank Ltd.	13	16	NIB Bank Ltd	179
3	The Punjab Provincial Cooperative Bank Ltd.	151	17	Samba Bank Ltd	28
4	Zarai Taraqiati Bank Ltd.	361	18	Silk Bank Ltd	85
			19	Soneri Bank Ltd.	233
			20	Standard Charted Bank	130
			21	Summit Bank	181
			22	United Bank Ltd.	1277

Source: (Banking Statistics of Pakistan, 2012)

3.4. Distinguishing Features of the Banking System of Pakistan

Commercial banks foster the process of economic development by accelerating the rate of capital formation and providing credit for the growth of trade and industries in the country. In the developing economies commercial banks also play an important role to achieve certain socio-economic objectives set by the state. Being a developing economy, the motive behind establishing commercial banks in Pakistan was also helping the government to attain certain socio-economic objectives in addition to the general objectives of promoting trade and industrialization in the country. However, with the growth of commercial banks it was realized by the SBP and government that instead of catering the needs of broad based and priority sectors of the economy, most of the bank credit was concentrated in the small group of big businesses. Therefore, to rectify this situation, the government of Pakistan nationalized all the commercial banks in 1974 by consolidating them into five big banks. This step of the government of Pakistan was in line with the notion of socialism in banking, which is expressed as: "without big banks, socialism is impossible. The big banks are the 'state apparatus' which we need to bring about socialism and which we take ready made from capitalism" (Gravy, 1977). This idea of socialism was adopted by the governments in Asia, Africa and Latin America around 1960's and 1970's who nationalized their existing commercial banks and started new ones (La Porta et al., 2002).

After nationalization in 1974, the banking system of Pakistan has passed through different structural changes to achieve its current state of development. These structural changes are the distinguishing features of the banking sector of Pakistan that make it worthy to research. The key feature is its transformation from a wholly public owned sector to a majority privately owned sector as a result of induction of new private banks and privatisation of public owned banks. This shift has changed the overall objective of banking sector from the socio-economic welfare to profit maximization because private banks are profit-oriented organizations. However, SBP as a regulator of financial sector in Pakistan still pursue the objective of socio-economic welfare while devising different banking regulations because according to State Bank of Pakistan Act 1956 the objective of SBP is to "regulate the monetary and credit system of Pakistan and to foster its growth in the best national interest with a view to securing monetary stability and fuller utilisation of the country's productive resources".

The second prominent feature is the consolidation in the banking sector of Pakistan that initiated in 2000, to fulfil the minimum capital requirement imposed under the Basel Accord I and II. Consequently, the number of banks is reduced significantly over the past few years.

The third feature is the accumulation of NPLs in the banking sector of Pakistan. This problem started after the nationalization of banks and is still a prominent problem. Many factors are contributing to this trend such as subprime financial crises worldwide and energy crises and economic downturn in Pakistan that had adversely affected the repayment capability of borrowers. To control this menace of NPLs, SBP has introduced not only different reforms but also provided detailed guidelines on risk management (covers both credit risk and liquidity risk) considering it an important area for the establishment of sound financial sector.

Another major change observed in the banking system is the shift in the asset mix of banks (investments and loans) as a result of which advances to deposit ratio (ADR) of banks is reducing and investments to deposit ratio (IDR) is increasing gradually (explained in detail in section 3.4.3). This shift in asset mix is actually an outcome of the risk aversion behaviour of banks in response to the increasing NPLs since 2007. This trend indicates that banks have diverted their resources from commercial banking to investment banking. Although, commercial banks are allowed to undertake investment and leasing business[14] however, these activities are not their prime-banking objective.

[14] In this respect commercial banks in Pakistan have some elements of universal banking although it is not yet started in the banking sector of Pakistan.

Another important transition in banking operations is the emerging trend of Islamic banking as result of which not only full-fledged banks were opened in the private sector but the conventional banks were allowed to set up, Islamic banking subsidiaries and open their standalone Islamic banking branches. Now five full-fledged Islamic banks are operating in Pakistan. In addition to Islamic banks, many other commercial banks are also pursuing Islamic banking through their Islamic banking windows and branches.

The nature of these features demands that the evaluation method should measure the efficiency of the banking system based on the two separate objectives pursued by the commercial banks and SBP (as a regulator and representative of government in a developing economy). Commercial banks are the profit-oriented organizations and their goal is profit maximization. On the other hand, the objective of SBP is effective intermediation of resources to obtain macro-economic objectives.

In order to evaluate the performance of commercial banks in Pakistan based on the two different objectives set for them, we need to model the banking operations in two different dimensions. Moreover, we have some additional information based on different banking characteristics that need to be added in the standard DEA evaluation to estimate the efficiency of operations in both dimensions.

For this purpose, the current study has modelled the DEA evaluation to assess the intermediation (SBP’s objective) and profitability (commercial banks’ objective) aspects of banking operations. However, to model the efficiency based on the distinguishing features of Pakistani banking sector, a DEA based framework called the DEATOB Framework, is proposed in the current study. This framework creates a better-informed DEA model that is capable of adding additional information regarding different banking operations into the standard DEA estimation. Although this framework is designed keeping in view the specific features of banking sector of Pakistan, it is equally applicable to the banking sectors of other countries.

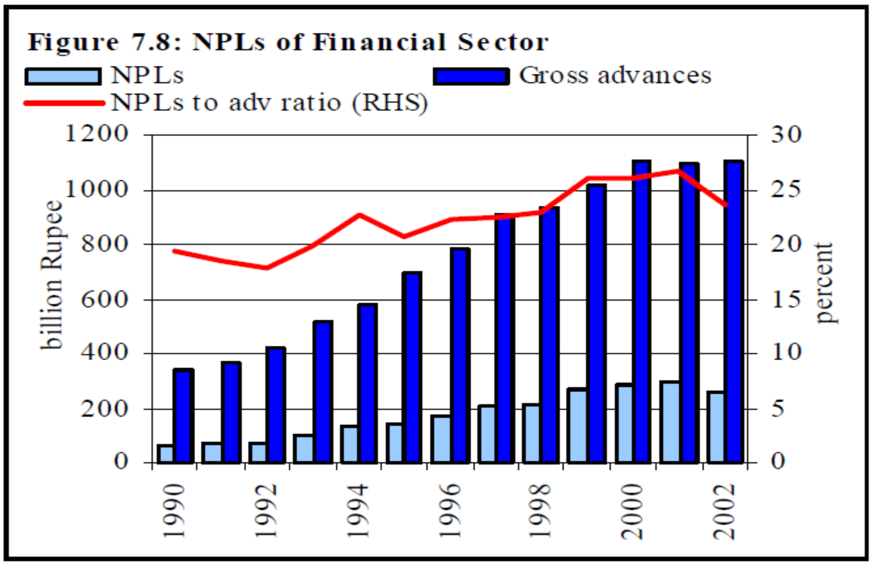
The next few sections describe details of some of the distinguishing features of banking sector of Pakistan that have not been covered in the evolution of banking system of Pakistan.

3.4.1. Evolution of Non-Performing Loans

A large share of earning assets[15] in total assets of a bank leads to the higher profitability. However, the large amounts of earning assets do not always secure the large amounts of profits due to the contamination of earning assets with the poor quality assets. These poor quality assets, generally termed as NPLs, not only reduce income and profitability but also lead to the solvency risk of financial institution (State Bank of Pakistan, 2001-2002). After nationalization, a large amount of NPLs piled up in the banking sector of Pakistan mainly due to the loans provided by nationalized commercial banks (NCBs) on political grounds particularly in early 1990's. Consequently, both NPLs and their ratio to loans witnessed a considerable increase during 1990's as can be seen from this figure.

[15] Earning assets of a bank are the assets that produce interest and dividend for a bank such as investments, stocks, bonds, and loans.

Figure 3. 2 The growing amount of NPLs



Source: (State Bank of Pakistan, 2001-2002)

Initially, banks were reluctant to write off bad loans mainly due to the poor quality of underlying collateral and avoiding any legal complications that may arise because of lacunas in the judicial framework. Therefore, in 1997 SBP introduced a strict disclosure requirement that forced all banks to disclose the actual classification of their loans. This disclosure requirement revealed the existence of substantial amount of NPLs and resulted in the considerable rise in the NPLs and their ratio to advances in the banking sector. However, NPLs to advances ratio reduced after 2000 due to larger increase in advances and a stagnant value of NPLs and this declining trend continued till 2006 as shown in Table 3.4. The NPLs to advances ratio started to increase again in 2007 and it was found that infection rate was more in small banks as compared to large banks (State Bank of Pakistan, 2009-2010).

Indirect impact of global recession and slowdown in domestic economic activity in 2008 increased the probability of loans default due to inability of borrowers to pay back their loans hence, enhanced the potential risk of losses for banks. Therefore, most of the banks showed reluctance in extending loans and shifted their asset allocation to investments. In response to this shift, the volume of loans started to reduce after 2008 that resulted into declining advances to deposit ratio (ADR) in the following years after touching the highest value of 71.5% in 2008. The value of ADR was 51% in 2012 as shown in Table 3.4.

The mounting amount of NPLs resulted in the increasing NPLs to advances ratio that increased from 7.6% in 2007 to 10.5% in 2008. In 2009, twenty four banks were having double digit NPLs to advances ratio out of which 11 banks had this ratio more than 20% (State Bank of Pakistan, 2009-2010). NPLs to advances ratio continued to increase till 2011 and touched the peak value of 14.94%. However, with a slight decline of 1% in 2012 this ratio became 13.94%. The reason behind this decline was the rescheduling and restructuring of portfolios that restricted the flow of NPLs by ensuring that the viable corporations should remain operational and continue to repay their loans (State Bank of Pakistan, 2012b). Rescheduling and restructuring induced the recoveries of loans and reduced the amount of NPLs. Public sector commercial banks were the main contributors towards the decreasing NPLs followed by the foreign banks. This trend is obvious from the Table 3.3.

Table 3. 3 Position of NPLs in different categories of scheduled banks and overall banking sector.

Billion Rupees

Banks	NPLs					
	31-12-2008	31-12-2009	31-12-2010	31-12-2011	31-12-2012	36-06-2013
All Banks	**313.7**	**432.3**	**547.8**	**607.1**	**607.2**	**616.5**
Commercial Banks	**284.5**	**404.0**	**515.4**	**572.5**	**577.0**	**579.0**
Public Sector Commercial Banks	77.6	115.2	164.2	186.6	165.3	163.2
Local Private Banks	203.9	282.7	344.2	378.4	402.6	409.3
Foreign Banks	3.0	6.2	7.0	7.6	9.1	6.6
Specialised Banks	**29.1**	**28.2**	**32.4**	**34.6**	**30.2**	**37.5**

Source: (State Bank of Pakistan, 2013)

The increasing volume of NPLs not only reflects the degree of deterioration in the asset quality but also negatively affects the overall performance of banking system. More specifically, it reduces the earning assets of banks on one hand, and increases the expenses in the form of loan loss provision on the other hand. Loan loss provision is the NPLs related cost incurred to cover the risk attached to loan portfolio according to the rates specified by the SBP. Provisions are maintained against both performing and non-performing loans. However, the rate of provision[16] is quite nominal for performing loans but higher for NPLs. Provisions to loan ratio indicated an increasing trend since 1990's to 2007. In 2007, new provisioning requirements were laid down as a result of which provisions to loan ratio is stable around 69% since 2008 as shown in Table 3.4.

The brief history about NPLs in Pakistan indicates that NPLs is a major problem in the banking sector that not only deteriorates the asset quality but also reduces the profitability of banks. These adverse impacts of NPLs on asset quality and profitability necessitate the need to include risk factor based on the asset quality into the efficiency evaluation of commercial banks.

Table 3. 4 The key ratios and figures representing the NPLs and liquidity position in Pakistan

Category/Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NPLs	173	183	231	240	244	232.00	211.00	200.00	177.00	175.50	214.20	313.70	432.30	547.80	607.10	634.80
NPLs to Advances Ratio	26.5	22.8	25.9	23.5	23.4	21.8	17	11.6	8.3	6.9	7.6	10.5	12.6	14.84	14.94	13.94
Advances to Deposit Ratio	49.6	48.2	51.8	60.4	58.3	52.2	52.5	61.5	66.5	70.3	66.8	71.5	65.31	61.4	54.78	51
Provisions to Loans Ratio	47	59	49	55	55	61	64	70	76.8	77.8	86.1	69.6	69.9	67.9	69.95	71.5
Liquid Assets to Total Assets Ratio	39.8	40.1	38.3	36	38.5	46.7	45.1	36.6	33.7	31.9	33.7	28.6	13.08	16.484	21.502	19.268

Source (State Bank of Pakistan, 2001-2002, Banking Statistics of Pakistan, 2002-2012)

[16] The rate of loan loss provision for different categories of performing and non-performing loans are provided in prudential regulations 2011 of banks and arranged in Table 8.1 given in Chapter 8 section 8.3.4.

3.4.2. Liquidity Management in the Banking Sector of Pakistan

In addition to the declining NPLs and NPLs to advances ratio since 2003, ADR witnessed a rising trend due to the aggressive lending by local private banks. ADR increased from 52.5 in 2003 to 71.5 in 2008, indicating that banks are left with lesser liquidity in the form of liquid assets[17]. This trend is also evident from the decreasing liquid assets to total assets ratio that reduced from 45.1 to 28.6 during this time period as shown in Table 3.4.

Liquidity[18] management is the part of risk management framework of banks. The difficulties in managing the liquidity of bank may lead to bank's collapse and by extension to the bank failures (Largan, 2000). To control the liquidity position in banks, SBP has two different kinds of reserve requirements; Cash Reserve Requirement (CRR) and Statutory Liquidity Requirement (SLR). These reserve requirements also serve as an important monitory policy tool. CRR which is governed under Section 36(1) of SBP Act 1956, refers to the portion of bank's demand[19] and time[20] (with a tenor of less than one year) deposits kept with the SBP as mandatory requirement. CRR serves dual purpose: first, it ensures that this portion of bank's deposits is risk free and second, this acts as monetary policy tool for controlling the supply of money and inflation by making it unavailable to banks for lending. Commercial banks do not earn any interest on this amount.

SLR, governed under Section 29 of the Banking Companies Ordinance, 1962, is the amount that the commercial banks are required to maintain in the form of gold or

[17] Liquid assets include cash in Pakistan including foreign currency, balance with State Bank of Pakistan (on account of 5% CRR), balance with NBP, unencumbered approved securities and assigned capital of the foreign banks held in SBP.

[18] Liquidity refers to banks' ability to maintain sufficient funds to meet their financial commitments, which may, in turn, be related to their ability to attract deposits.

[19] Demand deposit is a kind of deposit that is payable to customers on their demand.

[20] Time liabilities refer to the liabilities of commercial banks that they are liable to pay to the customers after a certain period mutually agreed upon such as after 6 months, 1 year etc. depending upon the term of deposit but not payable on demand.

government and approved[21] securities before providing credit to the customers. It is determined as a percentage of total demand and time liabilities (with a tenor of less than one year). SLR is determined and maintained by SBP to control the expansion of bank's credit and implicitly ensures the solvency of commercial banks. For compliance of this regulation every banking company has to submit a weekly return to SBP.

Keeping in view the importance of liquidity and deteriorating liquidity condition in Pakistan, in July 2006, SBP increased the SLR to 18 % from the previous 15% on both time and demand liabilities. Moreover, SBP also introduced different CRR for different categories of deposits that was initially maintained at 5% of both time and demand deposits. The CRR was increased to 7% for demand liabilities (including current, saving and fixed with a maturity period less than six months) and reduced to 3% for time liabilities (with tenure 6 months and over). Banks generally have most of their deposits in the form of demand liabilities therefore these requirements of SBP substantially increased the liquidity of banks (State Bank of Pakistan, 2006).

The global financial crisis originated in the form of liquidity crisis from subprime mortgage market in 2007 and shifted to full-blown solvency crisis after one year in September 2008. In response to these crises, in 2007, SBP further tightened the reserve requirements by abolishing 3% CRR on time deposits and revising the definition of demand liabilities to include fixed deposits of up to one year while maintaining the 7% CRR on demand deposits. Due to these tightening measures, ADR started to decline after 2007.

In May 2008, reserve requirements were further tightened by increasing SLR to 19% and CRR to 9% to safeguard the banking system from liquidity crisis. However, an

[21] Approved securities mean bond and shares of different companies considered secure by SBP.

unexpected withdrawal of deposits was experienced in 2008 that created the liquidity management problem for banks. In that situation SBP reduced the CRR to 5% of demand deposits. Moreover, SLR was relaxed by, enhancing the list of SLR eligible securities and removing time deposits with maturity of one year from demand liabilities (State Bank of Pakistan, 2008). These rates of CRR (5%) and SLR (19%) are still prevailing in the banking sector of Pakistan and used as the principal determinants of banks' liquidity.

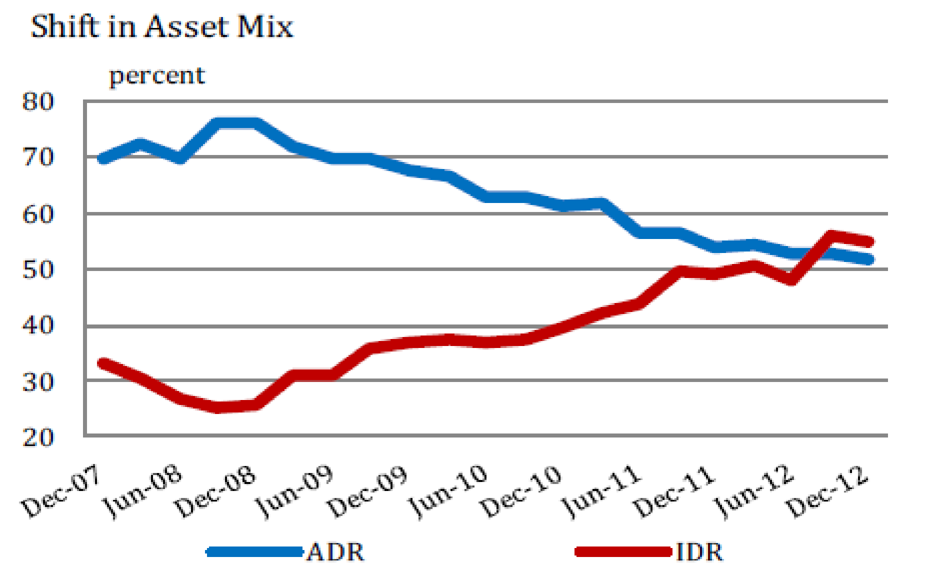
Considering the importance of liquidity in risk management and reserve requirements as a tool for liquidity management, the current study has considered SLR as one of the component of the proposed framework.

3.4.3. Shift in Asset Mix of Banks

Financial deepening and outreach of the intermediation services has been an important objective of SBP. This objective has been reinforced in almost all the banking reforms introduced in Pakistan at different time periods. However, after the global financial crises of 2007-2008 and slow down of domestic business activity, the banking sector of Pakistan suffered with the problem of growing NPLs due to the inability of borrowers to repay their loans. As a result, banks adopted a cautious approach towards lending by limiting credit flows to high quality private borrowers and public as well as private sector borrowers for meeting their seasonal requirements (State Bank of Pakistan, 2012b). Moreover, the excess funds were deployed to investments particularly, high yield government securities that dampened the risk appetite of banks. These developments led to the shift in the asset allocation from advances to investments that decreased the ADR after 2007. Another contributing factor towards decreasing ADR was the tightened reserve requirement, imposed by SBP on all scheduled banks, to avoid the liquidity risk in the banking sector in response to the subprime crises.

This shift in asset mix of banks coupled with the tightened liquidity requirements not only decreased ADR but also increased the investment to deposit ratio (IDR) in the next few years as shown in Figure 3.3. This trend in the banking sector of Pakistan is in line with the literature on credit crunch[22] according to which credit crunch results in either reduction of total assets of the banks or reduction in the bank credit supply to the economy and shifting of resources towards less risky assets such as government bonds (Laeven and Majnoni, 2003).

Figure 3. 3 The shift in asset allocation from advances to investments represented as changing trends of ADR and IDR



Source: (State Bank of Pakistan, 2012b)

The shift in asset mix is an important development in the banking sector of Pakistan that appeared as an outcome of the risk averting behaviour of banks. However, this development represents the diverging behaviour of banks from the macro-economic objective of financial deepening set by the SBP. This shift in the asset mix of banks

[22] Credit crunch refers to the simultaneous shortage of capital and the contraction in the supply of new loans.

has served as an important stimulus for measuring the disintermediation behaviour of banking sector through the proposed framework.

3.5. Banking Systems of Pakistan and Other Asian Countries – Similarities and Differences

Banking system of Pakistan provides an array of banking intermediation services that are common around the globe and include: accepting deposits, advancing loans, making investments, credit cards, foreign exchange, and payment related services.

Banking system of Pakistan has similarities with other Asian countries in terms of structure, banking reforms and regulations. Pakistan neighbours India and same kind of trends emerged in the banking systems of both countries. For example both these countries nationalized their commercial banks (India nationalized 14 commercial banks in 1969 and 6 in 1980 and Pakistan nationalized 14 commercial banks in 1974) in order to cope with the inequitable distribution of bank credit. However, this nationalization process wiped away all the private banks from the banking arena of Pakistan, but in India, the number of private banks remained stagnant and their branch expansion was also restricted. Presently, 27 state owned banks are operating in India including 19 nationalized banks (Das and Ghosh, 2006). Unlike India there are only 5 state owned banks in Pakistan and include only one nationalized bank.

Moreover, countries in the Indian Sub-continent of South Asia (Bangladesh, India and Pakistan) introduced similar reforms throughout the 1990’s that aimed at creating more profitable, diversified, efficient and resilient banking system. A number of reforms include: strengthening of regulatory environment (through financial amendments and introduction of different acts and ordinances), restructuring of public sector banks, privatization of public sector banks, and an effort to remove barriers to market entry (Jaffry et al., 2007). Under restructuring of banks, the public sector banks in all these countries initiated the process of cutting excessive use of manpower and non- performing loans whereas under privatization a number of banks were privatized in all the countries. In response to removal of barrier to market entry, new private banks were allowed to start their operations in these countries along with the reduction in the restriction on branching of both private and foreign banks.

Accumulation of non-performing loans is one of the problems faced by the banking sector of Pakistan (State Bank of Pakistan, 2001-2002, 2013) which is also common in most of the Asian countries such as Bangladesh (Jaffry et al., 2007), Hong Kong (Drake et al., 2006), India (Ataullah et al., 2004, Ataullah and Le, 2006, Das and Ghosh, 2006), Indonesia (Thoraneenitiyan and Avkiran, 2009), Japan (Drake and Hall, 2003, Drake et al., 2009), Malaysia (Sufian, 2009), Singapore (Sufian and Majid, 2007) and Thailand (Leightner and Lovell, 1998) and became prevalent particularly after the Asian banking crisis of 1997. All these countries have introduced various regulatory measures at times under their risk management frameworks.

Banks in Pakistan were not affected by the Asian banking crisis of 1997, however after the crisis banking system in Pakistan adopted bank restructuring measures similar to Indonesia, Korea, Thailand, Malaysia and Philippine. These measures include relaxation of barriers to the entry of foreign banks and domestic mergers and takeovers. The former measure provided additional freedom to foreign banks and allowed them to engage in a broader scope of activities whereas with latter measure weak and distressed banks were merged as a way to reduce the failure risk and inefficiency (Thoraneenitiyan and Avkiran, 2009). As a result of relaxation of barriers to entry, a number of foreign banks started their operations and expended their branch network in Pakistan but gradually most of the foreign banks merged with the private domestic banks. Currently, only 7 foreign banks are operating in Pakistan with very limited branch network (ranging from 1 to 10).

Two other after crisis banking measures include the recapitalization of troubled banks and privatization of the state owned banks (Jaffry et al., 2007, Thoraneenitiyan and Avkiran, 2009). The recapitalization approach was adopted in Indonesian and Korean banking systems. In contrast, only the later measure was exercised in Pakistan as a result of which two more nationalized banks (United Bank and Habib Bank) were privatized that increased the number of privatized banks from 2 to 4 leaving only one nationalized bank.

3.6. Conclusion

This chapter presents an overview of the financial system of Pakistan particularly, commercial banks. A brief introduction of the regulatory structure of the financial system in Pakistan is included in the chapter in order to provide an idea about the regulatory authorities responsible for the control of commercial banks. This chapter also examines the evolution of banking sector since independence. Moreover, the emergence of different banking subgroups emanated from different banking reforms, introduced for the stability and prudence of banking system, is detailed in this chapter. The chapter also highlights some of the distinguishing features of the banking system of Pakistan that are used in modelling the banking behaviour and building the proposed framework of the study to evaluate the efficiency of the banking sector. The details of the methodology and the proposed framework are provided in the next three chapters.

CHAPTER 4
THEORETICAL FOUNDATIONS OF DATA ENVELOPMENT ANALYSIS

4.1. Introduction

This chapter provides a comprehensive review of Data Envelopment Analysis (DEA) as the main research technique implemented in the current study. In DEA context, this chapter outlines background, terminology, theoretical concepts, and the mathematical formulation of different DEA models. The review of DEA is followed by discussion of weight restrictions as a traditional method for restricting weight flexibility and their associated problems. This chapter also introduces the idea of the trade-off approach with the mathematical formulation of different DEA models with production trade-offs. In addition, some of the limitations associated with the trade-off approach are discussed in the chapter. The last section provides the overview of different methods used for the investigation of returns to scale characteristics of DMUs.

4.2. Foundations of DEA Based Efficiency Measurement

Efficiency measurement of firms and industries has been a fundamental concern for economists, operations researchers and management scientists. The concept of efficiency and its measurement is not new. It dated back to Smith (1776) who attempted to explain the relationship between land tenure and efficient crop production. However, a general interest in growth and productivity developed in the immediate post war years. The foundation of the concept of frontier efficiency measurement was laid down by the fundamental work of Debreu (1951), Koopmans (1951) and Shephard (1953). The concept of technical efficiency was introduced by Koopmans (1951) in the following words: “an input-output vector is technically efficient if, and only if, increasing any output or decreasing any input is possible only by decreasing some other output or increasing some input” (p-60). Debreu (1951) was the first who introduced the first measure of technical efficiency through a coefficient of resource utilization for the efficiency measurement of an economy. This coefficient of utilization measured efficiency in output expanding direction. Debreu and Shephard both introduced a way to model multiple output technology by using distance function though; this multiple output modelling was approached in two different dimensions. Debreu touched this concept from output expanding side whereas Shephard highlighted the input conservation side of the radial distance of production unit from the frontier (Kumbhakar and Lovell, 2000, Fried et al., 2008).

Farrell (1957) was the first in measuring the productive efficiency empirically. Drawing inspiration from Koopmans and Debreu, Farrell laid the foundation for new approaches to micro level efficiency and productivity studies. His work provided insight into two issues: how to define efficiency and productivity, and how to calculate the benchmark technology and efficiency measures (Førsund and Sarafoglou, 2002). Farrell's contribution was path breaking in three aspects. First, the efficiency measures were based on the uniform radial expansion or contraction from the inefficient observation to the frontier. Second, the production frontier provides a most conservative piecewise linear envelopment of the data. Third, the frontier is obtained by solving system of linear equations obeying two conditions on unit isoquant: its slope is not positive and no observed point lies between it and the origin (Farrell, 1957). Along with defining cost efficiency, he also provided the decomposition of cost efficiency into technical efficiency, price (allocative) efficiency while describing the concept of overall efficiency. For detailed discussion about the evolution of efficiency measurement through frontier analysis see the work of Kumbhakar and Lovell (2000), Førsund and Sarafoglou (2002), Coelli et al. (2005), Førsund et al. (2009) and Cooper et al. (2011).

Farrell's piecewise linear hull approach of frontier estimation was considered by only few authors in two decades following his paper. Boles (1966), Shephard (1972) and Afriat (1972) proposed the mathematical programming methods that could achieve the same task, but these methods did not receive much attention till Charnes et al. (1978) used this concept in their paper and named it CCR[23] model. The term Data Envelopment Analysis was coined the first time by Charnes et al. (1978) who have defined it in the following words:

"A mathematical programming model applied to observational data [that] provides a new way of obtaining empirical estimates of relations – such as the production functions and/or efficient production possibility surfaces – that are cornerstones of modern economics".

CCR model generalized the single output/multiple input technical efficiency measure of Farrell (1957) to multiple output/multiple input case. This model used the optimization method of mathematical programming to construct a single "virtual" output to single "virtual" input relative efficiency measure (Charnes et al., 1994).

However, since its advent in 1978, a tremendous growth has been observed in the theoretical developments and practical applications of DEA. As reported in Charnes et al. (1978), DEA was originally developed to provide an improved method for the evaluation of public sector entities. Later, it has been extensively used in public as well as private enterprises covering a broad spectrum of applications in manufacturing, agriculture, banking, insurance, education, health services, sports and many more. Before providing a detailed review of different DEA models we have provided different definitional constructs for efficiency measurement through DEA in the next section.

[23] CCR stands for Charnes, Cooper and Rhodes.

4.3. Definitional Constructs in Efficiency Measurement Using DEA

4.3.1. Production Process, Productivity and Efficiency

Production process is the act of transforming a set of inputs into a set of outputs. The economic performance of the production units (called Decision Making Unit (DMU) in DEA terminology) is commonly measured in terms of "efficiency" or "productivity". Although, "productivity" and "efficiency" are two different terms nevertheless, these are often treated equivalent. Productivity of a DMU refers to the ratio of its outputs to its inputs whereas efficiency is a relative concept that involves "comparing observed output to maximum potential output obtainable from the input, or comparing observed input to minimum potential input required to produce the output, or some combination of the two" (Fried et al., 2008) p.8). More precisely, productivity is a descriptive measure of performance whereas efficiency is a normative measure (Ray, 2004) p-15).

Figure 4. 1 The production process

In DEA, efficiency is a measure of performance within a group relative to the best performer and there can be more than one best performer in a group. Best performer(s) is (are) assigned an efficiency score of 1 whereas the rest of the DMUs are assigned a score between 0 and 1.

4.3.2. Production Possibility Set (PPS)

The production function or the production possibility set forms the foundation of efficiency analysis. PPS represents all the observed input-output correspondences pertaining to DMUs being assessed, which are assumed producible.

To formulize the PPS construction in DEA, consider a set of n DMUs with a pair of non-negative input and output vectors [(x_j , y_j), j= 1,2,…,n]. Each unit DMU$_j$ ($j \in J$) uses i=1,2,...,m inputs denoted by a vector x_j = (x_{1j},…,x_{mj}) $\in R^m_+$ to produce r = 1,2,…,s outputs denoted by a vector y_j = (y_{1j},……y_{sj}) $\in R^s_+$. The production possibility set is denoted by T and can be represented by set:

$T = \{(x, y) \in R^{m+s} \mid x \text{ can produce } y\}$.

The comparison of each DMU with the efficient boundary (frontier) of T determines the efficiency of that DMU.

Figure 4.2 shows a PPS in two dimensions for the single input and single output case constructed by the convex combination of the observed input-output correspondences. The boundary ABED is the efficient frontier and all the DMUs on it are Pareto-efficient[24]. PPS is determined by the area on and below the efficient boundary of the frontier. The name “Data Envelopment Analysis” has been derived from this property of efficient frontier because in mathematical terminology, such a frontier is said to “envelop” all the points that lie either on or below it.

Unit C lies below the efficient frontier ABED and thus is relatively inefficient unit as compared to the observed units A, B, D, E and hypothetical unit C1 located on the efficient boundary. The hypothetical unit C1 is produced through interpolation between units A and B that can produce same amount of output as unit C by using less amount of input and thus can serve as target for unit C.

[24] A DMU is Pareto efficient if and only if it is not possible to improve any of its inputs or outputs without worsening some of its other inputs or outputs (Cooper et al., 2011).

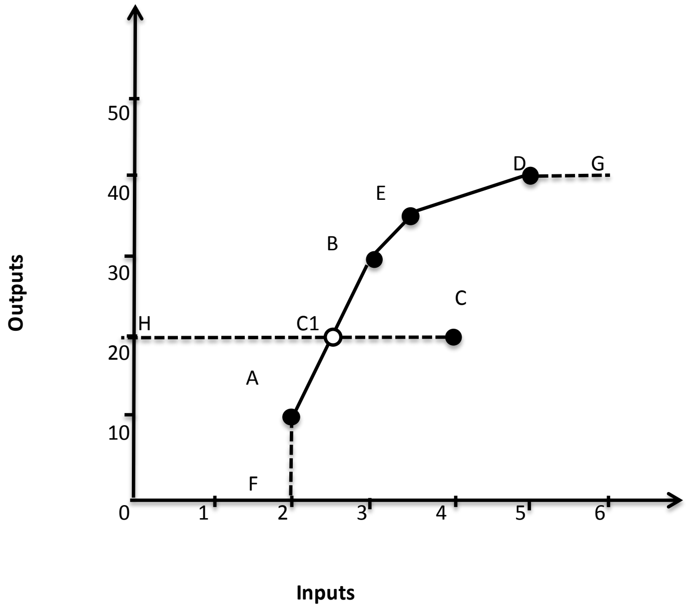


Figure 4. 2 Illustration of production possibility set

4.3.3. Axioms of Production Possibility Set

The production possibility set in DEA is characterized by the following five production axioms (Banker et al., 1984, Thanassoulis, 2003).

Axiom 4.1. Feasibility of Observed Data / Inclusion of Observation

This axiom states that all the observed DMUs are included in the feasible PPS, i.e. $(x_j , y_j) \in T$ for all $j = 1,2,\ldots,n$.

Axiom 4.2. Convexity

If $(x , y) \in T$ and $(x', y') \in T$ then $(\lambda x+(1-\lambda)x', \lambda y+ (1-\lambda)y') \in T$ for all $\lambda \in (0, 1)$.

Axiom 4.3. Monotonicity of Technology / Inefficient Production

This axiom means that any extra amount of input or output can be removed at no cost or in other words it is possible to produce more output with fewer resources. This axiom is also known as free disposability and can be expressed as follows.

a. Free Disposability of Inputs

If $(x', y') \in T$ and $x \geq x'$ then $(x, y') \in T$. In this expression $x \geq x'$ represents that at least one element of x is greater than corresponding element x′.

b. Free Disposability of Outputs

If $(x', y') \in T$ and $y' \geq y \geq 0$ then $(x', y) \in T$.

c. No Output Can be Produced Without Some Inputs

$(x', 0) \in T$; but if $y' > 0$ then $(0, y') \notin T$.

Axiom 4.4. Minimum Extrapolation or Closedness

T is the intersection (smallest) of all sets satisfying Axioms 4.1-4.3.

DEA models are generally categorized into two major production technologies named constant returns to scale (CRS) and variable returns to scale (VRS) on the basis of economic concept of returns to scale (explained in detail in section 4.3.5). Constant returns to scale is based on the original DEA model proposed by Charnes, Cooper and Rhodes (1978) and called CCR model. CCR model was modified by Banker, Charnes and Cooper (1984) into variable returns to scale model (VRS) called BCC[25] model. Axioms 4.1 to 4.4 define the PPS under VRS technology. For constructing PPS under CRS technology Axiom 4.5 is required in addition to the axioms representing VRS technology. This additional axiom is called the proportionality or constant returns to scale axiom which is mentioned as "Ray Unboundedness" in Banker et al. (1984).

Axiom 4.5. Ray Unboundedness

If $(x, y) \in T$, then $(kx, ky) \in T$ for any $k \geq 0$.

PPS for CRS and VRS technology are presented in Figure 4.3. This figure shows that PPS presented in Figure 4.2 is actually constructed under the VRS technology. Frontier in VRS is linear piecewise that has a convex shape and has already been

[25] Named after Banker Charnes and Cooper.

discussed in section 4.3.2. The efficient frontier for CRS technology is represented by the ray OBEM which is passing through the origin. PPS boundary under CRS technology is in the linear form and starting from the origin which is different from the efficient frontier ABED constructed for VRS technology. PPS in CRS technology consists of the set of all the units located on or below the ray OBEM. According to CRS assumption, DMUs B and E are efficient units that are located on the efficient frontier whereas DMUs A, C and D are inefficient units. For inefficient unit C, the efficient target is now hypothetical unit C2 that lies on the CRS efficient frontier.

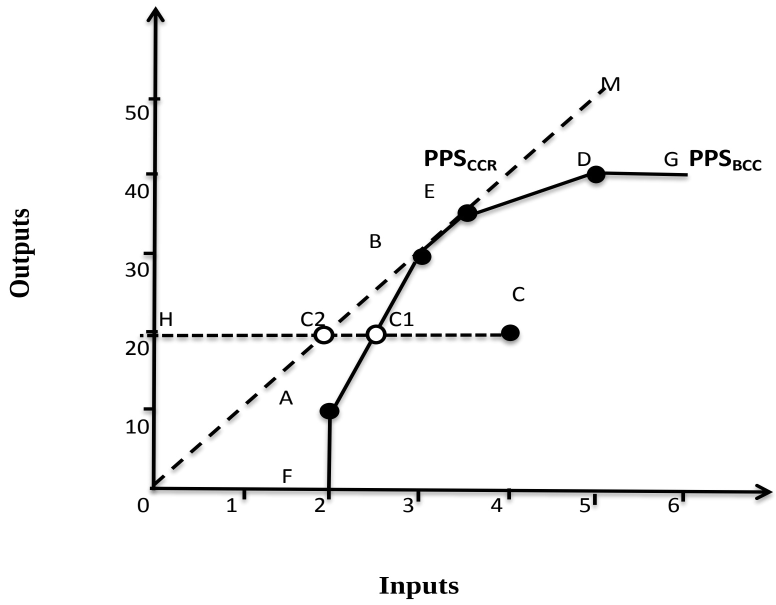


Figure 4. 3 Illustration of production possibility set under CRS and VRS

4.3.4. Technical Efficiency

Once a production frontier is estimated, the technical efficiency of a DMU can be calculated. Technical efficiency is based on the fundamental work of Farrell (1957) and is referred as "Farrell measure of efficiency". Farrell (1957) defined technical efficiency as *"the degree to which a decision making unit produces the maximum feasible output from a given bundle of inputs, or uses the minimum feasible amount of* *inputs to produce a given level of output".* Based on this concept, technical efficiency can be measured as technical input efficiency (minimize inputs for a given output level) or technical output efficiency (maximize output with given inputs). For example, in Figure 4.2 the input technical efficiency of unit C represents the deviation of C's input from the minimum input, which produces the output level equal to C (the corresponding point C1 on the efficient frontier) and is calculated as:

Technical Input Efficiency of DMU C = $\frac{\text{Efficient Input}}{\text{Observed input}} = \frac{HC1}{HC}$

4.3.5. Returns to Scale (RTS)

The notion of returns to scale (RTS) represents "*the measurement of increase in the output relative to a proportional increase in all inputs, evaluated as marginal changes at a point in input-output space*" (Førsund and Hjalmarsson, 2004). In economics literature three kinds of RTS have been identified; constant returns to scale (CRS), increasing returns to scale (IRS) and decreasing returns to scale (DRS). A production correspondence is considered to exhibit CRS if an increase in input level results in the proportional increase in output level. RTS is considered IRS if increase in input brings about more than proportional increase in output, whereas RTS is DRS if proportional increase in input brings about less than proportional increase in output.

For example, if the input of a DMU increases by 10%, the resulting increase in output level would be the deciding factor. If a proportional increase of 10% in output is observed then production technology holds CRS at that unit. In graphical representation the tangent hyperplane to the frontier at that point passes through the origin (Banker et al., 1984, Read, 1998).

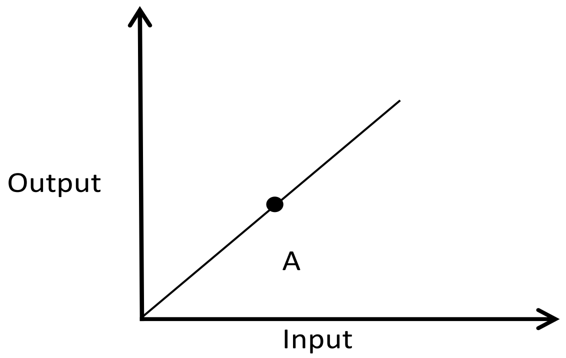


Figure 4. 4 Constant returns to scale

If an increase of 10% in input leads to an increase of more than 10% in output, then frontier at that point exhibits IRS. This is equivalent to the tangent hyperplane at that frontier point having a negative intersection on the output axis. This is illustrated in the figure below.

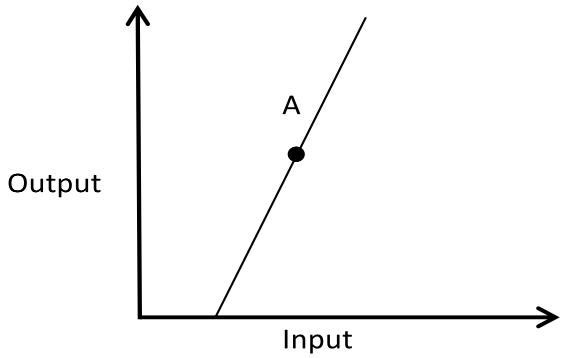


Figure 4. 5 Increasing returns to scale

In contrast, if an increase of 10% in input leads to an increase of less than 10% in output, the production technology exhibits DRS and the tangent hyperplane at that frontier point has a positive intersection with the output axis.

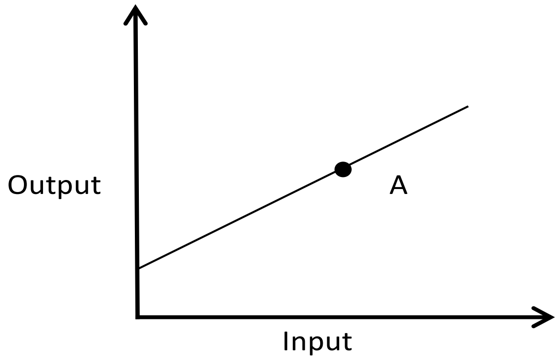


Figure 4. 6 Decreasing returns to scale

The term variable returns to scale (VRS) is commonly used to describe any frontier that does not hold CRS. However, VRS production technology not only allows DMUs to operate at IRS and DRS but also at CRS. Figures 4.4, 4.5, and 4.6 represent frontiers exhibiting CRS, IRS, and DRS globally. However, it is possible for a frontier to exhibit these properties locally as shown in Figure 4.2. In this figure, segment AB on the frontier exhibits IRS, segment BE exhibits CRS and segment ED exhibits DRS.

4.4. Efficiency Measurement with DEA

Data Envelopment Analysis is a data oriented linear programming algorithm (Charnes et al., 1978, Banker et al., 1984) where the efficient frontier is approximated in a non-parametric way for estimating the efficiency of DMUs with respect to multiple inputs and outputs without taking into account their market prices (Charnes et al., 1981).

DEA involves the construction of non-parametric piece wise frontier (also called efficient frontier) that envelops all the observed units. Efficiency of DMUs is measured relative to that efficient frontier by either reducing inputs or increasing outputs with a simple restriction that all the DMUs are located on or below it. Any deviation from the efficient frontier is treated as inefficiency. Each DMU that is not on the frontier (termed as inefficient DMU) is scaled against a linear or convex combination of DMUs located closed to it on the frontier. For each inefficient unit, DEA determines the inefficiency level of each input and output. Best performer is assigned an efficiency score of 1 whereas the rest of the DMUs are assigned a score between 0 and 1.

In DEA based analysis, a set of linear programs is solved to determine; (1) the optimal efficiency score of each DMU, (2) the target values for inputs and outputs of inefficient units to reach the efficient frontier and (3) a reference set of comparable efficient units. One important characteristic of DEA is that it provides a single measure of efficiency while dealing with multiple inputs and outputs without *a priori* underlying functional form assumption.

The efficient frontier in DEA is characterized by two alternative approaches: output oriented (output maximization) and input-oriented (input minimization). Under input oriented model, the objective is to evaluate by how much inputs can be reduced while keeping at least the present output levels. Alternatively, under output oriented model the objective is to increase the output levels while maintaining the current input levels. Both these concepts with one input and one output are presented in Figure 4.7. In this figure DMU A, B, D, and E are efficient, whereas DMU C is inefficient. DMU C can be projected on the efficient frontier in two fundamental directions termed as input oriented and output oriented directions. In input orientation, DMU C is projected at point C1 by reducing its input while keeping its current output level. On the other hand, under output-oriented DEA, its output is augmented to project it at point C2 on the efficient frontier without changing input level.

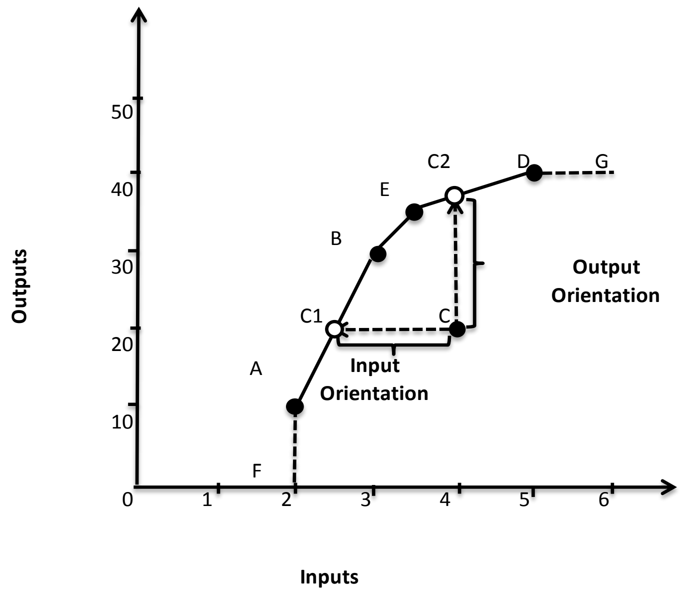


Figure 4. 7 Illustration of input orientation and output orientation with one input and one output

4.5. Envelopment DEA Models

In addition to two orientations introduced in the previous section, there are two major contexts in which efficiency of DMUs using DEA is measured. The first context is production based and called envelopment models. This name reflects the fact that such models measure the DEA efficiency with reference to a production possibility set (PPS) boundary that envelops the input and output levels observed at DMUs comprising the data set as depicted in Figures 4.2, 4.3 and 4.7. The second context is value-based and measures efficiency by implicitly assigning values to inputs and outputs and is referred as *multiplier model.* The original CCR DEA model proposed by Charnes et al. (1978) was transformed into linear programming models in both multiplier and envelopment forms.

DEA models also differ in terms of RTS consideration. The original CCR model assumes CRS technology that allows DMUs to be scaled up and down as mentioned in the Axiom 4.5. Just like real DMUs, scaled unit is also a member of the PPS under CRS. This model was modified by Banker et al. (1984), who named this model as BCC model, which assumed the VRS technology. VRS allows a DMU to be compared with other DMUs of the same size (Coelli et al., 2005). The assumptions regarding the PPS of both technologies have already been discussed in section 4.3.3. The next section describes both CRS and VRS technologies in the context of envelopment model.

4.5.1. CRS and VRS Envelopment Models

For formulating CRS and VRS envelopment models consider a set of n DMUs [j= 1,2,…, j_0,…,n] with a pair of non-negative input and output vectors (x_j , y_j). DMU $_{j0}$ represents the DMU under evaluation. Each unit DMU$_j$ ($j \in J$) uses i=1,2,…,m inputs denoted by a vector $x_j = (x_{1j},\ldots,x_{mj}) \in R^m_+$ to produce r = 1,2,…,s outputs denoted by a vector $y_j = (y_{1j},\ldots,y_{sj}) \in R^s_+$. Table 4.1 presents envelopment DEA models for any observed DMU with output orientation (Model 4.1) and input orientation (Model 4.2) under CRS consideration.

Table 4. 1 CRS envelopment DEA models

Output Oriented CRS Envelopment Model			**Input Oriented CRS Envelopment Model**		
$\phi^* =$Max ϕ		(4.1.1)	θ^*= Min θ		(4.2.1)
Subject to:			Subject to:		
$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{ij0}$	i=1,2,...,m	(4.1.2)	$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{ij0}$	i=1,2,...,m	(4.2.2)
$\sum_{j=1}^{n} \lambda_j y_{rj} \geq \phi y_{rj0}$	r=1,2,...,s	(4.1.3)	$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rj0}$	r=1,2,...,s	(4.2.3)
$\lambda_j \geq 0$	j=1,2,…,n	(4.1.4)	$\lambda_j \geq 0$	j=1,2,…,n	(4.2.4)
ϕ Sign free		(4.1.5)	θ Sign free		(4.2.5)

In Models 4.1 and 4.2 DMU_0 represents one of the *n* DMUs under evaluation, x_{i0} and y_{r0} are the *i*th input and *r*th output for DMU_0 respectively. The Greek letter ϕ in Model 4.1.1 is the output improvement factor and its value is always greater than or equal to 1 i.e. $1 \leq \phi \leq \infty$. On the other hand, θ in Model 4.2.1 is the input minimization factor and its value lies between 0 and 1 i.e. $0 \leq \theta \leq 1$. Under the output orientation, the output level of DMU_0 is improved by the maximum possible ϕ or optimal ϕ^* whereas, in input orientation, its input level is reduced by minimum possible θ or optimal θ^* in order to project it on the efficient frontier. Both output oriented Model (4.1) and input oriented Model (4.2) are repeated for every DMU in the data set to find out the efficient and inefficient DMUs. The envelopment model can be interpreted as follows (Zhu, 2009).

1. Technical efficiency of DMU_0 in output orientation is measured by taking the reciprocal of ϕ^* ($1/\phi^*$) whereas in input orientation the value of θ^* represents the technical efficiency.
2. If $\theta^*=1$ or $\phi^*=1$ then DMU under evaluation is a frontier point or in other words is radially efficient (but not Pareto-efficient[26]). However, if $\phi^* > 1$ or $\theta^* < 1$ then DMU under evaluation is inefficient and requires improving either its output level or reduce its input level.
3. The left hand sides of Models 4.1 and 4.2 are usually called composite unit whereas the right hand side of these models represents a specific DMU under evaluation. The DMUs with non-zero optimal λ_j^* in the composite unit act as "reference set" or efficient targets for the specific DMU under evaluation. The reference set provides values for coefficients λ_j^* to define the hypothetically efficient DMU. The reference

[26] To be Pareto-efficient, a DMU must be technically efficient with zero slack variables. This concept is explained in section 4.5.3.

set presents how much output can be increased (ϕ^*) or input decreased (θ^*) for the DMU under evaluation to be efficient.

However, the assumption of proportionality is not always appropriate in real life context, particularly, when quality of products and services is involved in the evaluation. Moreover, this assumption of returns to scale is frequently discussed in relation to the scale of operations exhibited by DMUs. According to Coelli et al. (2005) *"CRS assumption is appropriate when all firms are operating at an optimal scale. The use of CRS specification when not all firms are operating at the optimal scale, results in measures of technical efficiency that are confounded by scale efficiencies"*.

Table 4.2 shows mathematical formulation for VRS envelopment models with output and input orientations.

Table 4. 2 VRS envelopment DEA models

Output Oriented VRS Envelopment Model			Input Oriented VRS Envelopment Model		
ϕ^*=Max ϕ		(4.3.1)	θ^*= Min θ		(4.4.1)
Subject to:			Subject to:		
$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{ij0}$	i=1,2,...,m	(4.3.2)	$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{ij0}$	i=1,2,...,m	(4.4.2)
$\sum_{j=1}^{n} \lambda_j y_{rj} \geq \phi y_{rj0}$	r=1,2,...,s	(4.3.3)	$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rj0}$	r=1,2,...,s	(4.4.3)
$\sum_{j=1}^{n} \lambda_j = 1$		(4.3.4)	$\sum_{j=1}^{n} \lambda_j = 1$		(4.4.4)
$\lambda_j \geq 0$	$j=1,2,\dots,j_0,\dots,n$	(4.3.5)	$\lambda_j \geq 0$	$j=1,2,\dots,j_0,\dots,n$	(4.4.5)
ϕ Sign free		(4.3.6)	θ Sign free		(4.4.6)

Theoretically, the sole difference in VRS and CRS envelopment models is the addition of convexity constraint $\sum_{j=1}^{n} \lambda_j =1$ in VRS Model added as 4.3.4 and 4.4.4 in output oriented and input oriented VRS models respectively.

The input oriented and output oriented efficiency scores are equal under CRS technology whereas, VRS technology generates different efficiency scores under input orientation and output orientation (Färe and Lovell, 1978). Moreover, efficiency scores of a DMU evaluated under CRS technology are always less than or equal to efficiency scores obtained under VRS technology. This is due to the fact that the distance of an inefficient DMU from the frontier is longer under CRS because CRS frontier does not envelops data as close as VRS frontier does as shown in Figure 4.3. Moreover, the discrimination of the CRS model is better than the VRS model as the smaller number of units is identified as efficient.

4.5.2. Technical, Pure Technical and Scale Efficiency

The basic concept of efficiency is called technical efficiency. It is based on the fundamental work of Farrell (1957) and is already explained in section 4.3.4. Technical efficiency can be further decomposed in to two components; pure technical efficiency and scale efficiency.

Technical Efficiency (TE) = Pure Technical Efficiency (PTE) $\times$ Scale Efficiency (SE).

In general, the use of the term technical efficiency refers to CRS efficiency scores because it does not account for scale effect. If the scale effect is eliminated from the technical efficiency, this becomes *pure technical efficiency*, a form in which normally, the efficiency scores of BCC model are described. *Scale efficiency* measures the impact of scale size on the production of a DMU (Thanassoulis, 2003).

According to CCR model it is postulated that radial expansion and contraction of all the observed DMUs and their non-negative combinations are possible therefore CCR score is called global technical efficiency. On the other hand, BCC model assumes the convex combinations of the observed DMUs (convexity constraint in axiom of PPS) so BCC score is referred as local pure technical efficiency. If a DMU is fully efficient in both CCR and BCC models then it is operating at *Most Productive Scale Size* (MPSS). If a DMU is fully efficient under BCC model and has lower score under CCR model then such DMU is considered efficient locally and not globally due to its scale size.

So, it is reasonable to measure the scale efficiency by the ratio of CCR to BCC model scores (Cooper et al., 2000). If we represent input oriented CCR and BCC scores of a DMU by θ^*_{CCR} *and* θ^*_{BCC}, respectively then scale efficiency is defined as:

$$\text{Scale Efficiency (SE)} = \theta^*_{CCR} \big/ \theta^*_{BCC} \, .$$

Scale efficiency is always less than or equal to one i.e. SE ≤ 1. As the efficiency scores of CRS technology are less than VRS technology (discussed in the previous section) therefore we can write this relationship in the following form:

$$TE_{CRS} = TE_{VRS} \times SE \, .$$

4.5.3. Mix Inefficiency

Generally, two kinds of inefficiencies exist in efficiency measurement through DEA. The first kind of inefficiency is referred as *technical inefficiency* and the second is called *mix inefficiency*. *Technical inefficiency* is the proportion of inefficiency, which is present in all the outputs (or inputs) that can be eliminated without changing the existing proportions of outputs (or inputs). On the other hand, mix inefficiency is the type of inefficiency that exists when only some but not all outputs (or inputs) exhibit inefficient behaviour. This kind of inefficiency cannot be eliminated without altering the proportion in which outputs are produced (or inputs are utilized) (Cooper et al., 2000). In terms of efficiency scores, an inefficient DMU is quickly identified because an inefficient DMU has the efficiency score less than one. On the other hand, a DMU having efficiency score equal to one, is radially efficient but may exhibit mix inefficiency. In DEA terminology such a DMU is not Pareto-efficient. Thus, an efficiency score of 1 does not always guarantee that a DMU is fully efficient (i.e. efficient in Pareto sense) as according to Pareto-Koopmans efficiency "A DMU is fully efficient (100%) if and only if it is not possible to improve any of its inputs or outputs without worsening some of its other inputs or outputs" (Cooper et al., 2011).

To illustrate the concept of mix inefficiency we consider Figure 4.8 showing five DMUs A, B, C, D and E with two outputs and one input. The efficient frontier consists of piece wise linear combination of points G, E, D, B, A, and F. The production possibility set is the region bounded by the axes and the frontier line. The Pareto efficient frontier[27] according to this data consists of points ABD. The piece wise linear form of the frontier DEG and AF can cause a few problems in the efficiency measurement because these sections of the frontier are parallel to the axes.

[27] Pareto efficient frontier is the set of points/DMUs that are Pareto efficient.

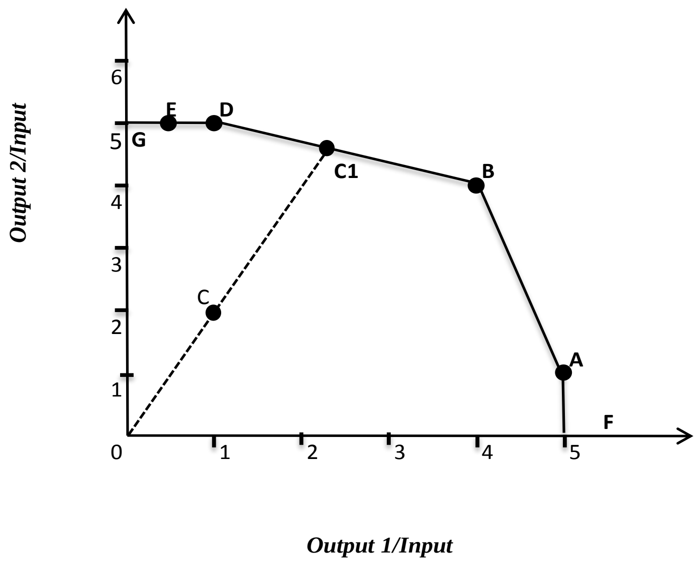


Figure 4. 8 Illustration of mix inefficiency

In this figure DMUs A, B, and D are efficient, whereas DMU C is inefficient. Now we have to find out whether DMU E is efficient or not. The observed DMU E lies on the segment GD of the frontier boundary, which is parallel to X-axis. The unit E produces same level of output 2, but less of output 1 than unit D by consuming same level of input. This difference of 0.5 between output 1 of DMU D and DMU E is called output slack in literature. Some authors argue that Farrell measure of efficiency (ϕ^* and θ^*) and non-zero input or output slacks are an indication of technical efficiency of a firm in DEA analysis (Coelli et al., 2005). However, according to Koopmans (1951) definition of technical efficiency "*a firm is only efficient if it operates on the frontier and furthermore all associated slacks are zero".* This represents that Koopmans (1951) definition of technical efficiency is stricter than Farrell (1957) definition. DMU E is efficient according to Farrell's definition but inefficient according to Koopmans definition of technical efficiency because, it is located on the frontier but has a slack of 0.5 in output 1. Moreover, DMU D dominates DMU E. Thus, DMU E has mix inefficiency because only output 1 exhibits inefficient behaviour that cannot be eliminated without altering the proportion of outputs.

Whether a DMU exhibits mix inefficiency or not, can be tested by solving an additional linear program called the second stage optimization and the computation proceeds in two stages. At the first stage, the normal linear programming Model 4.3 for output orientation (i.e. output maximization) and Model 4.4 for input orientation (i.e. input reduction) under VRS consideration are solved to get optimal ϕ^* and θ^*respectively.Then at the second stage, the optimal scores of the first stage are used in constraints 4.5.3 for output orientation and 4.6.2 for input orientation to find out output and input slacks respectively. Output and input slacks are abbreviated as s^+ and s^- respectively. Output slack (s^+) has superscript positive sign because this slack needs to be increased and input slack (s^-) has superscript negative sign because this slack needs to be reduced. The non-zero slacks and /or the value of ϕ^* >1 and θ^* <1 identify the sources and amounts of inefficiency exhibited by each output and input of the DMU being evaluated.

The second stage optimization models for testing mix inefficiencies under VRS considerations are given in the Table 4.3 for both output orientation and input orientation.

Table 4. 3 The second stage VRS envelopment DEA models for testing mix inefficiency

Output Oriented VRS Envelopment Model			**Input Oriented VRS Envelopment Model**		
Max $\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$		(4.5.1)	Max $\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$		(4.6.1)
Subject to:			Subject to:		
$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{ij0}$	i=1,2,...,m	(4.5.2)	$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{ij0}$	i=1,2,...,m	(4.6.2)
$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = \phi y_{ij0}$	r=1,2,...,s	(4.5.3)	$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rj0}$	r=1,2,...,s	(4.6.3)
$\sum_{j=1}^{n} \lambda_j = 1$		(4.5.4)	$\sum_{j=1}^{n} \lambda_j = 1$	j=1,2,…,n	(4.6.4)
$\lambda_j \geq 0$	j=1,2,…,n	(4.5.5)	$\lambda_j \geq 0$		(4.6.5)
ϕ Sign free		(4.5.6)	θ Sign free		(4.6.6)
$s_i^-, s_r^+ \geq 0$ for any i and r		(4.5.7)	$s_i^-, s_r^+ \geq 0$ for any i and r		(4.6.7)

The second stage CRS models for testing mix inefficiency with output and input orientations are similar to VRS models except they do not have convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ presented in Models 4.5.4 and 4.6.4. A DMU is fully efficient with output orientation if and only if the following two conditions are satisfied (Cooper et al., 2011):

(i) The first stage optimal solution to Model 4.3 is 1 i.e. (ϕ^* =1).

(ii) The second stage optimal solution to Model 4.5 is 0 (s^- = 0 and s^+ = 0 for all i and r).

If we check these conditions for DMU E the first stage solution of Model 4.3 is 1 however at the second stage there is an output slack of 0.5 (s^{+}= 0.5) in output 1. The same results are generated for CRS technology.

Similarly, a DMU must fulfil the following two conditions to be fully efficient with input orientation:

(i) The first stage solution of Model 4.4 should be 1 (θ^{*}=1).

(ii) The second stage optimization solution of Model 4.6 should be 0 (s^{-} 0 and s^{+} = 0 for all i and r).

In DEA terminology both these conditions are referred as “Koopmans” or “strong” efficiency (Cooper et al., 2000). However, if the efficiency at the first stage in the DEA evaluation is equal to 1 whereas, the input or output slack is not equal to zero then the DMU exhibits mix inefficiency which cannot be eliminated without changing the existing proportion of inputs or outputs respectively. Such a DMU is termed as weakly efficient. The same interpretation is valid for CRS technology.

4.6. Multiplier DEA Models

The original model introduced by Charnes et al. (1978) to measure the relative efficiency of DMUs, was in the ratio form and expressed as the ratio of weighted combination of outputs (virtual outputs) to weighted combination of inputs (virtual inputs). When this ratio of single virtual output to virtual input for a particular DMU is translated into linear programming model, it is known as multiplier model (value based model). In mathematical programming parlance this ratio, which is to be maximized, forms the objective function for the specific DMU being evaluated. Symbolically this ratio form led to the following fractional programming problem for DMU_0.

Maximize $h_0\,(u,v) = \frac{\sum_{r=1}^{s} u_r y_{rj0}}{\sum_{i=1}^{m} v_i x_{ij0}}$

Subject to:

$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \qquad (j = 1,2,\ldots,n).$

$u_r \geq 0 \qquad (r = 1,2,\ldots,s).$

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

This ratio form generates infinite number of solutions; if (u^*, v^*) is optimal then $(\alpha u^*, \alpha v^*)$ is also optimal for all α >0. Moreover, this form cannot be used in actual computation due to its non-linearity and non-convexity. However, Charnes and Cooper (1962) led to the specific solution for the transformation of this fractional form into an equivalent linear programming problem that formed the basis for the linear programming model of Charnes, Cooper and Rhodes CCR model (Cooper et al., 2011).

Multiplier DEA form is the dual of envelopment DEA form and both these forms generate same efficiency scores for a unit under assessment however, their interpretations are quite different. The envelopment DEA models measure the efficiency of a DMU based on the efficient frontier that helps to calculate the efficiency scores along with the identification of efficient targets and peers for inefficient DMUs. These models have a technological meaning of efficiency in the form of improvement factor for inputs and outputs. On the other hand, multiplier models measure the efficiency of a DMU as the ratio of total imputed value of its output levels to the total imputed value of its input levels (Thanassoulis, 2003). These models can provide us information about the areas of good and bad performance on the basis of the weights assigned to the inputs and outputs by the formulated problem. Multiplier forms have more of a managerial meaning as the relative position of the

DMU is measured in relation to other DMUs assuming the most favourable weights of inputs and outputs (Podinovski, 2007a).

4.6.1. CRS and VRS Multiplier Models

The original multiplier model introduced by Charnes et al. (1978) was CCR model that assumed CRS therefore we start with the CRS multiplier formulation first. The mathematical formulation of multiplier models for CRS technology with output and input orientations has been given in Models 4.7 and 4.8 respectively in Table 4.4. These are dual linear programming models of Models 4.1 and 4.2. Vectors u and v represent the output and input weights (multipliers) or shadow prices respectively. These are the dual variables of the constraints 4.1.2 and 4.1.3 in output orientation and 4.2.2 and 4.2.3 in input orientation.

Table 4. 4 CRS multiplier DEA models

Output Oriented CRS Multiplier Model	Input Oriented CRS Multiplier Model
Min $\sum_{i=1}^{m} v_i\, x_{ij0}$	Max $\sum_{r=1}^{s} u_r\, y_{rj0}$
Subject to: (4.7)	Subject to: (4.8)
$\sum_{r=1}^{s} u_r\, y_{rj0} = 1$	$\sum_{i=1}^{m} v_i\, x_{ij0} = 1$
$\sum_{r=1}^{s} u_r\, y_{rj} - \sum_{i=1}^{m} v_i\, x_{ij} \le 0$	$\sum_{r=1}^{s} u_r\, y_{rj} - \sum_{i=1}^{m} v_i\, x_{ij} \le 0$
$j=1,2,\ldots,j_0,\ldots,n$	$j=1,2,\ldots,j_0,\ldots,n$
$u_r \ge 0$ $r=1,2,\ldots,s$	$u_r \ge 0$ $r=1,2,\ldots,s$
$v_i \ge 0$ $i=1,2,\ldots,m$	$v_i \ge 0$ $i=1,2,\ldots,m$

The multiplier models under VRS technology for output orientation and input orientation are provided in Table 4.5 in the form of Models 4.9 and 4.10 respectively. Model 4.9 is the dual of Model 4.3 for output orientation whereas Model 4.10 is the dual of Model 4.4 for input orientation. These multiplier VRS models include an additional free variable u_0 which is the dual variable corresponding to the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ of envelopment models. The value of this free variable reflects the scale size impact on the productivity of a DMU (Banker et al., 1984, Banker and Thrall, 1992) as explained in section 4.8 of this chapter.

Table 4. 5 VRS multiplier DEA models

Output Oriented VRS Multiplier Model		**Input Oriented VRS Multiplier Model**	
Min $\sum_{i=1}^{m} v_i\, x_{ij0} + u_0$		Max $\sum_{r=1}^{s} u_r\, y_{rj0} + u_0$	
Subject to:		Subject to:	
$\sum_{r=1}^{s} u_r\, y_{rj0} = 1$	(4.9)	$\sum_{i=1}^{m} v_i\, x_{ij0} = 1$	(4.10)
$\sum_{r=1}^{s} u_r\, y_{rj} - \sum_{i=1}^{m} v_i\, x_{ij} - u_0 \le 0$		$\sum_{r=1}^{s} u_r\, y_{rj} - \sum_{i=1}^{m} v_i\, x_{ij} + u_0 \le 0$	
$u_r \ge 0$	$r=1,2,\ldots,s$	$u_r \ge 0$	$r=1,2,\ldots,s$
$v_i \ge 0$	$i=1,2,\ldots,m$	$v_i \ge 0$	$i=1,2,\ldots,m$
u_0 Sign free		u_0 Sign free	

4.7. Weight Restrictions and Production Trade-Offs in DEA

4.7.1. Weight Restrictions

In standard DEA multiplier model, relative efficiency is calculated by a comparative ratio of the sum of weighted outputs to the sum of weighted inputs for each DMU subject to the condition that this ratio for each DMU should not exceed one. While calculating efficiency, a DMU has complete flexibility to choose weights such that the ratio of sum of weighted outputs to sum of weighted inputs is maximized in order to maximize its efficiency score. This weight flexibility in DEA is obvious in two different ways; first, the assignment of *a priori* value to different weights is not required and second, the same factor is assigned a different weight while calculating the relative efficiency of different DMUs. The advantage of allowing such weight flexibility is that an inefficient DMU is identified with its own set of weights without any doubt about the fairness of weighting structure. Moreover, for each DMU this weight flexibility may help to identify the aspects of good and bad operating practices that could be helpful to improve its performance (Dyson and Thanassoulis, 1988).

However, the total weight flexibility in DEA has some drawbacks as well. The major drawback is the possibility of assigning unrealistic weight profile to DMU/s in the assessment process. This unrealistic weighting structure appears in the form of zero or a negligible weight assigned to some inputs/outputs and is equivalent to neglecting those inputs/outputs from the assessment process. Consequently, the relative efficiency of DMU may not reflect its efficiency on all inputs and outputs because DMU is assessed only on the subset of inputs and outputs representing partial picture of DMUs activities. Such an assessment may lead to two extreme scenarios. First, a certain DMU may be classified as relatively efficient just because its ratio for one output (possibly minor) to one input is the highest as compared to other DMUs while effectively ignoring the rest of the inputs and outputs. Second, the inefficient DMUs may appear even more inefficient merely because those have been assessed only on their worst aspect and comparatively better aspects have been effectively ignored in the assessment (Dyson and Thanassoulis, 1988).

Moreover, the allocation of zero or minimal weight to certain input or output in the production process is against the economic notion of "marginal rate of substitution" [28]

[28] The marginal rate of substitution (MRS) can be defined as, keeping constant the total output, how much should input 1 decrease if input 2 increases by one extra unit or vice versa. In other words, it

indicating that output can be produced without input or input may not produce anything.

Another drawback of weight flexibility in DEA is the poor discriminatory power among DMUs, a situation when DEA awards most of the units with maximum or near maximum efficiency scores (Podinovski and Thanassoulis, 2007). Such a situation arises particularly, where there is a small number of units to assess relative to the number of input and output variables that characterize the activities of DMUs adequately. Moreover, the same problem may be encountered when many units and few input-output variables are involved in the assessment process. That is so, because if some units have unusual mix of input and output variables, then in radial measure of efficiency they would only be compared with each other. However, this problem of poor discrimination may arise even in the presence of many DMUs in comparison to the number of input-output variables particularly, when the assessment technology is VRS and the subset of units exhibit very different scale sizes (Podinovski and Thanassoulis, 2007).

Use of weight restrictions in DEA models, is a traditional way to deal with the problems of weight flexibility. Weight restrictions involve the constraining of input/output weights in DEA models according to some general view of their perceived importance such that the subsequent assessment cannot ignore any input or output and assigns some weights to inputs/outputs. The idea of weight restrictions was introduced by Thompson et al. (1986) who used it initially, for the determination of the best location for establishment of a physics laboratory. They argued that it is necessary to put some restrictions on factors weights reflecting the realistic assessment

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shows the relation between inputs, and the trade-offs amongst them, without changing the level of total output or vice versa.

of DMUs. The efficiency scores obtained after introduction of weight restrictions are less than the efficiency scores obtained with original formulation. Consequently, the number of efficient DMUs reduces while improving discrimination which indicates that higher efficiency scores are obtained as a result of unrealistic weight profile (Podinovski and Thanassoulis, 2007).

Weight restrictions are one of the methods used for incorporating value judgments. Value judgments refer to *a priori* knowledge about production process or recourse to assumptions, which are outside the data and could be added to the assessment of DMUs. Allen et al. (1997) have defined value judgments in the following words:

"Logical constructs, incorporated within an efficiency assessment study, reflecting the preferences of decision makers in the process of assessing efficiency".

They listed a number of reasons that motivated the use of value judgments in DEA such as:

- To incorporate prior views of decision makers on: value of inputs and outputs or inefficient and efficient DMUs
- To relate values of certain inputs and/or outputs
- To estimate the overall efficiency of DMUs
- To preserve the economic notion of input/output substitution
- To increase the discrimination of models.

Different weight restriction approaches have been introduced in DEA literature based on value judgments. The first type of weight restrictions were introduced by Thompson et al. (1986) in the form of "Assurance Region (AR)". This approach was further improved by Thompson et al. (1990). The second method was suggested by Golany (1988) and is called Golany method that was subsequently improved by Ali and Seiford (1993). The third method is called the cone ratio and was introduced by

Charnes et al. (1989) and was used later by Charnes et al. (1990). The fourth method was developed by Wong and Beasley (1990) who suggested to restrict the virtual inputs and/or outputs instead of restricting the actual weights of inputs and outputs. There are some other methods described in the DEA literature and include, facet models (Bessent et al., 1988, Green et al., 1996) and generating unobserved DMUs (Thanassoulis and Allen, 1998). For detailed description of these methods reader is referred to the collective work of Allen et al. (1997), Thanassoulis (2003), and Cook and Seiford (2009).

4.7.2. Problems with Weight Restrictions

Weight restrictions are widely used in DEA models (Dyson and Thanassoulis, 1988, Thompson et al., 1990, Wong and Beasley, 1990, Li et al., 2008) to reduce the unbalanced weight profile and improve the discrimination of the model. Many methods have been suggested to develop weight restrictions (Allen et al., 1997) but these are mainly based on value judgments regarding the perceived importance of inputs and outputs or the monetary considerations derived from input costs or output prices. The effect of incorporating weight restrictions in DEA model is clear algebraically, but their practical meanings in managerial, economic and technological terms are somewhat vague. An established drawback of this method is that the envelopment form of DEA becomes distorted and efficiency measures lose their economic and technological meanings (Allen et al., 1997). This ambiguity not only arises in practical terms but also experienced while interpreting efficiency results. The major reason behind these ambiguities is the use of weight restrictions without linking them to technological realities of production process under consideration. Efficiency results without weight restrictions characterize the radial improvement of inputs (in input orientation case) and outputs (in output orientation case) where DMU under consideration remains feasible. This radial nature of efficiency and feasibility of DMU is no longer observed in case of models with weight restrictions (Allen et al., 1997, Thanassoulis and Allen, 1998). Therefore, with the use of weight restrictions, the problem of poor discrimination is transformed to the problem of interpreting analysis results (Podinovski, 2002).

4.7.3. Production Trade-Offs

To overcome the drawbacks associated with weight restrictions and improve the discrimination in DEA model, Podinovski (2004) introduced the idea of *"production trade-offs"* through "*the trade-off approach"*. Production trade-off represents "*simultaneous changes in inputs and/or outputs that are possible in technology under consideration*". Production trade-offs enrich the standard CRS and VRS DEA models by incorporating additional technological judgments related to the production process. Unlike weight restrictions, the trade-off approach preserves the technological meaning of efficiency as technologically realistic radial improvement factor for inputs and outputs and efficient targets of inefficient units are always feasible and producible. This fact was proved by Podinovski (2004) as the *fundamental theorem of weight restrictions*. The resulting model provides better discrimination between efficient and inefficient DMUs because, production trade-offs are an outcome of technological thinking based on technological realities and not a result of value thinking based on the perceived importance and monetary considerations of inputs and outputs.

The incorporation of production trade-offs in DEA model expands the production technology by adding additional information of logical nature. PPS generated through the use of standard DEA model may not include all the producible production points because, the PPS generated by DEA is only the subset of PPS with production trade-offs (as shown in Figure 4.9).

In the trade-off approach, the technological judgments can be incorporated either as production trade-offs in the envelopment form or as weight restrictions in the dual multiplier form. The mathematical effect of incorporating these judgments in both forms (envelopment and multiplier) is the same. The more natural way of trade-offs incorporation is in envelopment form where these are added as additional terms in the existing composite units. One practical problem of this method is that standard DEA software does not support production trade-offs implementation. However, the general linear programming optimizers are perfectly suitable for this purpose.

For incorporation in the multiplier form, production trade-offs are translated into equivalent linear weight restrictions and then added as a new constraint in the multiplier model. This method of constructing weight restrictions still falls under the umbrella of general trade-off approach (Podinovski, 2004) because instead of allowing DEA technology to automatically calculate and assign values to multipliers in the multiplier model, it allows users to define an acceptable range of multipliers values for a pair of relevant variables (input/output) based on the technological thinking (Podinovski, 2004). This construction of weight restrictions not only conveys new technology information but also complements the information contained in the set of observed DMUs. Trade-offs translated into weight restrictions can easily be used in any standard DEA software that supports efficiency computations with weight restrictions.

It is important to clarify here that the notion of production trade-offs is completely different from the concept of marginal rate of substitution used in production economics. Marginal rates of substitution are only applicable to units located on the efficient boundary of PPS and are generally different for each unit. Conversely, same trade-off can be defined and applied to all units whether efficient or inefficient.

Moreover, trade-offs are formulated in a conservative, relaxed, undemanding and cautious way which make them valid and equally applicable for all units in the technology (Podinovski, 2005).

Production trade-offs naturally exist in almost every real production technology and can be identified easily in most of the cases. To illustrate that how production trade-offs expand the PPS meaningfully we have considered an example of hypothetical banks which only use deposits to create loans and investments as shown in Table 4.6 (suppose data are in million £.). PPS for this data under VRS is plotted by taking loans/deposits on X-axis and investments/deposits on Y-axis in Figure 4.9.

Table 4. 6 Hypothetical data of banks for the development of production trade-offs

Bank	Deposits (Input)	Loans (Output)	Investments (Output)
A	1	5	1
B	1	4	4
C	1	1	2
D	1	1	5

For the development of trade-offs suppose there are two technological judgments that express the relationship between inputs and outputs.

Judgment 4.1*. No extra resources should be claimed, if the amount of loans is reduced by one million, and the amount of investments is increased by one million.*

Judgment 4.2*. No extra resources should be claimed, if the amount of loans is increased by one million, and the amount of investments is decreased by two million.*

These two judgments describe the two-way relationship in the form of production trade-offs between loans and investments. For example, in Judgment 4.1 we assume that it should be possible to increase the amount of investments by any positive number N and to reduce the amount of loans by any positive number N without requiring any extra resource. The effect of Judgment 4.1 and Judgment 4.2 on the PPS using VRS technology is shown in Figure 4.9. Efficient frontier with VRS technology is bounded by EABDF. Production trade-off in the form of Judgment 4.1 expands the VRS technology segment BF up to segment BG by adding new area FBG on the left hand side of the bank B. This new segment is obtained by consecutive replacement of loans with investments from bank B with the ratio of 1:1 until loans become 0. All banks in this new area FBG are producible because these are obtained from the composite bank of VRS technology through the incorporation of technologically realistic trade-offs. Similarly, the incorporation of Judgment 4.2 expands the efficient frontier boundary BE up to BH from bank B by consecutive replacement of two million of investments with one million of loans. With this replacement ratio of 2:1 between investments and loans, PPS expands by adding new area EBH at the right hand side of the bank B within which all the hypothetical banks are technologically feasible and producible.

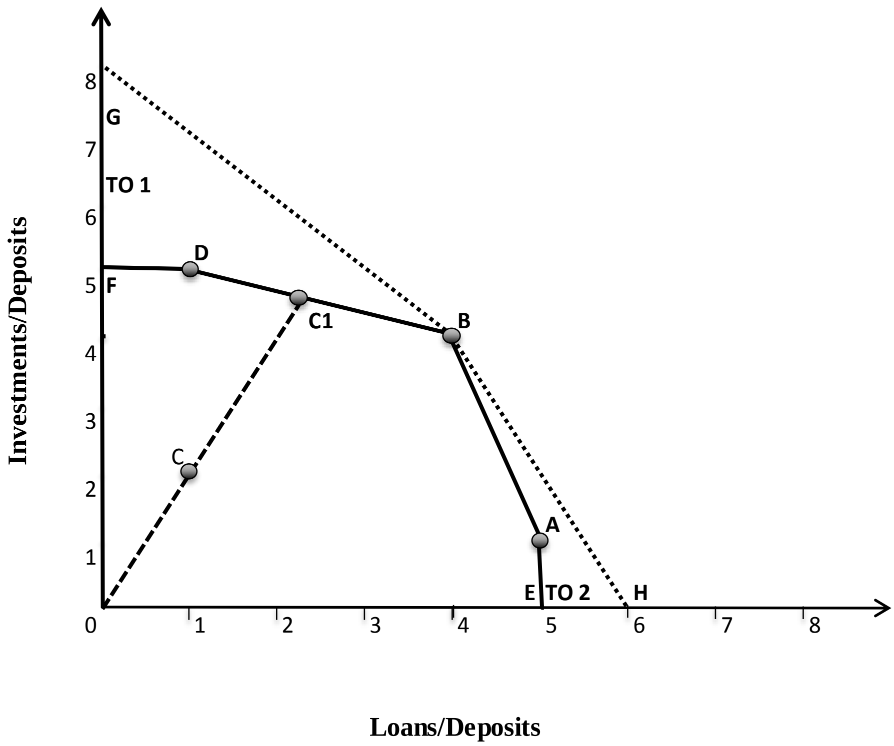

Figure 4. 9 Production possibility set with production trade-offs

One thing is noticeable in Figure 4.9 that the discrimination of the DEA model is improved as a result of deploying production trade-offs in the form of judgment 4.1 and judgment 4.2 because now bank B is the only efficient unit that lies on the efficient frontier which is defined as piecewise linear boundary GBH.

The deployment of production trade-offs in the form of judgment 4.1 and judgment 4.2 in the envelopment DEA model is given in Model 4.11. This model measures the output oriented VRS efficiency of the bank B with the new trade-offs technology.

Model 4.11

Max ϕ (4.11.1)

Subject to:

$1\,\lambda_1 + 1\,\lambda_2 + 1\,\lambda_3 + 1\,\lambda_4 + 0\,\pi_1 + 0\,\pi_2 \le 1$ (4.11.2)

$5\,\lambda_1 + 4\,\lambda_2 + 1\,\lambda_3 + 1\,\lambda_4 - 1\,\pi_1 + 1\,\pi_2 \ge 4\,\phi$ (4.11.3)

$1\,\lambda_1 + 4\,\lambda_2 + 2\,\lambda_3 + 5\,\lambda_4 + 1\,\pi_1 - 2\,\pi_2 \ge 4\,\phi$ (4.11.4)

$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 = 1$ (4.11.5)

$\lambda_1, \lambda_2, \lambda_3, \lambda_4, \pi_1, \pi_2 \ge 0$ (4.11.6)

ϕ Sign free (4.11.7)

On the left hand side of the model, first four terms involving multipliers λs represent composite bank that is feasible in VRS technology and the last two non-negative terms with multipliers π_1 and π_2 modify the composite bank according to the trade-offs in Judgments 4.1 and 4.2 respectively. The model on the left hand side represents new hypothetical banks in the expanded area of the trade-offs that are technologically feasible and producible. The model on the right hand side represents the producible radial target whose both outputs are equal to $4\,\phi$. The Greek letter ϕ represents the technologically realistic radial output expansion factor. Zero value with multiplier π_1 and π_2 in the first inequality means that input is not modified, as we do not have any trade-off judgment related to deposits.

Let us conceptualize changes in PPS as a result of incorporation of production trade-offs. Podinovski (2004) extended Banker et al. (1984) axioms of production technology. Under the VRS technology we have four main Axioms from 4.1-4.4 whereas under the CRS technology an additional production Axiom 4.5 is provided in the section 4.3.3. In case of production trade-offs, we have one additional Axiom 4.6. Axiom 4.4 of closedness needs to be restated explicitly as suggested by Podinovski (2004) so we are providing it again as Axiom 4.7.

As mentioned in section 4.3.2, PPS denoted by T, is the set of input and output vectors (x_j , y_j) such that $x_j \geq 0$ can produce $y_j \geq 0$. Suppose we have K trade-off relationships between inputs and/or outputs of the form (P_t , Q_t) where $t = 1,2,\ldots,K$. Also the vectors $P_t \in R^m$ and $Q_t \in R^s$ represents the trade-offs modifications for inputs and outputs respectively. The vector π_t represents weights corresponding to the modification of the composite units.

Axiom 4.6. Feasibility of Production Trade-Offs.

Let $(x_j , y_j) \in T$. Then, for any trade-off t in the form (P_t , Q_t) and any $\pi_t \geq 0$, the unit $(x_j + \pi_t P_t, y_j + \pi_t Q_t) \in T$, provided $x_j + \pi_t P_t \geq 0$ and $y_j + \pi_t Q_t \geq 0$.

Axiom 4.7. Closedness - Axiom 4.4 Reinforced

The set T is closed.

The Axiom 4.7 states that the set T contains all its limits points. In case of trade-offs this Axiom needs to be stated explicitly because in contrast with the standard DEA CRS and VRS technologies without trade-offs this axiom does not follow from other axioms (Podinovski, 2004).

After providing the illustrative example and extended PPS consideration the general DEA envelopment models under VRS technology with production trade-offs are provided in Table 4.7 under both input and output orientations.

Table 4. 7 VRS envelopment DEA models with production trade-offs

Output Oriented VRS Envelopment Model With Trade-Offs		**Input Oriented VRS Envelopment Model With Trade-Offs**	
Max ϕ	(4.12.1)	Min θ	(4.13.1)
Subject to:		Subject to:	
$\sum_{j=1}^{n} \lambda_j x_{ij} + \sum_{t=1}^{k} \pi_t P_t \leq x_{ij0}$	(4.12.2)	$\sum_{j=1}^{n} \lambda_j x_{ij} + \sum_{t=1}^{k} \pi_t P_t \leq \theta x_{ij0}$	(4.13.2)
$\sum_{j=1}^{n} \lambda_j y_{rj} + \sum_{t=1}^{k} \pi_t Q_t \geq \phi y_{rj0}$	(4.12.3)	$\sum_{j=1}^{n} \lambda_j y_{rj} + \sum_{t=1}^{k} \pi_t Q_t \geq y_{rj0}$	(4.13.3)
$\sum_{j=1}^{n} \lambda_j = 1$	(4.12.4)	$\sum_{j=1}^{n} \lambda_j = 1$	(4.13.4)
$\lambda, \pi \geq 0$	(4.12.5)	$\lambda, \pi \geq 0$	(4.13.5)
ϕ Sign free	(4.12.6)	θ Sign free	(4.13.6)

Two judgments of our illustration in the envelopment model can be expressed in the (P_t , Q_t) form representing inputs and outputs respectively as follows:

$P_1 = (0)$, $Q_1 = (-1, 1)$ (4.14.1)

$P_2 = (0)$, $Q_2 = (1, -2)$ (4.14.2)

Q_1 in 4.14.1 describes the trade-off used in the first judgment and Q_2 (4.14.2) describes the trade-off of the second judgment. In both Q_1 and Q_2 the first number represents the change in loans whereas the second number represents the change in investments as a result of trade-off defined between them. P_1 and P_2 both contain 0 because there is no change in deposits as we have not defined any trade-off for deposits.

As described earlier in this section, production trade-offs can be incorporated in the multiplier model in the form of weight restrictions which is similar to the incorporation of trade-offs in the envelopment model. One main problem associated with the weight restrictions is their unclear economic meaning when converted from multiplier to envelopment form. However, this problem does not arise in case of the trade-off approach because trade-offs based on technological thinking are originally developed in the envelopment form and then translated to equivalent weight restrictions that does not create any ambiguity in the economic meaning and efficiency interpretation of a weight restriction. The only difference is that in the envelopment model trade-offs are added as hypothetical unit to the technology whereas in multiplier model these restrictions are added as an additional constraint in the linear program that reflects the new feasible region (PPS). The new constraint that is added to the multiplier model can be written in the following form.

$a_1u_1 + a_2u_2 - b_1v_1 \leq 0$ (4.15)

In this model a_1 and a_2 represent two outputs whereas b_1 represents one input as we are considering the illustration of two outputs and one input. Here u_1 and u_2 are the weights attached to loans and investments respectively and $v_1$is the weight attached to the deposits. The dual of Model 4.11 is provided in Model 4.16 that is an output oriented multiplier model under VRS technology with trade-offs for bank B.

Model 4.16

Min $1v_1 + u_0$ (4.16.1)

Subject to:

$4u_1 + 4u_2 = 1$ (4.16.2)

$5u_1 + 1u_2 - 1v_1 - u_0 \leq 0$ (4.16.3)

$4u_1 + 4u_2 - 1v_1 - u_0 \leq 0$ (4.16.4)

$1u_1 + 2u_2 - 1v_1 - u_0 \leq 0$ (4.16.5)

$1u_1 + 5u_2 - 1v_1 - u_0 \leq 0$ (4.16.6)

$-1u_1 + 1u_2 - 0v_1 \leq 0$ (4.16.7)

$1u_1 - 2u_2 - 0v_1 \leq 0$ (4.16.8)

$u_1, u_2, v_1 \geq 0$ (4.16.9)

u_0 sign free (4.16.10)

Trade-off judgments are translated into weight restrictions constraints as can be seen in Models (4.16.7) and (4.16.8). u_0 is a sign free variable that corresponds to the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ in the envelopment model.

The general forms of DEA multiplier models under VRS technology with trade-offs for both output oriented and input oriented models are given in Models 4.17 and 4.18 in Table 4.8.

Table 4. 8 VRS multiplier DEA models with production trade-offs

Output Oriented VRS Multiplier Model With Trade-Offs			**Input Oriented VRS Multiplier Model With Trade-Offs**		
Min $\sum_{i=1}^{m} v_i\, x_{ij0} + u_0$		(4.17.1)	Max $\sum_{r=1}^{s} u_r\, y_{rj0} + u_0$		(4.18.1)
Subject to:			Subject to:		
$\sum_{r=1}^{s} u_r\, y_{rj0} = 1$		(4.17.2)	$\sum_{i=1}^{m} v_i\, x_{ij0} = 1$		(4.18.2)
$\sum_{r=1}^{s} u_r\, y_{rj} - \sum_{i=1}^{m} v_i\, x_{ij} - u_0 \leq 0$		(4.17.3)	$\sum_{r=1}^{s} u_r\, y_{rj} - \sum_{i=1}^{m} v_i\, x_{ij} + u_0 \leq 0$		(4.18.3)
$\sum_{r=1}^{s} u_r\, Q_t - \sum_{i=1}^{m} v_i\, P_t \leq 0$	t=1,2,...,k	(4.17.4)	$\sum_{r=1}^{s} u_r\, Q_t - \sum_{i=1}^{m} v_i\, P_t \leq 0$	t=1,2,...,k	(4.18.4)
$u_r \geq 0$	r=1,2,...,s	(4.17.5)	$u_r \geq 0$	r=1,2,...,s	(4.18.5)
$v_i \geq 0$	i=1,2,...,m	(4.17.6)	$v_i \geq 0$	i=1,2,...,m	(4.18.6)
u_0 Sign free		(4.17.7)	u_0 Sign free		(4.18.7)

Production trade-offs have been translated into the equivalent weight restrictions in the form of set of constraints as represented in Model 4.17.4 for output orientation and Model 4.18.4 for input orientation. It is noteworthy in these models that trade-offs are translated into same weight restriction irrespective of the orientation of model and the DMU under evaluation.

CRS models for input and output orientations are similar to VRS models provided in Tables 4.7 (envelopment models) and 4.8 (multiplier models). There is only one difference that the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ is removed from CRS envelopment form and free variable u_0 is excluded from the CRS multiplier form.

Production trade-offs provided in judgments 4.1 and 4.2 only provide the relationship between two outputs. Generally, we can express the trade-off relationship between any set of input and/or output. To illustrate the trade-off relationship between input and output, we define a new trade-off between deposits and investments as judgment 4.3.

Judgment 4.3. *To increase the amount of investments by 1 million, it is sufficient to increase the amount of deposits by 2 million.*

Judgment 4.3 can be incorporated in the envelopment model by introducing an additional term π_3 as presented in Model 4.19. The envelopment Models 4.11.2 to 4.11.4 defined for Judgment 4.1 and judgment 4.2 is transformed to Models 4.19.1 to 4.19.3.

$$1\,\lambda_1 + 1\,\lambda_2 + 1\,\lambda_3 + 1\,\lambda_4 + 0\,\pi_1 + 0\,\pi_2 + 2\,\pi_3 \le 1 \qquad (4.19.1)$$

$$5\,\lambda_1 + 4\,\lambda_2 + 1\,\lambda_3 + 1\,\lambda_4 - 1\,\pi_1 + 1\,\pi_2 + 0\,\pi_3 \ge 4\,\phi \qquad (4.19.2)$$

$$1\,\lambda_1 + 4\,\lambda_2 + 2\,\lambda_3 + 5\,\lambda_4 + 1\,\pi_1 - 2\,\pi_2 + 1\,\pi_3 \ge 4\,\phi \qquad (4.19.3)$$

In multiplier form this new trade-off relationship between deposits and investments is translated into an additional constraint as Model 4.20 and added to Model 4.16.

$$1u_2 - 2v_1 \le 0 \qquad (4.20)$$

Duality theorem guarantees that imposing weight restrictions in multiplier DEA models under the trade-off approach does not generate infeasible solution in the multiplier form (Podinovski, 2004). Infeasible solution in multiplier form corresponds to unbounded solution in the envelopment form, which is only possible if at least one of the trade-offs is formulated incorrectly and require a review of trade-offs to rectify the mistake.

4.7.4. Limitations of Production Trade-Offs

Production trade-offs represent the simultaneous changes in inputs and/or outputs that are possible in technology under consideration. In a production trade-off, this change in inputs and outputs is defined in the form of relationship between inputs and outputs. However, one major limitation of this approach is that it can define relationship only between the variables included in the chosen model and cannot provide any idea about the relationship existing between variables that are not included in the DEA model.

Another limitation of production trade-offs is the unboundedness of the PPS as a result of unlimited application of trade-offs. This unboundedness is due to the extreme assumptions of the Axiom 4.6 needed for the theoretical definition of the PPS. However this situation is not unique in the DEA. For example Axiom 4.5 defined for the CRS technology states that any plausible unit can be proportionally scaled up and scaled down by any positive number. This axiom does not make any practical sense for the extreme values of the scaling factor and does not create any problem as far as the scaling factor is realistic in the optimal solution (Podinovski, 2004). Similarly, Axiom 4.6 needs to be applied by a reasonable number of times to be in the reasonable proximity of the observed DMUs. This is because the optimal solutions to the DEA models in the presence of production trade-offs will concern units (for example, efficient target) in such proximity. Therefore, instead of verifying the full assumption of Axiom 4.6 it should be ensured that the defined production trade-off is realistic for all the observed DMUs.

Moreover, while defining production trade-offs, one basic assumption is made that no additional resources are required. This assumption is objectionable sometimes (particularly in case of trade-offs defined between inputs and outputs) because unlimited production of one output is not possible by consuming only one input keeping the rest of the inputs constant. This assumption holds only when simple trade-offs are applied only by a reasonable number of times because in that case there would be negligible change in the inputs not involved in the production trade-offs. However, while formulating complex trade-offs, involving multiple outputs and inputs, researchers need to be cautious while defining trade-offs because in that case this assumption may not be true.

4.8. Methods Used for Returns to Scale Investigation

Three basic methods are identified in DEA literature to determine the RTS nature of DMUs. The first method is termed as CCR RTS method by Seiford and Zhu (1999a) and was suggested by Banker (1984). The second method, called BCC RTS method by Seiford and Zhu (1999a), was proposed by Banker and Thrall (1992). The third method was proposed by Färe et al. (1985) and called Scale Efficiency Index.

In CCR RTS model Banker (1984) introduced the notion of most productive scale size (MPSS) and showed that CCR model can be employed to test the RTS nature of DMUs by looking at the sum of the CCR optimal lambda (λ^*) values. A DMU exhibits MPSS if it is fully efficient in both CCR and BCC models. In Figure 4.3, DMUs B and E are two units that are located at the intersection of VRS and CRS frontiers and operating at MPSS. The interpretation of RTS characteristic through the sum of optimal λ values is provided in Theorem 4.1.

Theorem 4.1 (Banker, 1984)

(i) CRS prevails at DMU_0 if $\sum_{j=1}^{n} \lambda_j = 1$ in at least one of the alternate optimum.

(ii) DRS prevails at DMU_0 if $\sum_{j=1}^{n} \lambda_j > 1$ for all alternate optima.

(iii) IRS prevails at DMU_0 if $\sum_{j=1}^{n} \lambda_j < 1$ for all alternate optima.

In the BCC RTS method Banker et al. (1984) introduced the free BCC dual variable (u_0) in multiplier model (corresponding to $\sum_{j=1}^{n} \lambda_j$ =1 in the VRS envelopment model) that estimates the RTS nature of DMU by allowing the VRS. Banker and Thrall (1992) suggested that the sign of u_0 could determine the RTS characteristics of a DMU. RTS characterization for input oriented models is mentioned in Theorem 4.2a.

Theorem 4.2a (Banker and Thrall, 1992)-Input Oriented Model

(i) Increasing RTS prevails at DMU_0 if and only if u_0^* >0 for all optimal solutions.

(ii) Decreasing RTS prevails at DMU_0 if and only if u_0^* < 0 for all optimal solutions.

(iii) Constant RTS prevails at DMU_0 if and only if u_0^* = 0 for at least one of the optimal solutions.

The determination of RTS nature for VRS output-oriented multiplier model presented in Model 4.9 is given in Theorem 4.2b.

Theorem 4.2b (Banker and Thrall, 1992)-Output Oriented Model

(i) Increasing RTS prevails at DMU_0 if and only if u_0^*< 0 for all optimal solutions.

(ii) Decreasing RTS prevails at DMU_0 if and only if u_0^* > 0 for all optimal solutions.

(iii) Constant RTS prevails at DMU_0 if and only if $u_0^* = 0$ for at least one of the optimal solutions.

Färe et al. (1985) proposed the method called Scale Efficiency Index for the RTS investigation using ratios of radial measure. This method adds another DEA model to CRS and VRS models whose frontier exhibits non increasing returns to scale (NIRS) given in Model 4.21. The NIRS model is obtained by replacing the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ with the constraint $\sum_{j=1}^{n} \lambda_j \leq 1$ and the optimal radial efficiency in this model is denoted by θ_{NIRS}^*.

Model 4.21

Min θ_{NIRS}

Subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{ij0}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rj0}$$

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

$\lambda_j \geq 0$

θ_{NIRS} Sign free

There is also a non-decreasing returns to scale (NDRS) model but this has been less applied (Seiford and Thrall, 1990). The NDRS model is obtained by replacing the convexity constraint $\sum_{j=1}^{n} \lambda_j$ =1 with the constraint $\sum_{j=1}^{n} \lambda_j$ ≥1 and the optimal radial efficiency in this model is denoted by θ^*_{NDRS}. Under the NIRS model DMU can only be scaled up but not down whereas, in case of NDRS model DMU can only be scaled down not up (Cooper et al., 2000).

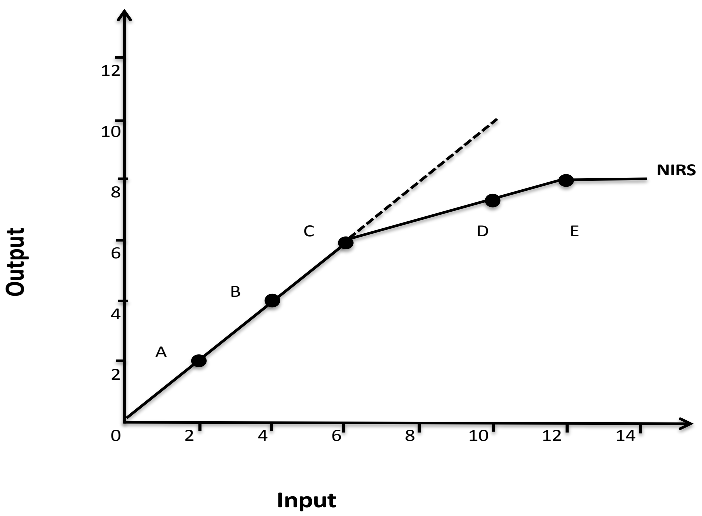

Figure 4. 10 Illustrating non-increasing returns to scale

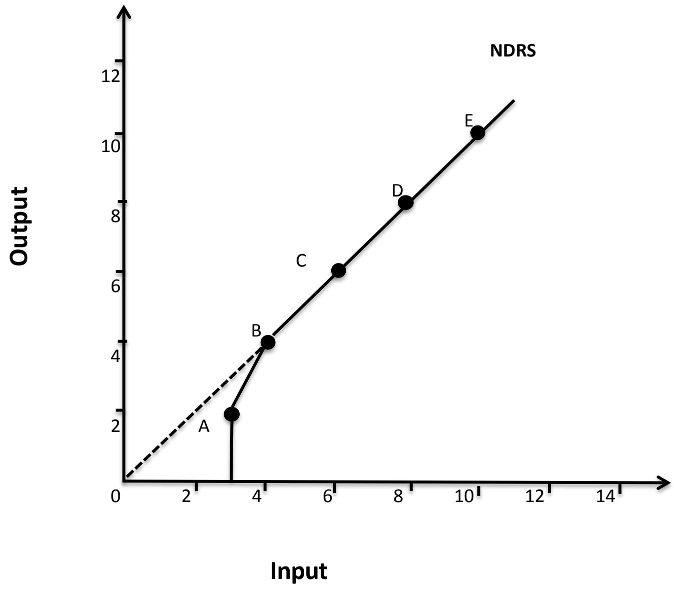

Figure 4. 11 Illustrating non-decreasing returns to scale

Both NIRS and NDRS are shown in Figures 4.10 and 4.11 respectively as the thick frontiers lines and the area below and to the right of the frontier line.

Let us denote the optimal radial efficiency measure in the input-oriented CCR and BCC Models given in 4.2 and 4.4 as θ^*_{CRS} and θ^*_{VRS} respectively. Scale efficiency index method provides a comparison of different RTS efficient frontiers. Investigation of RTS through the optimal radial efficiency scores obtained in CRS, VRS and NIRS models is provided in Theorem 4.3.

Theorem 4.3 (Färe et al., 1985)

(i) $\theta^*_{CRS} = \theta^*_{VRS}$ if and only if CRS prevails on DMU. Otherwise

(ii) $\theta^*_{VRS} \neq \theta^*_{NIRS}$ if and only if DMU_0 exhibits IRS

(iii) $\theta^*_{VRS} = \theta^*_{NIRS}$ if and only if DMU_0 exhibits DRS

As this method uses only the optimal values of the DEA model therefore is not affected by the possible multiple optimal solutions. Moreover, this method is applicable to both envelopment and multiplier DEA models (Cook and Zhu, 2008).

RTS is the property of the Pareto-efficient boundary and all the three methods described above for the investigation of RTS are only applicable to the units located on the frontier. Different authors have suggested different methods to investigate the RTS nature of inefficient DMUs. Tone (1996) suggested a BCC model based method where RTS of inefficient units is automatically determined from their reference set. Banker et al. (2004) addressed the problem of RTS investigation for inefficient units through the projection of that unit onto efficient frontier and then estimating the RTS characterization for the projected unit. Golany and Yu (1997) suggested a method based on linear programming variants of BCC model. They used the optimal values of improvement factors estimated for inputs and outputs to evaluate the RTS nature of the DMUs. However, in all above mentioned methods difference in the RTS may exist under input and output orientations while projecting inefficient unit on the efficient frontier.

In the current study we are interested to determine the RTS characteristics of banks with the application of production trade-offs (in the form of the DEATOB Framework) in the standard VRS model. Among the above mentioned methods, the CCR RTS method suggested by Banker (1984), can only be employed on the CRS model. We cannot use this method as we are using output oriented DEA model with VRS assumption for the empirical analysis.

The second method proposed by Banker and Thrall (1992) suggested that the sign of u_0 could determine the RTS characteristics of a DMU. This method was extended by Tone (2001) to determine the RTS characteristics with weight restrictions. However, the limitation of this method is that it suggested the RTS determination with only non-linked homogenous weight restrictions. As we are using both linked and non-linked homogenous weight restrictions therefore we cannot apply this method for the determination of RTS in our study.

The third method proposed by Färe et al. (1985) is applicable on the convex technologies. DEA is a convex technology and production trade-offs is a theoretical development that expands the PPS of DEA technology therefore it implies that trade-offs are the part of a convex technology. Considering production trade-offs as a part of convex technology, we can use the scale efficiency index method of Färe et al. (1985) for the determination of RTS in the current study.

4.9. Conclusion

In this chapter we have provided a comprehensive literature review of the DEA's theoretical foundations. In the beginning of the chapter few basic concepts of efficiency measurement have been described for the clear understanding of the DEA technique explained in the later sections. Review of DEA theory has covered: the concept of orientation (input orientation and output orientation), the fundamental returns to scale considerations (CRS and VRS), envelopment and multiplier forms of DEA models. Moreover, the concept of weight flexibility in DEA and the use of weight restriction as a traditional method to limit the weight flexibility are discussed in this chapter. After describing problems related to the use of weight restrictions, the theoretical concept of production trade-offs, proposed by Podinovski (2004), is introduced. In this section the workability of production trade-offs is also explained with the hypothetical example of banks. The concept of production trade-offs in DEA is the core of the DEATOB Framework proposed in the current study. Using this concept the detailed development process of the DEATOB Framework has been explained in Chapter 6. This chapter has also provided an overview of different methods used for the investigation of RTS characteristics of DMUs. From among those methods, the scale efficiency index method, proposed by Färe et al. (1985), has been used in the empirical analysis to determine the RTS characteristics of commercial banks in Pakistan.

CHAPTER 5

DEVELOPING A DEA MODEL FOR BANKING EFFICIENCY

5.1. Introduction

This chapter describes the major methodological considerations in relation to developing a DEA model for the estimation of banking efficiency. The current study aims to propose a framework which is capable of incorporating additional information about different bank specific characteristics into the standard DEA model in order to transform it to a better informed DEA model. To incorporate the additional information, the current study considers the idea of production trade-offs introduced by Podinovski (2004). A detailed review of DEA and production trade-offs is provided in the previous chapter.

Application of DEA in banking industry starts with the selection of bank behaviour model used for conceptualizing the production possibilities and selecting input-output variables. Therefore, this chapter describes the selection of appropriate banking model for the current study in DEA context and explains all the input-output variables corresponding to the selected banking models of the study. This chapter also describes the technological considerations such as choice of returns to scale and choice of orientation. Finally, a detailed description of data set from the banking sector of Pakistan is provided in the chapter.

5.2. Banking Efficiency Model for the Current Study

Model specification for efficiency evaluation is the crucial step in building an appropriate banking model that in turn, influences the selection of input and output variables. In spite of a long-standing disagreement regarding which banking model is perfect for the efficiency measurement of financial institutions, there is a general consensus that each approach reflects a particular aspect of the banking activities (Camanho and Dyson, 2005).

For modelling the banking activities in our study, we consider the objectives set by the SBP as the financial regulatory authority in Pakistan and the commercial banks as business organizations. SBP's objective is to foster the economic growth by providing financial resources to the non-financial sector whereas commercial banks pursue the profit maximization goal. Both these goals represent two different dimensions of banking activities and together contribute towards the financial stability of the banking sector in Pakistan. In the light of these two objectives we have selected two different banking models for the current study. To evaluate banks according to the objective of SBP, we employ the intermediation banking model because it considers intermediation as the key role performed by the commercial banks. As this study focuses on the efficiency of banking sector of Pakistan at institutional level so, this selection of intermediation model is also in line with the Ferrier and Lovell (1990) and Berger and Humphrey (1997) point of views that intermediation approach is appropriate for measuring the efficiency of financial institution as a whole. For modelling the banking activities according to the objective of commercial banks, we have chosen profitability approach that measures the profit efficiency of banks. The intermediation efficiency of banks is an indicator of their lending ability, which is tied to the profit generating ability of banks as a going concern.

However, from different variants of intermediation approach, we have selected asset approach (details of different variants of intermediation approach are provided in Chapter 2 section 2.7.2). There are two main reasons for this selection. First, keeping in view the basic concept of intermediation, this study considers deposits as input and all earning assets as output. The second reason is, if revenues and costs are used as proxies for assets and liabilities (selected in asset approach) then intermediation approach becomes profitability (operating) approach (Avkiran, 2009a). In that case, profitability approach reflects the profit efficiency of banks for the provision of intermediation services. Consequently, both intermediation and profit efficiencies reveal the performance of same banking operations in the two different dimensions. As the current study intends to extend the proposed framework on the profitability approach to demonstrate applicability of the proposed framework on multiple banking approaches, the operating version of asset approach best describes the profit dimension of banks. The use of asset approach and its operating version in the form of profitability approach evaluate banking operations both from the intermediation (asset generation) and profitability (profit generation) point of view. Independent evaluation of the intermediation and profitability aspects is not possible in case of combining assets with revenues in inputs and liabilities with costs in outputs while specifying input/output set of intermediation approach as done in banking studies among others by Yue (1992), Miller and Noulas (1996), Drake and Hall (2003), Sathye (2003).

5.3. Specification of Variables

Selection of input and output variables in banking sector is a major problem because there is no consensus in the literature about what constitutes inputs and outputs. According to Bergendahl (1998) “There have been almost as many assumptions of inputs and outputs as there have been applications of DEA” (p. 235).

There has been a debate about what banks produce (outputs) and what kind of resources (inputs) they consume in the production process. Generally, the output of banks includes those services, which are considered prime important to the purpose of banks by bank’s management and researchers. Inputs include those resources, which are required to produce outputs such that outputs would only increase (decrease) if the input level is increased (decreased) (Sherman and Gold, 1985).

The choice of input-output variables based on a banking model is an important issue that must be addressed in the banking efficiency studies. However, such a choice is influenced by the selection of underlying concept of the banking firm, the particular question that is required to be answered by the study and the availability of the reliable data (Pastor et al., 1997).

It is a commonly agreed fact that the choice of variables in the efficiency studies has significant impact on the results (Tortosa-Ausina, 2002a, Tortosa-Ausina, 2002b, Das and Ghosh, 2006). So a considerable attention must be paid while deciding and placing variables into inputs and outputs. The purpose of research and context play very important role in the selection of final inputs and outputs (Paradi et al., 2011b). However, the variable selection is often constrained by the non-availability of data on the relevant variables (Das and Ghosh, 2006, Fethi and Pasiouras, 2010).

The present study has considered two perspectives of banking modelling behaviour. The first perspective covers the intermediation aspect under intermediation model and the second addresses the profitability aspect with profitability model. Intermediation model is the main approach selected for development of the proposed framework of the study. Under the intermediation model, input and output variables have been selected according to asset approach given by Sealey and Lindley (1977). Input variables of this approach include: physical capital, deposits and labour cost whereas output variables are loans and investments. Many studies have used this set of inputs and outputs following intermediation approach such as Huang and Wang (2002), Isik and Hassan (2002), Casu et al. (2004), Das and Ghosh (2006), Drake et al. (2009), Pasiouras (2008a), Sufian (2009), and Thoraneenitiyan and Avkiran (2009). Banking literature on the causes of bank failures revealed that the failing banks have large proportions of NPLs (Demirguc-Kunt, 1989, Barr and Siems, 1994, Wahlen, 1994, Berger and Deyoung, 1997, Reinhart and Rogoff, 2011). A review of the banking sector of Pakistan indicated that NPLs have become a growing problem for Pakistan's economy. Therefore, to account for the risk attached to the NPLs in the banking context, we have included them in the intermediation model as an additional variable. NPLs are actually a bad output that has been placed on the input side following Scheel (2001) and Thanassoulis et al. (2008).

To address the profitability aspect of banks we have extended our proposed framework to the profitability approach. At the input (cost) side, interest expenses and non-interest expenses are used as a proxy for deposits, labour and capital expenses. On the output side, interest income and non-interest-income (segregated into other income and fee, commission and brokerage charges) are used as proxy for loans, investments and other earning assets. This input-output set represents the full range of resources used and outputs created which is consistent with the approach recommended by Dyson et al. (2001). This input-output combination is also used in other studies such as Charnes et al. (1990), Yue (1992), Miller and Noulas (1996), Bhattacharyya et al. (1997), Leightner and Lovell (1998), Sathye (2003), Sturm and Williams (2004), Drake et al. (2006), Pasiouras (2008a), Sturm and Williams (2008), Avkiran (2009a, 2009b), Drake et al. (2009), Sufian (2009). Keeping in view the importance of accounting for risk and lending quality in the efficiency evaluation of banking sector, the current study is using loan loss provision as an additional input in the profitability model. Loan loss provision is also used as input in the studies conducted by Leightner and Lovell (1998), Drake and Hall (2003), Drake et al. (2006), Pasiouras (2008a), Drake et al. (2009).

Input and output variables under both intermediation and profitability approaches are provided in the Table 5.1.

Table 5. 1 Input and output variables selected under the intermediation and profitability approaches

Intermediation Approach		**Profitability Approach**	
Inputs	**Outputs**	**Inputs**	**Outputs**
Physical Capital Deposits Labour Cost Non-Performing Loans	Loans Investments	Interest Expenses Non-Interest Expenses Loan Loss Provision	Interest Income Fee, Commission and Brokerage Income Other Income

5.3.1. Input Variables

This section provides the description of input variables for both intermediation and profitability approaches in detail.

5.3.1.1. Physical Capital

Physical capital is a term used for all fixed assets that represents the book value of property, furniture and fixture, electrical office equipment, plant, machinery, vehicles, building improvements and premises purchased directly or acquired by bank through capital lease measured at cost minus accumulated depreciation and impairment losses. This category does not include intangible assets and capital work-in-progress.

5.3.1.2. Deposits

The long-standing controversy exists regarding the role of deposits or more specifically about their treatment as input or output. This controversy arises due to the fact that deposits possess both input and output characteristics and can be treated either input or output depending upon what banking aspect the model is intended to capture. Therefore, multiple ways of treating deposits has been described in banking literature. In some studies these have been treated as input keeping in view the intermediation function of banks (Mester, 1987). The lesser amount of deposits is better as it indicates that banks are doing more lending with fewer amounts of deposits. However, this implies that banks have access to other resources of funds that are cheaper than deposits (Paradi et al., 2011a). Some other studies have described these as output (Ferrier and Lovell, 1990, Berger and Humphrey, 1992a) because the higher value of deposits reflects banks efficiency in attracting depositors. Even some studies have tried to resolve this controversy by treating deposits as both input and output simultaneously (Aly et al., 1990, Humphrey, 1993). However, this method raises the problem of not capturing the banking intermediation function of creating loans out of deposits (Pastor et al., 1997).

In the current study, deposits have been treated as input following the intermediation approach of Sealey and Lindley (1977). Deposits include fixed deposits, saving deposits and current deposits accepted from customers as well as financial institutions and borrowings from financial institutions.

5.3.1.3. Labour Cost

There are two different ways to measure this variable. The first way is to measure the total labour expenses of the staff incurred during a year, while alternative way is to use the number of full time employees on payroll during a year. In the domestic market, if there is market power in the labour market then labour quality heterogeneity is reflected in number of employees. However, if there is no market power in the labour market then labour quality/productivity is reflected in the wages and differences in efficiency are attributable to management of the firm. However, if the differences in wages are due to market imperfections instead of differences in the quality of labour then the firm with lower wage amount will be overestimated in terms of efficiency assessment. In the international market differences in wages are due to the labour market segmentation so cannot be attributed to labour quality heterogeneity (Pastor et al., 1997). Therefore, the final decision lies with the objectives of the study. Mostly the number of full time staff is used to eliminate the dispute on the differences in the pay scale. However, if the management has the flexibility of hiring employees in different capacities such as low cost staff assisting the high cost staff in different operations then salary cost is better option because it would reflect the efficient resource management.

Labour in the current study is represented by the total labour expenses of staff incurred during the year because management of commercial banks in Pakistan has the flexibility of hiring staff in different capacities. Labour cost includes salaries and wages of permanent and contractual staff, charges for defined benefit plan, contribution to defined benefit plan, workers welfare fund, medical expenses, and charges for employees compensated absence.

5.3.1.4. Non-Performing Loans (NPLs)

NPLs represent the portion of issued loans, that suffers from the problem of non-repayment and is in default or close to default. The current study has considered NPLs in the intermediation banking model to incorporate the risk effect into the efficiency evaluation of banks. This risk mainly arises due to the presence of poor quality or bad loans and failure to account for such loans may lead to miscalculation of inefficiency level of banks (Mester, 1996). NPLs are the anti-isotonic[29] or undesirable output of banks and make banks vulnerable by increasing their riskiness in case of having large quantities of NPLs as compared to their peers. Four different

[29] Anti-isotonic output behaves opposite to the normal outputs which means when it increases it can be expected to lead to increase the other output/s.

approaches have been mentioned in literature to handle such bad and undesirable outputs in DEA model (Dyson et al., 2001, Scheel, 2001).

The first approach is, to keep the undesirable factor on the output side but invert its value. However, this practice destroys the ratio or interval scale of the data and the resulting data require further transformation (Dyson et al., 2001). The second approach is to subtract the amount of undesirable output from the comparatively large amount and the result would be isotonic. In case of banks, this could be achieved by subtracting the amount of NPLs from the total loans (Thoraneenitiyan and Avkiran, 2009). The third approach is to move undesirable factor from the output side to input side where the lower is this value the better is the efficiency score (Thanassoulis et al., 2008). The last approach is to treat undesirable output as weakly disposable output which means that undesirable output can be reduced but at the cost of fewer other desirable outputs (Hailu and Veeman, 2001, Färe and Grosskopf, 2003, Hailu, 2003).

The current study has chosen for the third approach following Thanassoulis et al. (2008) and placed NPLs at the input side. NPLs have been used in the analysis of cost efficiency of banks by Hughes and Mester (1993) and Berger and Deyoung (1997). Few other researchers such as Lotfi et al. (2010), and Paradi et al. (2011b) have used them in the branch level banking studies whereas Asmild and Matthews (2012) have considered them at institution level banking study.

5.3.1.5. Interest Expenses

This category of input include interest paid on deposits, securities sold under repurchase agreements, sub-ordinated loans, call money borrowings, refinance borrowing from SBP, long term finance for export oriented projects from SBP and other short term and long term borrowings.

5.3.1.6. *Non-Interest Expenses*

Expenses include in this category are: administrative expenses, other provisions and write offs, other charges, and extraordinary items. Administrative expenses is a broad category that covers most of the operating expenses of banks such as salaries, rent rates and taxes, brokerage and commissions, repair charges, advertising expenses, donations, travelling expenses, medical expenses and depreciation charges etc.

5.3.1.7. *Loan Loss Provision*

It has long been argued in banking literature that the incorporation of loan quality/risk is important for efficiency studies. Failure to adequately account for risk factor can affect efficiency scores significantly (Altunbas et al., 2000, Drake and Hall, 2003). According to Laeven and Majnoni (2003) loan loss provision should be treated as cost no matter when it will materialize. Many studies have used loan loss provisions as input in the profitability model (for details see Leightner and Lovell (1998), Drake and Hall (2003), Drake et al. (2006), Pasiouras (2008a), Drake et al. (2009)). Following the risk based banking literature the current study has included loan loss provision as an input in the profitability model to capture the cost of risk taking in lending activities. This input represents the amount of provisions charged against loans in the form of general provisions[30] and specific provisions[31].

[30] General provision is maintained at the rate of 0.1% of advances other than non-performing loans and consumer financing. General provision against consumer financing is maintained at an amount equal to 1.5% of the fully secured performing portfolio and 5% of the unsecured performing portfolio as required by the Prudential Regulations 2011 issued by the State Bank of Pakistan.

[31] Specific provision is maintained for nonperforming loans at the rate of 25%, 50% and 100% for substandard loans, doubtful loans and loan losses category.

5.3.2. Output Variables

5.3.2.1. Loans

Loans, normally termed as “Advances” in the statement of financial position, are the major earning asset of banks and characterised as the fundamental product of the banking operations of commercial banks. This category includes loans, cash credits, running finance, net investment in finance lease, bills discounted and purchased funds excluding treasury bills and lending to financial institutions. The amount of loans provided in the financial statements is heterogeneous in credit quality. Therefore, to account for heterogeneity in the quality of loans, the amount of non-performing loans has been subtracted from the gross amount of loans and advances.

5.3.2.2. Investments

This category of output is an aggregate of three major types of securities i.e. held to maturity, available for sale and held for trading securities. Securities under these three categories include a wide range of instruments such as federal government securities (market treasury bills, Pakistan Investment Bonds (PIBs), foreign currency bonds, and Ijarah Sukuk bonds) fully paid ordinary shares, Term Finance Certificates, (TFCs), debentures, bonds and Participation Term Certificates (PTCs). The amount of investments used in the analysis is net of provisions and impairment/revaluation losses.

5.3.2.3. Interest Income

This output represents the income earned from both investments and loans. Interest income on loans covers interest income received from both individuals and financial institutions (call money, securities purchased under resale agreements and advances to financial institutions). Income from investments includes interest earned on; available for sale, held to maturity, and held for trading securities. This category of income also includes interest on deposits with other banks.

5.3.2.4. Fee, Commission and Brokerage Income

Fee, commission and brokerage charges represent the income from non-traditional[32] banking activities called off-balance sheet (OBS) activities[33]. Share of OBS income in banks' income is growing as a result of additional services provided by banks in response to increasing banking habits of people. Literature on banking efficiency has stressed the inclusion of OBS items in the banking outputs and concluded that omitting these non-traditional activities understates the efficiency estimates of banks (Rogers, 1998, Tortosa-Ausina, 2003, Casu and Girardone, 2005, Lozano-Vivas and Pasiouras, 2010).

5.3.2.5. Other Income

Other income consists of dividend, income from dealing in foreign currencies, gain on sale of securities, gain on revaluation of investments classified as held for trading, credit losses recovered, net profit on sale of assets, income from derivative contracts, interchange income, rent received from lockers and properties and other miscellaneous earnings.

5.4. Returns to Scale Considerations

While developing DEA model, researchers are often concerned about the nature of returns to scale that would better reflect the operations of DMUs included in the sample. DEA can be applied by assuming either constant returns to scale (CRS) or variable returns to scale (VRS). The original DEA model that was introduced by

[32] Non-traditional activities are the banking operations other than investing in securities and advancing loans.

[33] Off-balance sheet activities are not recorded in the balance sheets of banks but generate fee income for banks that improve their earnings ratios. These activities encompasses a variety of items such as certain letter of credits, discounting of bills, loan commitments, underwriting, guarantees etc. that generate fee income for banks.

Charnes et al. (1978) termed as CCR model was only applicable to technologies with CRS. CRS implies that there would be proportional increase in outputs if the level of inputs is increased that means efficiency of a unit is not influenced by the scale of operations. This model was subsequently modified by Banker et al. (1984) who relaxed the assumption of CRS and introduced the idea of VRS in the BCC model. VRS implies a disproportionate increase (decrease) in outputs as a result of increase (decrease) in inputs, which means efficiency would either increase or decrease as DMU grows in size.

It is also argued in the literature that CRS assumption is appropriate when all the firms are operating at an optimal scale otherwise VRS assumption is better because it provides the efficiency scores that are devoid of scale efficiency effect. VRS ensures that a firm is only benchmarked against firms of the same size whereas, in CRS a firm may be benchmarked against the firms that are substantially larger or smaller than it (Coelli et al., 2005).

The current study has employed VRS for the measurement of efficiency because CRS assumption does not hold in banking scenario, as there is not a proportional increase in outputs as a result of increase in inputs. Moreover, banks included in the sample differ in operational activities and assets sizes. For example, the "Big Five[34]" banks (Habib Bank, National Bank, Muslim Commercial Bank, Allied Bank and United Bank) in Pakistan are very large in assets size due to their vast branch network all over the country. In contrast, two foreign banks (Barclays Bank, and HSBC), some private banks (Samba Bank, Burj Bank and Dubai Islamic Bank) and one public sector bank (First Women Bank) are very small having assets less than Rupees 70 million.

[34] The term of "Big Five" is used for largest five commercial banks created as a result of nationalization of commercial banks in 1974.

However, we will also calculate efficiency scores with CRS to find out the scale efficiencies of commercial banks in Pakistan.

5.5. Choice of Orientation

While running DEA model another important decision has to make regarding the modelling option of input orientation and output orientation. Input orientation (also called input minimization or contraction) investigates the extent to which a particular bank can produce more output from its current input level. Alternatively, output orientation (also known as output maximization or expansion) examines the extent to which a bank can reduce its use of inputs while maintaining the current output levels.

However, which way of efficiency estimate is suitable for a bank, depends upon the managements' objectives and the variables that are under control. For example, if the management of a bank is undertaking a cost cutting exercise in branch network or downsizing, then input orientation is better to use. Conversely, if management has intention to increase the market share of bank then focus could shift towards output orientation (Sherman and Ladino, 1995, Athanassopoulos, 1998). In terms of control on variables, input orientation is used when inputs are controllable, and output orientation is used when outputs are controllable (Thanassoulis, 2003).

In the present study we employ output orientation for the performance evaluation of banks operating in Pakistan. SBP, being a banking supervision and regulatory authority of a developing economy, is targeting the policies that promote financial inclusion[35] so that financial services are available to all individuals and firms across the country. In order to pursue this aim of enhancing outreach of financial services,

[35] Financial inclusion work covers a broad range of issues from ensuring, people have access to financial services to helping people to manage their money better.

commercial banks in Pakistan under Branch Licencing Policy (BLP)[36] are allowed to open 20% branches in rural or underserved areas. Moreover, banks are also allowed to open sub-branches, sales & service centres and mobile banking units (State Bank of Pakistan, 2012b). Keeping in view this financial inclusion strategy and liberalized Branch Licencing Policy of SBP, output orientation is better to use in order to measure the effectiveness of financial services.

Moreover the financial sector of Pakistan is experiencing more and more concentration as a result of on-going process of consolidation in response to the minimum capital requirement (MCR) that has significantly reduced the number of banks operating in Pakistan. This reduction in the number of market players has posed the challenge of increasing market share for remaining banks who are trying to meet this challenge by extending their network, introducing new banking products and improving service quality. This objective of increasing market share pursued by commercial banks also supports the use of output orientation for the efficiency evaluation of banking sector in Pakistan.

Output orientation has been used formerly, in many banking studies to measure the efficiency of banks using DEA such as, Sherman and Ladino (1995), Anthanassopoulos (1998), Mostafa (2009), Ataullah and Le (2006) and Assaf et al. (2011).

5.6. Data Definition

5.6.1. Data Set

Data set of the study consists of commercial banks operating in Pakistan in the year 2012. Commercial banks in Pakistan are operating in public, private and foreign sectors. Our sample includes banks from all these sectors. However, final sample only

[36] For reference see Banking Policy and Regulation Department Circular Letter No. 15 dated October 12, 2007 and Banking Policy and Regulation Department Circular No 08 dated April 09, 2011.

includes those banks which have more than five branches in Pakistan and also had been operational for three consecutive years preceding 2012. The former condition removed four small and outlier foreign banks: Deutsche Bank, HSBC Bank Oman S.A.O.G., Industrial and Commercial Bank of China Ltd and the Bank of Tokyo-Mitsubishi UJH Ltd. These banks are operating in the major cities of Pakistan only to serve clients of their parent banks abroad. These banks may have completely different considerations from other banks having significant retail presence in the country, for choosing their input and output mix. The latter selection criterion removed newly formed public sector bank, Sindh Bank Ltd., having relatively less developed input and output mix as compared to old banks.

In spite of being scheduled banks, we have excluded specialized banks from the sample, given their different business philosophy, scope and regulatory requirements as compared to commercial banks. Our final sample has 29 commercial banks comprising four public sector, three foreign and twenty two private banks. Table 5.2 provides a complete list of banks included in the sample along with their branches.

Among the 22 private domestic banks, 5 are Islamic banks that include: Al Baraka Bank, Bank Islami, Burj Bank, Dubai Islamic Bank and Meezan Bank. Islamic banks carry out their operations in consonance with the fundamental principles of law of Islamic transactions set out in Islamic Shariah that differ conceptually from the banking principles of private banks (whose operations are based on conventional banking). This conceptual difference between the Islamic banks and the rest of the private banks (named private domestic banks in the thesis) differentiate them from conventional private banks and gives rise to the need of evaluating Islamic banks as an independent group. Therefore, the current study separates Islamic banks from the rest of the private banks in the empirical analysis in spite of being in private ownership so that their efficiency can be evaluated (as a group) and compared with the rest of the banking groups (public, private domestic and foreign banks).

Banking sector of Pakistan frequently use the term of "Big Five" for largest five commercial banks created as a result of nationalization of commercial banks in 1974 and include: Habib Bank, National Bank, Muslim Commercial Bank, Allied Bank and United Bank. However, presently National Bank is the only public sector bank while the rest of the four are private domestic banks (privatisation process of these banks is described in detail in Chapter 3 section 3.3).

Table 5. 2 Commercial banks and their branches included in the data set

Sr No.	Name of Bank	Number of Branches
	Private Banks	**7862**
1	Al Baraka Bank Pakistan Ltd.	90
2	Allied Bank of Pakistan Ltd.	873
3	Askari Commercial Bank Ltd.	236
4	Bank Al Falah Ltd.	453
5	Bank Al Habib Ltd.	307
6	Bank Islami Pakistan Ltd.	83
7	Burj Bank Ltd	67
8	Dubai Islamic Bank Ltd.	100
9	Faysal Bank Ltd.	265
10	Habib Bank Ltd.	1496
11	Habib Metropolitan Bank Ltd.	143
12	JS Bank Ltd.	77
13	KASB Bank Ltd.	70
14	Muslim Commercial Bank Ltd.	1179
15	Meezan Bank Ltd	310
16	NIB Bank Ltd	179
17	Samba Bank Ltd	28
18	Silk Bank Ltd	85
19	Soneri Bank Ltd.	233
20	Standard Charted Bank	130
21	Summit Bank	181
22	United Bank Ltd.	1277
	Public Banks	**1718**
1	Bank of Punjab Ltd.	302
2	Bank of Khyber Ltd.	78
3	First Women Bank Ltd.	42
4	National Bank of Pakistan Ltd.	1296
	Foreign Banks	24
1	Barclays Bank PLC Pakistan	7
2	Citi Bank	7
3	HSBC Bank Middle East Ltd	10

Source:(Banking Statistics of Pakistan, 2012)

5.6.2. Data Sources

Data required for the current study are both primary and secondary in nature. Primary data are required to develop feasible and realistic trade-off relationships between different input-output variables. Primary data have been collected by having one-to-one conversation with personnel of different banks, mainly from credit and treasury departments using the elite interview approach[37]. Once the potential trade-off relationships are identified, these are discussed (through emails, phone, Skype, Tango and face-to-face meetings) with the banking practitioners in order to assess the acceptability of the developed trade-offs in the banking environment.

Secondary data are the financial data of banks for the year 2012 that have been collected from audited annual reports for that year. Secondary data include statement of financial position and statement of comprehensive income where data are managed according to the International Accounting Standard (IAS). Another important source of data are banking circulars and notifications issued by different departments of SBP from time-to-time containing data regarding different rules and regulations governing banking operations of all banks operating in Pakistan. These rules are helpful to develop trade-off relationships between input-output variables. Other sources of data include: Economic Survey of Pakistan published by Ministry of Finance, Government of Pakistan and various reports published by State Bank of Pakistan (SBP) such as Banking Statistics of Pakistan, Financial Sector Assessment, Banking Stability Review and Financial Stability Review.

Financial data for different variables used in the intermediation and profitability banking models are provided in Appendix B and denominated in Pakistani Rupees (in million).

[37] Elite interview is an approach of undertaking discussions with people who are chosen because of who they are or what position they occupy. For reference reader is referred to (Richards, 1996).

5.7. Framework Development and Empirical Application

In the next three chapters we illustrate the development and application of the proposed framework using the data set identified above. All these chapters reflect different implications of our methodological framework. Through the DEATOB Framework (our proposed framework) we aim to provide an insight on the application of production trade-offs on the efficiency evaluation of banking sector using DEA. However, our main objective throughout this research is to ensure that the framework we propose is applicable on the real world case. The development and empirical application of the proposed framework is summarised in Figure 5.1.

All the calculations in the illustrative example and empirical application of the proposed framework are performed using LP solver embedded in Microsoft Excel. For the validation of results obtained through LP solver all the calculations are also performed using DEA software named Efficiency Measurement System (EMS).

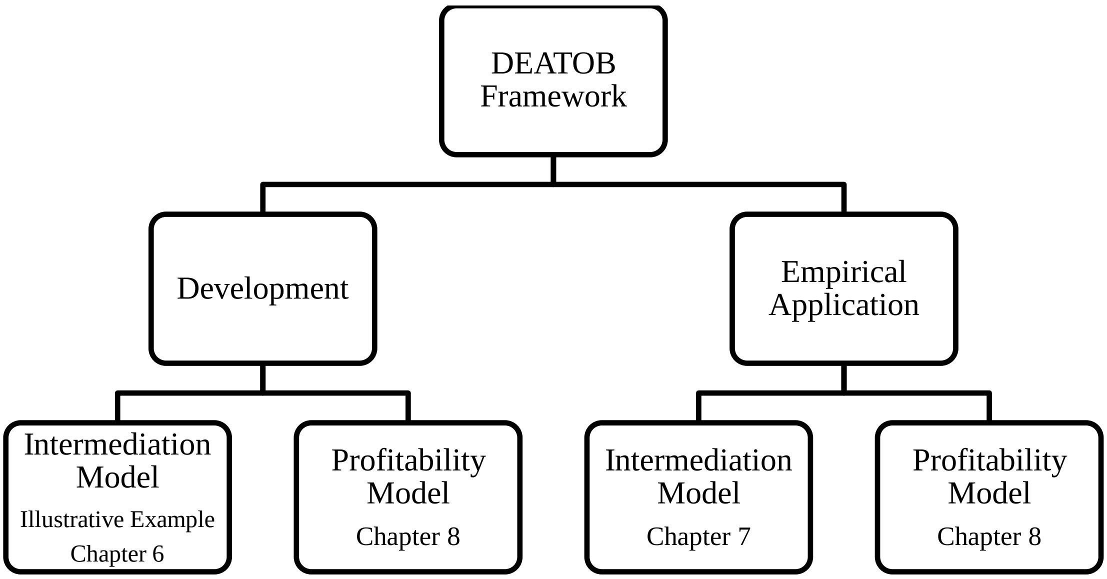

Figure 5. 1 Summary of the development and empirical application of the proposed frameworks

5.8. Conclusion

This chapter has described different methodological considerations such as selection of appropriate banking model, specification of input-output variables, choice of returns to scale and choice of orientation. Intermediation banking model is selected as the main underlying banking approach of the study to develop the proposed framework. In addition, profitability model is selected to extend the proposed framework to measure the profit efficiency of banks. Specification of variables has covered the detailed description of inputs and outputs used in the study for intermediation as well as profitability banking models. Besides, nature, sources and selection criteria for the final sample of the study is also discussed. Selected banking models and their variable specification is used for developing trade-offs for the proposed frameworks and empirical analysis with output orientation considering VRS technology.

CHAPTER 6

DEATOB FRAMEWORK

6.1. Introduction

In this chapter we have described development process of the proposed framework to achieve the primary objective of this study. This framework has a number of constituent trade-offs that have been developed through a multistage process. Construction of the proposed Framework is derived from the intermediation process of banks. Based on the intermediation process, different banking operations that acted as basis for formulating these trade-offs have been explained. Our main purpose in this chapter is to clarify the development process of trade-offs in the banking context. To explain the mathematical formulation and application of each trade-off of the DEATOB Framework, a numerical illustration is used. This illustration is also used to show the impact of each trade-off on the optimal weights and efficiency scores. The chapter also summarizes different types of trade-offs developed for the DEATOB Framework and various methods used for developing these trade-offs. The chapter also provides the mathematical formulation of the complete DEATOB Framework based on the illustration data. In the last section, few limitations of the DEATOB Framework are described.

6.2. Conceptual Framework

An integration of production trade-offs and DEA model for the efficiency evaluation of banking institutions, as an alternative to standard DEA models, has been argued in this study to provide a better insight into the performance of banks and their benchmarking practices. The resulting integrated technique is named as the DEATOB Framework as shown in Figure 6.1. This framework enriches the traditional DEA model by adding additional information about the transformation process of banks in the form of production trade-offs. An additional benefit that arises as a by-product of this framework is its ability to address the renowned curse of dimensionality[38] of DEA technique which is observed particularly in case of small data set.

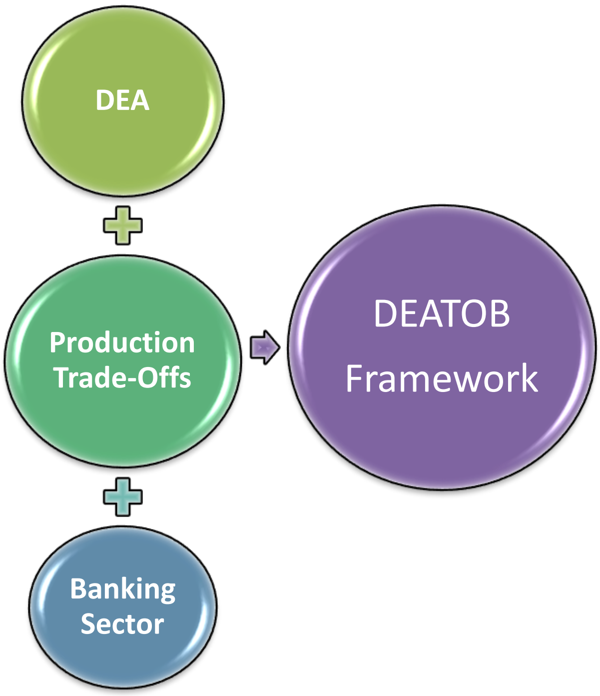

Figure 6. 1 The concept of the DEATOB Framework

The idea behind the conception of this study is to improve the DEA evaluation process by defining a better informed DEA model for banking industry. In fact, the proposed DEATOB Framework enhances the technological meanings of DEA assessment of banks instead of nullifying them. It is worth emphasising here that instead of developing a unique theory, the current study proposes a novel implementation

[38] The curse of dimensionality refers to an issue that arises in the form of high efficiency scores and poor discrimination among efficiency scores mainly due to the multiple dimensions (inputs and outputs) of firms (Coelli et al., 2005). The curse of dimensionality implies that when data set consists of a number of input and output variables (referred as multiple dimensions), the analysis requires sufficiently large sample size in order to obtain a reasonable estimation precision (Daraio and Simar, 2007).

framework based on the theoretical development of the trade-off approach introduced by Podinovski (2004).

Production trade-off represents a statement that certain simultaneous changes in the levels of inputs and/or outputs are technologically possible without affecting the levels of the remaining inputs and outputs (Podinovski, 2005). The trade-off approach is consistent with the other suggested developments in DEA literature such as weight restrictions. By incorporating additional information, both methods modify PPS and the efficient frontier that consists of relatively efficient units operating at their particular scales of operations. However, in production trade-offs the specification of additional information is based on "technology thinking" in contrast to weight restrictions where additional information is derived from "value thinking". Imposing weight restriction through value judgements and monetary considerations based on value thinking may render technologically unrealistic improvement targets for inefficient units (Podinovski, 2004, 2007a, b). The generated radial targets of inefficient units under the trade-off approach are always producible and input output mix is not distorted to attain 100% efficiency (Podinovski, 2004). Therefore, the trade-off approach not only meaningfully expands the PPS but also preserves the standard meaning of efficiency as a realistic radial improvement factor (Podinovski, 2004).

As described in Chapter 4 section 4.7.3, production trade-offs can be meaningfully applied in both envelopment and multiplier form because mathematical effect of production trade-offs on both forms is the same. In the current study we have opted for the second way of incorporating production trade-offs in DEA model i.e. we have translated production trade-offs into weight restrictions and applied them in the DEA multiplier model.

However, there are few key points which should be considered while defining trade-offs. Firstly, the trade-offs should be developed between input and/or output factors after understanding the production process in order to secure agreement from all units in the data set that trade-offs are logically possible and realistic. Secondly, the values or ratios of trade-offs between inputs and/or outputs should be reasonably conservative and undemanding so that all the DMUs in the data set accept them unanimously. Keeping in view these general guidelines about trade-offs development, we have described the development process of the DEATOB Framework in the following section.

6.3. DEATOB Framework Development Process

The development of the DEATOB Framework is a multistage process. The first stage is the ***identification*** stage at which the potential trade-offs are identified by understanding the production process of banks. The second stage is the ***validation*** stage that entails the discussion of these trade-offs with the banking professionals from the credit, treasury and operations departments to get their opinion on the initial values assigned to trade-offs. This is an important stage to assign realistic values to trade-offs in order to make them acceptable for all banks. The third stage is the ***evaluation*** where the workability of identified trade-offs is assessed in banking context. This stage overlaps the validation stage up to some extent because non workable trade-offs are discarded at this stage with experts' opinion. The fourth stage is the ***application*** stage at which agreed trade-offs are incorporated into the standard DEA model to see their effect. The final stage is the ***review*** of the technological correctness of the identified trade-off. This stage ensures that the developed trade-off is technologically feasible and is not contradicting with the conditions of any other trade-off developed for the Framework. However, if such a clash is detected in the form of infeasible solution then the whole process of developing a trade-off is repeated. These trade-offs' development stages are demonstrated in the following diagram.

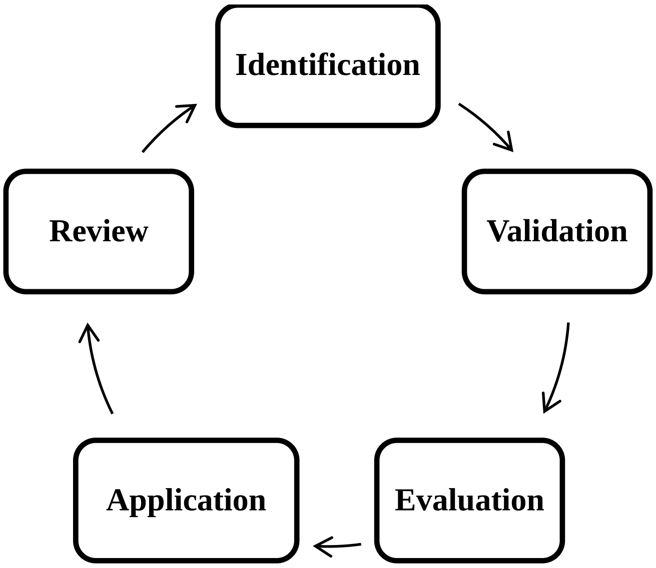

Figure 6. 2 Stages in the trade-offs development process

Identification of feasible trade-offs requires clear understanding of the production process. In other words, we should be clear about what kind of input variables are required to produce outputs in the production process and which inputs/outputs can substitute each other. This task becomes even more difficult in the banking industry where there is no consensus regarding the exact nature of inputs and outputs. Main controversy relates to the treatment of deposits as inputs or outputs. Different attempts have been made to tackle this issue by developing different banking behaviour modelling approaches as discussed in Chapter 2 section 2.7. We have selected intermediation approach in the current study to model the socio-economic behaviour of commercial banks according to the SBP objective and treated deposits as an input in the current study. A detail of inputs and outputs selected in the current study is provided in section 5.3 of Chapter 5. Keeping in view the intermediation function of banks, we attempt to develop different trade-offs in banking operations that, in aggregation, form the DEATOB Framework.

The key step in this development process is the identification of possible production trade-offs in banking operations that are transformed to their concrete shape after having discussions with the personnel from treasury and credit department because those are the main resource persons who actually deal with different real life banking operations in practice. The reason to discuss our trade-offs with them is to get data regarding acceptable values of trade-offs in the form of ranges that we require to formulate feasible and acceptable trade-offs.

Before starting our explanation regarding different trade-offs identified in the current study, we want to clarify banks' intermediation process. This process can be explained with the help of following diagram.

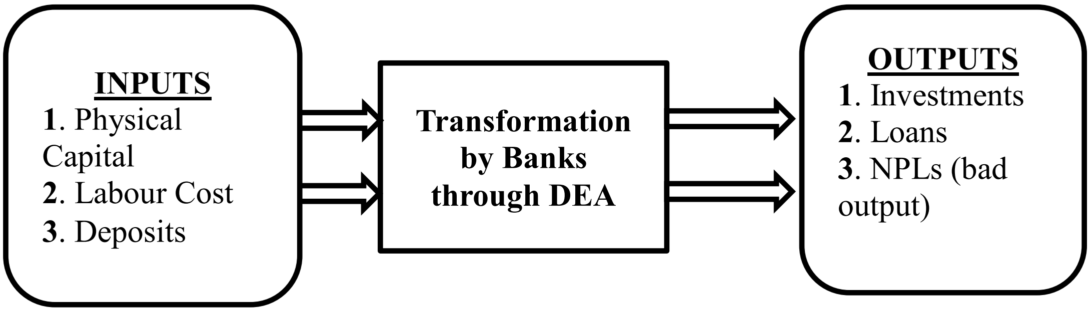

Figure 6. 3 The production process of banks

Banks accept deposits from individual and corporate customers by using labour and physical capital. This amount of deposits is used by banks for purchasing investments and creating loans. Hence, an increase in the amount of deposits brings about an increase in the amount of loans and investments.

Term "advances" in the statement of financial position of banks is a composite term that covers two main categories; good loans and bad loans. Good loans are the performing loans, for which repayment process is comparatively smooth in terms of receipt of principal as well as interest income. In contrast, bad loans called NPLs are that portion of loans which suffers from the problem of non-repayment. NPLs are generally classified into substandard[39], doubtful[40] and losses[41] on the basis of non-repayment for a specified period of time (State Bank of Pakistan, 2011b). As NPLs are bad output so these have been treated as input as mentioned in section 5.3.1.4 of Chapter 5. With every increase in loans, there is always a possibility that some of these loans would be NPLs. This whole system is shown in Figure 6.4.

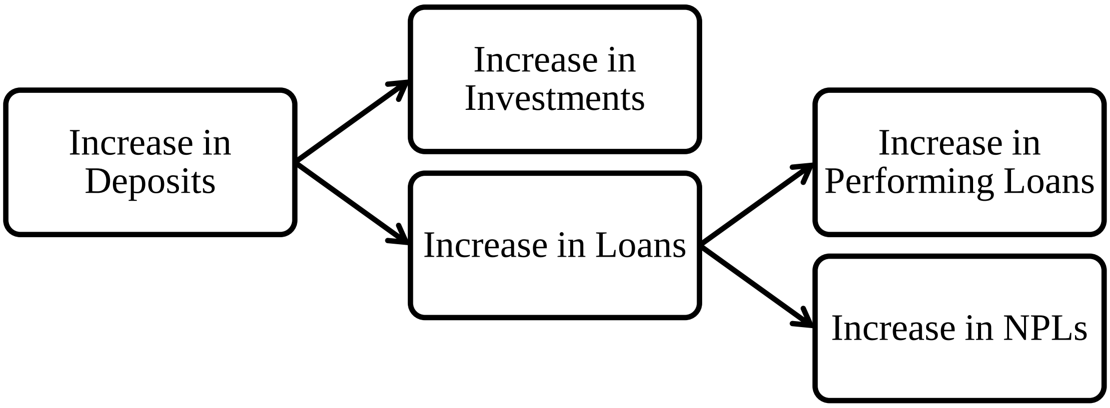

Figure 6. 4 The intermediation process of banks

6.3.1. Using Trade-Offs to Construct Weight Restrictions – An Illustration

To explain the process of developing and incorporating trade-offs in DEA multiplier model, we consider an illustration involving data from the banking sector which are actually a subset of the data set selected in the current study. Using that data, we first

[39] Substandard NPLs remain non-performing (interest/mark up or principal is overdue from the due date) for a period of 90 days or more. For this category, loan loss provision is maintained at 25% of the amount.
[40] Doubtful NPLs remain non-performing for a period of 180 days or more. For this category, loan loss provision is maintained at 50% of the amount.
[41] NPLs are declared as loss if they are non-performing for a period of 1 year or more and are identified as loss by the bank, internal or external auditor or central bank inspectors but that amount is not written off, wholly or partly. For this category, loan loss provision is maintained at 100% of the amount of loss.

develop trade-offs in envelopment model and then translate them into weight restrictions. Data set of this illustration is provided in the following Table.

Table 6. 1 Data used for illustration (figures in 100 million)

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans
A	23	16	838	66	400	249
B	197	178	14115	125	7971	5121
C	47	16	1257	110	498	436
D	16	12	706	21	479	216
E	242	110	8225	139	3812	3939
F	75	50	2763	93	880	1630
G	42	34	2489	5	1525	887
H	8	7	390	4	172	230

Data set consist of eight banks which use three inputs: physical capital, labour cost and deposits to produce three outputs: investments, loans and NPLs. As NPLs are a bad output so in this illustration they have been treated as input. Banks in this illustration differ in terms of operational activities and sizes so we are assuming VRS technology. Use of CRS is not always realistic in empirical applications because different factors such as imperfect competition, NPLs, regulatory changes, leverage concerns may cause banks to operate at sub-optimal level (Coelli et al., 2005). The output maximizing multiplier model (stated so because in envelopment model this is output oriented) with VRS technology for the efficiency assessment of bank A is provided as follows where weights of four inputs are represented by v_1 to v_4 and weights of two outputs are represented by u_1 and u_2:

Minimize $23v_1 + 16v_2 + 838v_3 + 66v_4 + u_0$ (6.1)

Subject to:

$400u_1 + 249u_2 = 1$

$400u_1 + 249u_2 - 23v_1 - 16v_2 - 838v_3 - 66v_4 - u_0 \leq 0$

$7971u_1 + 5121u_2 - 197v_1 - 178v_2 - 14115v_3 - 125v_4 - u_0 \leq 0$

$498u_1 + 436u_2 - 47v_1 - 16v_2 - 1257v_3 - 110v_4 - u_0 \leq 0$

$479u_1 + 216u_2 - 16v_1 - 12v_2 - 706v_3 - 21v_4 - u_0 \leq 0$

$3812u_1 + 3939u_2 - 242v_1 - 110v_2 - 8225v_3 - 139v_4 - u_0 \leq 0$

$880u_1 + 1630u_2 - 75v_1 - 50v_2 - 2763v_3 - 93v_4 - u_0 \leq 0$

$1525u_1 + 887u_2 - 42v_1 - 34v_2 - 2489v_3 - 5v_4 - u_0 \leq 0$

$172u_1 + 230u_2 - 8v_1 - 7v_2 - 390v_3 - 4v_4 - u_0 \leq 0$

$u_1, u_2, v_1, v_2, v_3, v_4, \geq 0,\ \ u_0$ is sign free

In this model, we have used linear multiplier form in which total weighted output is normalized. The term u_0 is the free variable which is dual to convexity constraint $\sum_{j=1}^{n} \lambda_j$ =1 of envelopment model. The efficiency of all banks along with their optimal weights are presented in Table 6.2 (all models in this chapter have been solved using excel solver and their results have been cross checked using DEA software Efficiency Measurement System (EMS)). Rounding of figures is avoided due to variation in weights allocated to different banks).

Table 6. 2 Efficiency scores and optimal weights with standard VRS model

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans	Efficiency (%)
A	0	0	0.0014847	0	0.001596342	0.0014561	78.45%
B	0	0	6.956E-05	0	0.000125456	0	100.00%
C	0	0.077248	0	0	0.000893909	0.0012739	87.70%
D	0	0	0.0012252	0	0.002088349	0	100.00%
E	0.0003472	0	0.0001105	0	0.000107765	0.0001496	100.00%
F	0.0010254	0	0.0003263	0	0.000318238	0.0004416	100.00%
G	0	0	0.0003952	0	0.000397045	0.000445	100.00%
H	0.006562	0	0.0020883	0	0.002036547	0.0028263	100.00%

Results indicate that six out of eight banks are efficient which clearly represent that this model is not sufficiently discriminating. Low discrimination in our model can be partly due to relatively large number of input/output variables as compared to number of banks under assessment. Some of the inputs and outputs have been assigned zero weight in the model which is another contributing factor towards low discrimination. For example banks B and D have attained 100% relative efficiency by assigning weight to just one input (deposits) and one output (investments) and assigned zero weight to the rest of the inputs and outputs. Assigning zero weights to three inputs (physical capital, labour cost and NPLs) and one output (loans) is equivalent to eliminating them from the assessment procedure which seems inappropriate and unrealistic if compared with real life production process of banks. Actually, not only zero but unreasonably small and large weight may also cause low discrimination (Podinovski, 2007b).

A traditional method, of handling the problems of zero weights and insufficient discrimination in optimal solution, is imposition of additional weight restrictions on input and output weights that hinder them to take zero values. Generally, these weights are assigned on the basis of perceived importance or monetary considerations. For example, in banking scenario if we consider perceived importance of outputs, then loans are more important than investments in the intermediation process and in terms of monetary considerations, loans generate more interest income as compared to investments due to their high interest rate. No doubt, the use of weight restrictions can improve the discrimination in the efficiency model however, the resulting efficiency results lose their technological meanings (Allen et al., 1997) and will no longer be interpreted as radial improvement factor (Podinovski, 2004). This problem with weight restrictions is observed due to the fact that weight restrictions are applied in DEA multiplier form, but the technological meanings of efficiency as a radial improvement factor are preserved in dual DEA envelopment form. Therefore, the best way, to handle problems associated with the traditional weight restrictions method, is first develop trade-offs in envelopment form and then translate them into equivalent weight restrictions in multiplier form in order to preserve the technological meanings of efficiency (Podinovski, 2004).

We incorporate weight restrictions in our chosen illustration by deriving them from identified production trade-offs. For this purpose, we consider linked[42] and non-linked homogenous[43] weight restrictions which can be represented in the following general form:

$$a_1u_1 + a_2u_2 - b_1v_1 - b_2v_2 - b_3v_3 - b_4v_4 \leq 0 \qquad (6.2)$$

where each of the coefficients a_1, a_2, b_1, b_2, b_3 and b_4 can be positive, negative or zero.

A complete model with weight restrictions is:

Minimize $23v_1 + 16v_2 + 838v_3 + 66v_4 + u_0$

Subject to:

$400u_1 + 249u_2 = 1$

$400u_1 + 249u_2 - 23v_1 - 16v_2 - 838v_3 - 66v_4 - u_0 \leq 0$

$7971u_1 + 5121u_2 - 197v_1 - 178v_2 - 14115v_3 - 125v_4 - u_0 \leq 0$

$498u_1 + 436u_2 - 47v_1 - 16v_2 - 1257v_3 - 110v_4 - u_0 \leq 0$

$479u_1 + 216u_2 - 16v_1 - 12v_2 - 706v_3 - 21v_4 - u_0 \leq 0$

$3812u_1 + 3939u_2 - 242v_1 - 110v_2 - 8225v_3 - 139v_4 - u_0 \leq 0$

$880u_1 + 1630u_2 - 75v_1 - 50v_2 - 2763v_3 - 93v_4 - u_0 \leq 0$

$1525u_1 + 887u_2 - 42v_1 - 34v_2 - 2489v_3 - 5v_4 - u_0 \leq 0$

$172u_1 + 230u_2 - 8v_1 - 7v_2 - 390v_3 - 4v_4 - u_0 \leq 0$

$a_1u_1 + a_2u_2 - b_1v_1 - b_2v_2 - b_3v_3 - b_4v_4 \leq 0 \qquad (6.3)$

$u_1, u_2, v_1, v_2, v_3, v_4 \geq 0,\ u_0$ is sign free

Dual of the Model (6.1) with weight restriction (6.2) is provided in the following envelopment model, where new variable ρ is dual variable corresponding constraint (6.2).

Maximize θ (6.4)

Subject to:

$400\lambda_1 + 7971\lambda_2 + 498\lambda_3 + 479\lambda_4 + 3812\lambda_5 + 880\lambda_6 + 1525\lambda_7 + 172\lambda_8 \quad + a_1\rho \geq 400\,\theta$

---

[42]Linked homogenous weight restrictions represent a linear homogenous relationship between at least one input and one output.

[43] A linear weight restriction is homogenous if it can be written as an inequality with a zero free constant (see Podinovski (2004)).

$249\lambda_1+5121\lambda_2+436\lambda_3+216\lambda_4+3939\lambda_5+1630\lambda_6+887\lambda_7+230\lambda_8 \quad +a_2\rho \quad \geq 249\,\theta$

$23\lambda_1+197\lambda_2+47\lambda_3+16\lambda_4+242\lambda_5+75\lambda_6+42\lambda_7+8\lambda_8 \quad +b_1\rho \quad \leq 23$

$16\lambda_1+178\lambda_2+16\lambda_3+12\lambda_4+110\lambda_5+50\lambda_6+34\lambda_7+7\lambda_8 \quad +b_2\rho \quad \leq 16$

$838\lambda_1+14115\lambda_2+1257\lambda_3+706\lambda_4+8225\lambda_5+2763\lambda_6+2489\lambda_7+390\lambda_8 +b_3\rho \quad \leq 838$

$66\lambda_1+125\lambda_2+110\lambda_3+21\lambda_4+139\lambda_5+93\lambda_6+5\lambda_7+4\lambda_8 \quad + b_4\rho \quad \leq 66$

$\sum_{j=1}^{8} \lambda_j = 1$

$\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6, \lambda_7, \lambda_8, \rho \geq 0$

θ Sign free

The left hand side (LHS) of this model represents the composite DMU (which in our case is a bank) formed by the combination of all observed DMUs with coefficients λ_j which is technologically possible in VRS technology. The last term in the composite unit is a production trade-off that modifies composite unit with the vector

$$(a_1, a_2, b_1, b_2, b_3, b_4)^T \tag{6.5}$$

multiplied by a factor $\rho \geq 0$.

This production trade-off modification represents that it is possible to simultaneously change the outputs by vector (a_1, a_2) provided the inputs are changed by the vector (b_1, b_2, b_3, b_4). If this trade-off is applied just once then ρ is equal to 1 otherwise it represents proportion (the number of times) in which a trade-off (6.5) is applied. While developing a trade-off our task is to ensure that this modification is meaningful and the resulting unit on the LHS is technologically feasible.

Without this additional last term (6.5), the composite unit on the LHS of the standard envelopment model (6.4) outperforms the unit on right hand side (RHS) in the weak sense of non-strict inequalities. That is why, the scaling factor θ is considered as output augmenting factor. If the task of developing feasible trade-off is achieved then the unit on the LHS would dominate the unit on RHS in weak sense and the meanings of θ would remain unchanged.

6.3.2. Development of Trade-Offs

Practically, many different trade-offs can be formulated in the same technology. Theoretically, trade-offs formulation does not necessitate the translation of trade-offs (6.5) into weight restrictions (6.2) because trade-offs can be incorporated exclusively either in envelopment or multiplier form and the solution of envelopment model (6.4) would generate the same efficiency results as solving multiplier model (6.3) with weight restrictions. However, we are using the trade-off approach in multiplier model due to two main reasons. Firstly, DEA software support weight restrictions but not trade-offs so we cannot cross validate our results of envelopment model obtained from general linear optimizer with results generated by DEA software. Secondly, optimal weights may provide a good idea regarding which weight restrictions or trade-offs are required to be formulated and what is the effect of their incorporation on optimal weights.

One important fact that we want to clarify before describing identified trade-offs, is that the process of developing trade-offs in multiplier form is not affected by the number of trade-offs developed. In case of multiple trade-offs, every trade-off is translated into equivalent weight restrictions added to standard DEA model in the form of separate constraint statement.

Major motivating factor behind the idea of application of trade-offs in our study is the development of a better informed model through the incorporation of banks' specific additional information in DEA model instead of handling the common problem of zero weights. Therefore, we consider our major objective of the study and illustrate how this will be accomplished through the DEATOB Framework.

6.3.2.1. Incorporation of Regulation and Loan Generating Capability

The incorporation of regulation and credit expansion capability as bank specific exogenous and endogenous factors into DEA model is the first element of our proposed DEATOB Framework. The trade-offs development process relating to these factors is explained in the following sections.

1. Trade-Off 1 – Liquidity Management Regulation as Exogenous Factor

Let us start the development of trade-offs for the DEATOB Framework by following the intermediation process depicted in Figure 6.4. We start with the first step of this process which shows that an increase in deposits brings about an increase in the amount of investments. Investing is not the core function of commercial banks according to the intermediation function, rather its basic purpose is to maintain liquidity on one hand, and diversify portfolio to avert risk on the other hand. Two kinds of regulatory requirements are attached with the amount of deposits. The first regulation is termed as cash reserve ratio (CRR) and the second is statutory liquidity ratio (SLR). CRR refers to that portion of bank's demand[44] and time[45] (with a tenor of less than one year) deposits which is kept with the State Bank of Pakistan[46] (SBP) as mandatory requirement. CRR serves dual purpose: first, it ensures that this portion of bank's deposits is risk free and second, this acts as tool of monetary policy for controlling supply of money and inflation by making it unavailable to banks for lending. Commercial banks do not earn any interest on this amount. Current CRR ratio for commercial banks is maintained as weekly average of 5%.

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[44]Demand deposit is a kind of deposit that is payable to customers on their demand.
[45] Time liabilities refer to the liabilities of commercial banks that they are liable to pay to the customers after a certain period mutually agreed upon such as after 6 months, 1 year etc. depending upon the term of deposit but not payable on demand.
[46] Central bank of Pakistan

SLR is the amount that commercial banks are required to maintain in the form of gold or government and approved[47] securities before providing credit to customers. It is determined as percentage of total demand and time liabilities (with a tenor of less than one year). SLR is determined and maintained by SBP to control the expansion of bank's credit and it implicitly ensures the solvency of commercial banks. For compliance of this regulation every banking company has to submit a weekly return to SBP. This means at the end of financial year this ratio would be maintained and reflected in the statement of financial position as the amount of investments held by banks. As in our chosen banking model, deposits are input and investments are output so among both deposit related regulations (CRR and SLR), SLR can be used to develop trade-off which is an exogenous factor that we translate into weight restriction.

There are few limitations regarding our data which we want to communicate before translation of SLR into trade-off. In our banking model we have used total deposits which are aggregate of time and demand deposits whereas, for SLR we need segregated data of demand and time deposits having a tenor of less than one year. Generally, annual reports of banks in Pakistan do not provide detailed segregation of time deposits on the basis of maturity time so we are unable to get this amount. Therefore, we use the amount of total deposits as input. On the output side, the amount of total investments has been used instead of splitting it into approved and non-approved securities in order to make this amount comparable with the total amount of deposits chosen as input. Another limitation of our data set is that it includes Islamic banks as well. Different rate of SLR has been set by SBP for Islamic banks. Current SLR is 19% for public and private commercial banks whereas 14% for Islamic banks.

[47] Approved securities mean bond and shares of different companies considered secure by SBP.

However, for our trade-off we even consider a smaller value of 10% to make it conservative and less demanding due to the formulation of relationship between total deposits and total investments. In fact, our purpose in this thesis is to devise a way to identify and develop trade-offs in banking sector. Therefore, instead of sticking to exact rate of SLR, exact amount of deposits on which this ratio is calculated and the exact nature of investments in the form of which this ratio is maintained our focus is on developing trade-off. However, if there is a large data set having same rate of SLR and segregation of term deposits then the developed trade-off would reflect the actual SLR. Trade-off with SLR can be defined as follows:

Judgment 1: Without requiring any additional resource, if the amount of deposits increases by 1 million, the amount of investments increases by 0.1 million (10% of increase in deposits).

In terms of notations presented in Model (6.4) this judgement can be written as follows:

$$(a_1, a_2, b_1, b_2, b_3, b_4) = (0.1, 0, 0, 0, 1, 0) \tag{6.6}$$

When we translate this notation into inequality (6.2) we get the following weight restriction statement:

$$0.1u_1 - 1v_3 \leq 0 \tag{6.7}$$

This trade-off implies that the weight ratio $\frac{v_3}{u_1}$ would be greater than or equal to 0.1. So instead of providing any arbitrary base for weight restriction on deposits and investments we have added a regulation that expands technology meaningfully.

Table 6. 3 Efficiency scores and optimal weights with Trade-Off 1

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans	Efficiency (%)
A	0	0	0.0014847	0	0.001596342	0.0014561	78.45%
B	0	0	7.014E-05	0	7.86466E-05	7.285E-05	100.00%
C	0	0.06725	0.0001295	0	0.00092477	0.0012387	86.21%
D	0	0	0.0013764	0	0.001479901	0.0013499	100.00%
E	0	0	0.000121	0	0.000121538	0.0001362	100.00%
F	0	0	0.0003557	0	0.000312221	0.0004449	100.00%
G	0	0	0.0003952	0	0.000397045	0.000445	100.00%
H	0	0	0.002317	0	0.002327869	0.0026092	100.00%

Results in Table 6.3 indicate that efficiency score of bank C decline and a positive optimal weight is assigned to all deposits as a result of incorporation of this trade-off.

2. Trade-Off 2 – Loan Generating Capability as Endogenous Factor

Now we consider the major banking function that is the core of intermediation process performed by banks, i.e. accepting deposits from individual and corporate customers and advancing loans. We again refer to Figure 6.4 which shows that increase in deposits increases the amount of loans. There is not any regulatory requirement regarding the floor (minimum limit) on advances to deposits ratio (ADR). However a ceiling (maximum limit) of 70%[48] has been imposed by SBP at advances to deposits ratio after excluding some specific kinds of loans[49] from advances category for the calculation of this ratio. So, how much loans a bank generates, depends not only on the demand for loans but also depends on the bank's strategy regarding its portfolio management or in other words how much it plans to invest in securities and other investments and how much it plans to advance as loans to private sector. That is why we have selected deposits to loans conversion as endogenous factor and formulated a trade-off for it.

[48] Please see BSD Circular No. 27 of 2008 issued by Banking Surveillance Department of SBP.
[49] Please see BSD Circular No. 28 of 2008 issued by Banking Surveillance Department of SBP.

A continuous decline has been observed in the ADR of banks since 2008 due to sluggishness in private sector credit and increasing lending of commercial banks to government in the form of investment in government papers as a result of their attractive rate of interest (State Bank of Pakistan, 2012a). Keeping in view this trend, we asked people from credit department of different banks regarding their attitude towards advancing loans. All of them agreed on ADR of at least 40% where advances include both performing loans and NPLs. So for developing our trade-off between deposits and loans we are using even conservative approach of 30% because in our model we develop a trade-off between deposits (input) and amount of performing loans (output) instead of total loans. We can define our trade-off as:

Judgement 2. Without requiring any additional resource, if the amount of deposits increases by 1 million, then the amount of loans increases by 0.3 million (30% of increase in deposits).

The notational representation of Model (6.4) for this judgement is as follows:

$(a_1, a_2, b_1, b_2, b_3, b_4)$ = (0, 0.3, 0, 0, 1, 0) (6.8)

The corresponding weight restrictions statement takes the form:

$$0.30u_2 - 1v_3 \leq 0 \quad (6.9)$$

Table 6. 4 Efficiency scores and optimal weights with Trade-Offs 1 and 2

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans	Efficiency (%)
A	0	0	0.0014847	0	0.001596342	0.0014561	78.45%
B	0	0	0.00007014	0	0.0000786	0.0000729	100.00%
C	0	0.050412	0.0003495	0	0.000989188	0.0011651	83.78%
D	0	0	0.0013764	0	0.001479901	0.0013499	100.00%
E	0	0	0.000121	0	0.000121538	0.0001362	100.00%
F	0	0	0.0003557	0	0.000312221	0.0004449	100.00%
G	0	0	0.0003952	0	0.000397045	0.000445	100.00%
H	0	0	0.002317	0	0.002327869	0.0026092	100.00%

Results in Table 6.4 show that bank C observed a further decline in the efficiency score as a result of incorporating endogenous factor relating to loan generating capability of banks.

3. Trade-Off 3 – Combined Effect of Exogenous and Endogenous Factors

In real life banking if the amount of deposits increases, it brings about a simultaneous increase in the amount of investments and loans. This fact combines the above mentioned two aspects which can also be meaningfully incorporated into a single trade-off. The combined trade-off can be restated as:

Judgment 3: Without requiring any additional resource, if the amount of deposits increases by 1 million, the amount of investments increases by 0.1 million (10% of increased amount of deposits) and the amount of loans increases by 0.3 million (30% of the increased amount of deposits).

The general form (6.2) enables us to specify two or more meaningful weight restrictions involving two or more weights in a single statement (Podinovski, 2007b). We can formulate the following trade-off which is fairly plausible:

$$(a_1, a_2, b_1, b_2, b_3, b_4) = (0.1, 0.3, 0, 0, 1, 0) \qquad (6.10)$$

This trade-off can be translated into the following weight restriction:

$$0.1u_1 + 0.30u_2 \; - 1v_3 \leq 0 \qquad (6.11)$$

In the above statement, weight restrictions are based on conservative judgment regarding increase in investments (10%) and increase in loans (30%). Although, it is possible to use more demanding ratios for investments and loans while developing trade-offs in order to make the model more discriminating. However, we are not doing this deliberately because we want to keep this model realistic without penalizing any bank.

Table 6. 5 Efficiency scores and optimal weights with Trade-Off 3

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans	Efficiency (%)
A	0	0	0.0014847	0	0.001596342	0.0014561	78.45%
B	0	0	7.014E-05	0	7.86466E-05	7.285E-05	100.00%
C	0	0.042648	0.0004492	0	0.000986151	0.0011686	82.60%
D	0	0	0.0013764	0	0.001479901	0.0013499	100.00%
E	0	0	0.000121	0	0.000121538	0.0001362	100.00%
F	0	0	0.0003557	0	0.000312221	0.0004449	100.00%
G	0	0	0.0003952	0	0.000397045	0.000445	100.00%
H	0	0	0.002317	0	0.002327869	0.0026092	100.00%

We can see from Table 6.5 that the combined effect of exogenous and endogenous factors in trade-off is more discriminating as compare to results of Trade-Offs 1 and 2 added one by one provided in Table 6.4. This is due to the fact that Trade-Off 3 is more complex and demanding as compared to Trade-Offs 1 and 2.

Now we explain the logic behind the improved discrimination of Trade-Off 3 with the help of general notations used for trade-offs in the envelopment form presented in Chapter 4 section 4.7.3. While constructing Trade-Off 1 (Model 6.7) we assume that increase in deposits, only increases investments without having any detrimental effect on loans. Changes in inputs (P_1) and outputs (Q_1) as a result of this trade-off can be expressed as:

$P_1 = (0, 0, 1, 0)$ and $Q_1 = (0.1, 0)$ (6.12)

Similarly, Trade-Off 2 (Model 6.9) creates a linkage between increase in deposits and increase in loans that can be expressed as:

$P_2 = (0, 0, 1, 0)$ and $Q_2 = (0, 0.3)$ (6.13)

P_2 and Q_2 represent changes in inputs and outputs respectively as a result of Trade-Off 2. According to Trade-Offs 1 and 2, we need two units of inputs if we want to increase both outputs (i.e. one input for one output in each case). The addition of both trade-offs would result into the following expression:

$P_1 + P_2 = (0, 0, 2, 0)$ and $Q_1 + Q_2 = (0.1, 0.3)$ (6.14)

However, the condition becomes more demanding in Trade-Off 3 (Model 6.11) where we consider that increase in investments and loans are observed simultaneously due to increase in deposits. The resulting changes in inputs ($P_{3)}$ and outputs (Q_3) are:

P_3 = (0, 0, 1, 0) and Q_3= (0.1, 0.3) (6.15)

This is apparent from expression (6.15) that Trade-Off 3 is more demanding as compared to Trade-Offs 1 and 2 because it requires increasing the same amount of outputs with only one million input.

6.3.2.2. Trade-Off 4 – Inclusion of Risk

In this section, we address the issue of poor loan quality and associated riskiness highlighted in the study (Chapter 2 section 2.9.1 and Chapter 3 section 3.4.1) by incorporating risk factor into the DEATOB Framework. In order to explain how we incorporate risk into the DEATOB Framework we refer to the last level of Figure 6.4. This indicates that every increase in the amount of loans actually increases the amount of both performing and non-performing loans. This model has incorporated NPLs to represent poor quality asset and their associated risk factor and treated them as input which is an established approach of treating bad output in literature as explained in Chapter 5 section 5.3.1.4.

The innovation of the DEATOB Framework in this study is to develop a linkage between NPLs (input) and loans (output) through production trade-offs. The need of this trade-off can also be judged from Table 6.2 where six banks have assigned zero weight to NPLs and a positive weight to loans whereas two units have assigned zero weight to both loans and NPLs. Although the latter situation has been removed by incorporating above mentioned trade-off however, the former situation is now applicable to all banks. To develop the linkage between NPLs and loans in the form of trade-off, we have to interview people from credit department who actually deal with the policies regarding loans. We tried to develop this trade-off by asking questions from experts in different ways but the most effective question that worked correctly for both of us (i.e. for us to convey the right idea behind the question and for them to understand and answer the question appropriately) is:

Q1. What is the expected rate of default for a loan advanced by bank?

We came up with different answers, depending upon the banks internal expectations other than the prudential regulations of loan loss provision[50] set by the SBP. Based on expert opinion, most relaxing range for the rate of loan default was 5%-20% of total loans whereas most restrictive range was 7%-10% of total loans. We have chosen the upper limit of the relax range i.e. 20%, while defining the trade-off because we have only performing loans at the output side of the model instead of gross loans. Another, reason for choosing this conservative limit for trade-off is to make it acceptable for all banks included in the sample. The trade-off for inclusion of asset quality/risk factor is defined as follows:

Judgement 4. Without claiming any extra resource, if the amount of loans increases by 1 million, the amount of NPLs increases by 0.2 million (20% of the increase in the amount of loans).

With this judgement we also assume at this stage that this change does not affect the amount of investments. The notational representation of Model (6.4) takes the following form as a result of judgement 4:

$(a_1, a_2, b_1, b_2, b_3, b_4)$ = (0, 1, 0, 0, 0, 0.2) (6.16)

[50] General provision is maintained at the rate of 0.1% of loans other than non-performing loans and consumer financing. General provision against the consumer financing is maintained at an amount equal to 1.5% of the fully secured performing portfolio and 5% of the unsecured performing portfolio as required by the Prudential Regulations 2011 issued by the State Bank of Pakistan whereas, the rate of specific provisions is provided in footnote 39, 40, and 41.

When we translate this notation into inequality (6.2) we get the following weight restrictions statement:

$$1u_2 - 0.2v_4 \leq 0 \qquad (6.17)$$

Table 6. 6 Efficiency scores and optimal weights with Trade-Off 4

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans	Efficiency (%)
A	0	0	0.001468	0	0.002502	0	71.84%
B	0	0	0.000070	0	0.000125	0	100.00%
C	0	0.079809	0.000201	0	0.002009	0	73.35%
D	0	0	0.001225	0	0.002088	0	100.00%
E	0	0	0.000105	0.000773	0.000103	0.000155	100.00%
F	0	0	0.000251	0.002928	0.000051	0.000586	100.00%
G	0	0	0.000364	0	0.000656	0	100.00%
H	0	0	0.002458	0.011695	0.002690	0.002339	100.00%

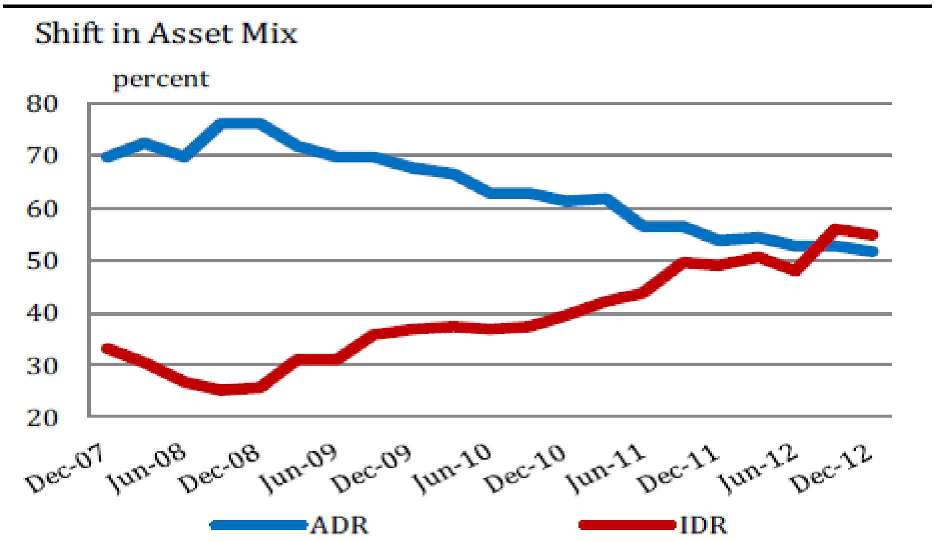
Addition of this Trade-Off with Trade-Off 3 has reduced the efficiency scores of both inefficient banks A and C. These results indicate that the discrimination of the model has improved.

6.3.2.3. Trade-Off 5 – Shift in Asset Mix as Bank Specific Characteristics

This set of trade-offs originated from an interesting development observed in the banking sector of Pakistan in the form of continuously declining ADR of banks since 2008, due to subdued allocation of credit to private sector. In contrast, investments to deposit ratio (IDR) is increasing due to the increasing appetite of banks for investments in government securities. Major reason signifying this portfolio shift is that government papers are a secure investment with attractive rate of interest where there is no fear of default and hence no accumulation of NPLs. However, some important facts can be observed as a result of this change in bank's portfolio management behaviour. First, it shows availability of sufficient loanable funds in banks, hence improve their liquidity. Second, it represents bank's growing risk aversion attitude towards private sector credit which is apparently riskier and seems less attractive when risk free investment with a decent rate of return is available. Third, it highlights a decline in banks' role of financial intermediary particularly in the perspective of socially and economically desirable allocation of funds[51] (State Bank of Pakistan, 2011a).

As a result of above mentioned trend, IDR of entire banking sector in Pakistan increased to about 55% whereas, on the flip side ADR observed a continuous decline after 2007 (State Bank of Pakistan, 2012b) as shown by Figure 6.5 below.

Figure 6. 5 Changing trend of advances to deposit ratio (ADR) and investments to deposit ratio (IDR)



Source: (State Bank of Pakistan, 2012b)

Above explanation indicates that banks have complete flexibility to choose between loans or investments depending on managements' preferences. This indicates that loans and investments can serve as a substitute for each other. We have considered this substitution effect as bank specific characteristic. This bank specific characteristic can be translated into two way relationships between investments and loans. The first trade-off relationship is the conversion of loans to investments and the second is

[51] Although conversion of deposits to any type of funding (i.e. government borrowing or private lending) is intermediation but lending to private sector increases economic activity and creates job opportunities.

conversion of investments into loans that are specified as Trade-Offs 5a and 5b respectively. The development need of these trade–offs can also be identified from Table 6.6 where most of the units have placed zero weight to loans. For formulating specific trade-offs in this respect we start with the conversion of loans into investments as Trade-Off 5a.

1. Trade-Off 5a – Increase in Investments and Decrease in Loans

In this section, we start with the conversion of loans into investments as Trade-Off 5a. This trade-off can be stated as:

Judgement 5. Without claiming any extra resource, if the amount of loans is decreased by 1 million, the amount of investments increases by 1 million.

The corresponding trade-off is:

$(a_1, a_2, b_1, b_2, b_3, b_4) = (1, -1, 0, 0, 0, 0)$ (6.18)

The equivalent weight restriction is:

$1u_1 - 1u_2 \leq 0$ (6.19)

Table 6. 7 Efficiency scores and optimal weights with Trade-Off 5a

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans	Efficiency (%)
A	0	0	0.0014718	0.0077129	0.001542576	0.0015426	56.80%
B	0	0	6.622E-05	0.0003819	7.63803E-05	7.638E-05	100.00%
C	0	0.04585	0.0004285	0.0053564	0.001071288	0.0010713	56.02%
D	0	0	0.0013735	0.0071976	0.001439515	0.0014395	88.01%
E	0	0	0.0001052	0.0007732	0.000102519	0.0001546	100.00%
F	0.002251	0	0.0001879	0.0028815	6.87898E-05	0.0005763	100.00%
G	0	0	0.0003595	0.0020735	0.000414691	0.0004147	100.00%
H	0	0	0.0019324	0.0164272	0.001420509	0.0032854	100.00%

These results indicate that the efficiency scores of already inefficient banks A and C further declined with the application of this trade-off. The bank D, one of the efficient banks with previous trade-offs, is no more efficient due to decrease in its efficiency score from 100% to 88.01%. Moreover, the model has assigned positive weights to investments and loans of all banks by the model.

2. Trade-Off 5b – Decrease in Investments and Increase in Loans

This Trade-Off is related to the conversion of investments into loans and is described in the form of second trade-off as follows:

Judgement 6. Without claiming any extra resource, if the amount of investments is decreased by 1 million, the amount of loans increases by 0.8 million.

This difference of 0.2 million in conversion from investments to loans is due to the increase in NPLs as a result of increase in loans for which we already have defined a trade-off as judgement 4. This trade-off generates the following notation for Model 6.4.

$$(a_1, a_2, b_1, b_2, b_3, b_4) = (-1, 0.8, 0, 0, 0, 0) \tag{6.20}$$

The resulting weight restriction is:

$$-1u_1 + 0.8u_2 \leq 0 \tag{6.21}$$

By combining Trade-Off 5a and 5b we obtain the weight ratio $u_1/\ u_2$ ranging from 0.8 to 1.

Table 6. 8 Efficiency scores and optimal weights with Trade-Off 5b

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans	Efficiency (%)
A	0	0	0.0014718	0.0077129	0.001542576	0.0015426	56.80%
B	0	0	6.622E-05	0.0003819	7.63803E-05	7.638E-05	100.00%
C	0	0.04585	0.0004285	0.0053564	0.001071288	0.0010713	56.02%
D	0	0	0.0013735	0.0071976	0.001439515	0.0014395	88.01%
E	0	0	0.0001082	0.0007154	0.00011446	0.0001431	98.28%
F	0	0	0.0003239	0.0021421	0.000342739	0.0004284	84.79%
G	0	0	0.0003595	0.0020735	0.000414691	0.0004147	100.00%
H	0	0	0.0022457	0.0136074	0.002177189	0.0027215	100.00%

By incorporating Trade-Off 5b, the number of efficient banks reduced from five (see Table 6.7) to three (see Table 6.8) as banks E and F are no more efficient. These results demonstrate that the discrimination of the model has improved significantly.

6.3.2.4. Additional Trade-Offs

In this section, we are presenting some additional production trade-offs that we have not used in our empirical analysis. However, we are describing the development procedure for these additional trade-offs in order to provide an idea, how these trade-offs are developed. The development process of these trade-off relationships is provided in the next sub sections.

1. Trade-Off 6 – Labour Versus Capital Trade-Offs

A composite form of computer and communication technology, known as information technology (IT), has fundamentally transformed the way banking is performed by both bankers and customers. From banker perspective although, there is no change in basic banking functions performed by banks however, the way of providing different banking services is completely transformed. Extensive application of IT in banking operations has improved the quality of banking services significantly by minimizing manual work, providing timely information online, creating centralized data repositories and introducing innovative banking products. From customers' point of view important benefits are availability of mobile, internet and ATM banking anywhere in the world.

No doubt, this increasing computerization and automation is easing the life of bankers nevertheless, it has created multiple threats for banking sector employees in the form of retrenchment, barriers to new job opportunities and demand for highly skilled IT professionals. This is due to the fact that introduction of IT in operations has increased productivity of labour force that requires less number of employees to do a particular job in comparison to number of employees required for manual completion of the same job.

Taking into account the number of employees required to perform a task manually, in comparison to computer aided work (labour – capital substitution effect), we have formulated labour versus capital (as computer technology requires capital) trade-offs. The need for these trade-offs is also obvious from Table 6.8 where DEA model has assigned zero weight to physical capital and labour of almost all the units. While developing these trade-offs we have kept in mind the depreciation rate of computer technology (25% per year) and linked it with the labour cost as we are not using the number of labour. For this purpose, we consider that the average salary of one person is equal to Rs. 20,000 per month (or Rs. 240,000 per annum which is an average salary at OG III[52] in the banking sector of Pakistan) and then compare it with the spending on computer technology. The straight line depreciation rate of 25% on computers indicates that computers become obsolete in four years. Therefore we have compared the cost of computers with the four years average salary of one employee (approximately 0.9 million). This labour–capital substitution can be two way, i.e. substitution of labour with capital and substitution of capital with labour. We start with the substitution of labour with capital and develop the following trade-off statement.

Judgement 7. Without changing outputs, if the amount of physical capital is increased by 1 million, the amount of labour cost decreases by 0.9 million (cost of one person for four years).

The corresponding trade-off is:

$$(a_1, a_2, b_1, b_2, b_3, b_4) = (0, 0, 1, -0.9, 0, 0) \qquad (6.22)$$

[52] OG III means Officer Grade III which is a minimum level of banking professionals in Pakistan.

The equivalent weight restriction is:

$$-1v_1 + 0.9v_2 \leq 0 \qquad (6.23)$$

The substitution of capital with labour can be stated in the form of trade-off as:

Judgement 8. Without changing outputs, if the amount of physical capital is decreased by 1 million, the amount of labour cost increases by 1.5 million (cost of one full time and one part time person for four years).

The corresponding trade-off is:

$$(a_1, a_2, b_1, b_2, b_3, b_4) = (0, 0, -1, 1.5, 0, 0) \qquad (6.24)$$

The equivalent weight restriction is:

$$1v_1 - 1.5v_2 \leq 0 \qquad (6.25)$$

As automation and computerization increases the productivity level of one person so while developing above trade-off we have considered the number of labour replacement[53] with sophisticated computer systems very conservatively. These two trade-offs represents that the ratio of weights $\frac{v_1}{v_2}$ ranges from 0.9 to 1.5.

Table 6. 9 Efficiency scores and optimal weights after incorporating Trade-Offs 6a and 6b

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans	Efficiency (%)
A	1.86E-16	2.83E-16	0.0014718	0.0077129	0.001542576	0.0015426	56.80%
B	0.001536	0.001024	3.273E-05	0.000428	7.04523E-05	8.561E-05	100.00%
C	1.29E-16	1.97E-16	0.0010221	0.0053564	0.001071288	0.0010713	52.96%
D	1.68E-16	2.66E-16	0.0013735	0.0071976	0.001439515	0.0014395	88.01%
E	8.09E-17	3.72E-17	0.0001082	0.0007154	0.00011446	0.0001431	98.28%
F	2.45E-16	1.21E-16	0.0003239	0.0021421	0.000342739	0.0004284	84.79%
G	0.009111	0.006074	0.0001659	0.0020735	0.000414691	0.0004147	100.00%
H	0.054688	0.036459	0.0009956	0.0124453	0.002489054	0.0024891	100.00%

It is apparent from the above table that the discrimination of model is further improved. Moreover, physical capital and labour cost are assigned positive optimal

[53]Based on the routine practice in Pakistan we assume that one part time employee cost half of the amount of one full time employee.

weights. However, most of these weights are extremely small which is due to their small data values as compared to values of the rest of the input and output variables. These labour-capital trade-offs are not confined to the banking industry only, rather are equally applicable to other organizations.

2. Trade-Off 7 – Decrease in Deposits

Deposits are a unique item in the balance sheet of banks that differentiate them from other types of business organizations. Deposits serve as a foundation for banks upon which they thrive and grow. These are the main raw material of banks in the intermediation process to generate investments and loans, thus are considered the ultimate source of banks profit and growth. Therefore, banks always try to increase them in order to increase their investments and loans which in turn, generate more income for banks in the form of interest.

However, sometimes banks may experience a decrease in deposits due to different reasons such as pre-mature withdrawal of term deposits, decrease in deposit rate, change in the consumer behaviour and in response to certain events when consumers tend to spend instead of saving. The liquidity gap created as a result of the deposit drain can be filled through internally available resources (such as cash reserve, investments and call money[54]) or external resources such as borrowing from other banks. Major deciding factors while choosing among different available options is the nature (short term or long term) and quantity of deposit drain. The first resort is internally available funds in the form of cash, investments and call money. If the liquidity need is not met through cash and call money (depends on availability of both these resources) then investments are sold. However, in case of short term need, the

[54] Call loan is a loan which is repayable on demand.

yield on investments is compared with the money market[55] lending rate before selling investments. If funds from money market are available at a lower rate than the yield of investment, then money is borrowed from money market instead of selling investments otherwise, investments are sold. If the quantity of drain is large, then a combination of different resources may be used to fill the liquidity gap (proportion of different resources may vary from bank to bank according to their financial position and preferences).

For developing trade-off, we assume that banks are capable of financing their deposit drain from internal resources because they are maintaining a mandatory level of CRR, SLR as well as capital adequacy ratio[56] (CAR) and minimum capital requirement[57] (MCR) imposed by SBP on all commercial banks under implementation process of Basel Accord I, II and III. Based on the above discussion, we can say that decrease in deposits brings about a subsequent decrease in investments and loans (two outputs used in intermediation model).

We contacted banking professional from different banks to develop the trade-off based on the routine of financing deposit drain through internal source of financing. However, by interviewing them we arrive at a consensus that a decrease in deposits is normally met through around 45% to 50% decrease in investments and about 1% to 2% decrease in loans (call money) whereas the rest of the amount is repaid through other sources of funds available to banks internally. Decrease in investments has a higher percentage than loans because it is easy to encash investments as compared to

[55] Money market is a segment of the financial market where financial instruments with high liquidity and very short maturities are traded. It is used by participants as a means for lending and borrowing in the short term, ranging from several days to less than one year.

[56] Capital adequacy ratio is the ratio of banks capital to risk weighted assets. For detail see SBP BPRD Circular No. 06 dated August 15, 2013 by Banking Policy and Regulations Department.

[57] Minimum capital requirement is the minimum amount of capital required to be maintained by the banks in Pakistan according to the prudential regulations of SBP. See BSD Circular No. 07 of 2009 by Banking Surveillance Department of SBP.

loans. To capture this decreasing effect of deposits we have developed the following trade-off.

Judgment 9: Without requiring any additional resource, if the amount of deposits decreases by 1 million, the amount of investments decreases by 0.45 million (45% of decrease in deposits) and the amount of loans decreases by 0.01 million (1% of decrease in deposits).

The resulting trade-off can be written as:

$(a_1, a_2, b_1, b_2, b_3, b_4)$ = (-0.45, -0.01, 0, 0, -1, 0) (6.26)

The trade-off statement takes the following form in weight restriction:

$$-0.45u_1 - 0.01u_2 + 1v_3 \leq 0 \quad (6.27)$$

Table 6. 10 Efficiency scores and optimal weights after incorporating Trade-Off 7

Bank	Physical Capital	Labour Cost	Total Deposits	NPLs	Investments	Loans	Efficiency (%)
A	0.024608	0.027343	0.0007096	0.0077129	0.001542576	0.0015426	48.88%
B	0.001319	0.001465	3.055E-05	0.0003819	7.63803E-05	7.638E-05	100.00%
C	0.01709	0.018989	0.0004928	0.0053564	0.001071288	0.0010713	43.87%
D	0.022964	0.025516	0.0006622	0.0071976	0.001439515	0.0014395	80.27%
E	0.002027	0.002252	5.394E-05	0.0007044	0.000116729	0.0001409	78.01%
F	0.006098	0.006776	0.0001623	0.0021193	0.000351197	0.0004239	68.80%
G	0.007161	0.007957	0.0001659	0.0020735	0.000414691	0.0004147	100.00%
H	0.03995	0.044389	0.0010282	0.0134283	0.002225261	0.0026857	100.00%

It is evident from the table that the incorporation of this trade-off has further reduced the efficiency scores of banks A, C, D, E and F. Moreover, this trade-off has also resolved the problem of allocating very small weights to labour cost and physical capital. Above all, the discrimination of the model has improved significantly.

3. Trade-Off 8 – Decrease in Loans and NPLs

We have already provided Trade-Off 4 for increase in loans and a subsequent increase in NPLs in section 6.3.2.2 above. However, there is also a possibility of decrease in the amount of loans as a result of retirement of old loans and reluctance of banks to advance further loans to private sector. The decrease in the amount of NPLs is observed in two cases; first, if loans from the loss category of NPLs are written off and second, if NPLs are rescheduled/restructured and they move from non-performing category to performing category. We are not considering the second case because this situation arises only in few special cases and consequently, NPLs decrease and loans increase. However, the first situation is very common in the normal course of banking operations. With the decrease in the amount of loans, a range of 0.1% to 1% decrease in NPLs to loans ratio was agreed by banking professionals. Considering the lower limit for this range we have formulated another trade-off regarding linkage between NPLs and loans which is stated as:

Judgement 10. Without claiming any extra resource, if the amount of loans decreases by 1 million, the amount of NPLs decreases by 0.001 million (0.1% of decrease in the amount of loans.

Judgement 10 can be written as follows:

$(a_1, a_2, b_1, b_2, b_3, b_4)$ = (0, -1, 0, 0, 0, -0.001) (6.28)

The related weight restriction statement is:

$$-1u_2 + 0.001v_4 \leq 0 \quad (6.29)$$

A range of 0.001 to 0.1 is obtained for the weights ratio u_2/v_4 by combining Trade-Offs 4 and 8.

Table 6. 11 Efficiency scores and optimal weights after incorporating Trade-Off 8

Bank	Physical Capital	Labour Cost	Total Deposits	Net NPLs	Investments	Loans & Advances	Efficiency (%)
A	0.024608	0.027343	0.0007096	0.0077129	0.001542576	0.0015426	48.88%
B	0.001655	0.001103	3.055E-05	0.0003819	7.63803E-05	7.638E-05	100.00%
C	0.01709	0.018989	0.0004928	0.0053564	0.001071288	0.0010713	43.87%
D	0.022964	0.025516	0.0006622	0.0071976	0.001439515	0.0014395	80.27%
E	0.002027	0.002252	5.394E-05	0.0007044	0.000116729	0.0001409	78.01%
F	0.006098	0.006776	0.0001623	0.0021193	0.000351197	0.0004239	68.80%
G	0.008987	0.005991	0.0001659	0.0020735	0.000414691	0.0004147	100.00%
H	0.049065	0.03271	0.0010282	0.0134283	0.002225261	0.0026857	100.00%

Results in Table 6.11 show that this Trade-Off does not affect the efficiency scores and weight profile of banks. We are not changing the values of this Trade-Off to a stricter range just for the sake of making changes in the efficiency scores because this was not acceptable by the banking professionals with whom we discussed our trade-offs to refine them.

However, we are still providing this trade-off considering the fact that DEA is data driven technique and the trade-off which is not affecting efficiency scores with our data set may make a change in the weight profile or efficiency scores with any other data set. It is also possible that a stricter range can be applied in any other financial environment which may improve the discrimination of the efficiency scores.

6.4. Different Types of Trade-Offs and their Development Methods

Previous sections have explained the development process of different trade-offs that collectively form the DEATOB Framework. It has been shown with the help of an illustration that the DEATOB Framework incorporated additional information about different banking operations into standard DEA model to create a better informed DEA model for efficiency evaluation of banks.

All the trade-offs which are developed for the DEATOB Framework, actually specify three distinct types of production trade-off relationships. The first kind represents production trade-offs between input variables and example of such trade-offs is the two way relationship between physical capital and labour provided in Trade-Off 6. The second type of production trade-offs are defined between output variables which are represented by two way trade-off relationships between investments and loans as Trade-Off 5. The final category of trade-offs is defined between input and output variables and include:

1. Two way trade-offs relationship between NPLs (input) and loans (output) in the form of Trade-Offs 4 and 8.
2. Two way trade-offs relationship of deposits (input), with investments (output) and loans (output) presented as Trade-Offs 3 and 7.

These three forms covers all the possible types of trade-offs as depicted in the following figure.

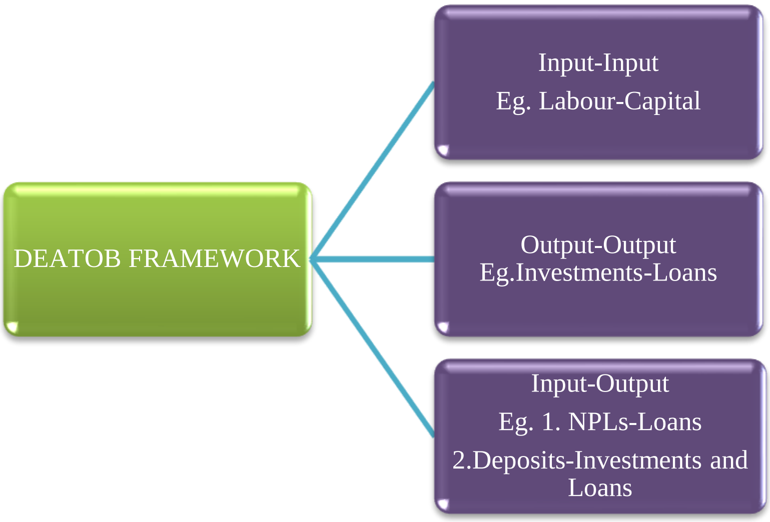


Figure 6. 6 The nature of trade-offs used in the DEATOB Framework

However, different methods of trade-offs identification and quantification have also been highlighted during the development process of the DEATOB Framework that are not based on the perceived importance or monetary consideration of the variables. Trade-offs are derived from the transformation process of the firms under evaluation.

A clear understanding of the transformation process facilitates the trade-offs identification process. For example, in the banking context, we have used the intermediation process for the identification of the Trade-Offs 1,2,3,7 and 8. In addition, any special trend in the industry under study may serve as the base for the development of the trade-offs such as we have used the shift in asset mix of banks to develop Trade-Off 5. Moreover, any technological change may serve this purpose such as advanced computer system that may replace the manpower in any industry as described in Trade-Off 6. Sometimes, researchers' intuition may identify any trade-off between different variables based on their knowledge and expertise.

Similarly, the values of trade-offs can be quantified in a meaningful way from many sources. The first important source is, the knowledge about actual banking practices that can be derived from the theory existing on those practices such as deposits are used to create loans and investments. The second important source is the regulations that govern different banking operations such as regulation regarding liquidity requirement for the minimum amount of investments used in the study for developing Trade-Off 1. The third important source is different rates used in the banking sector with regards to various activities carried out in the real life banking such as the rate of loan loss provision and the interest rates on deposits, loans, and investments (these rates are used for the development of trade-offs in the next chapter). The fourth source is the expert opinion of bankers on the matters about which there is not any special regulation or specified rate such as the expected rate of NPLs for any loan advanced by bank as used in Trade-Off 4. The final source that we have used in our study is the ratios existing between different variables that also provide an idea about the range of values that can be used while deciding values for trade-offs such as the rate of NPLs to performing loan ratio used to confirm the actual situation of NPLs in each bank.

However, the methods of identification and quantification may vary with the industry and the availability of sources.

6.5. Formulation of the Complete DEATOB Framework for the Illustration

A complete DEA model with all the trade-offs of the DEATOB Framework for illustration is presented below in multiplier form with all kinds of trade-off relationships translated into weight restrictions.

Minimize $23v_1 + 16v_2 + 838v_3 + 66v_4 + u_0$ (6.30)

Subject to:

$400u_1 + 249u_2 = 1$

$400u_1 + 249u_2 - 23v_1 - 16v_2 - 838v_3 - 66v_4 - u_0 \leq 0$

$7971u_1 + 5121u_2 - 197v_1 - 178v_2 - 14115v_3 - 125v_4 - u_0 \leq 0$

$498u_1 + 436u_2 - 47v_1 - 16v_2 - 1257v_3 - 110v_4 - u_0 \leq 0$

$479u_1 + 216u_2 - 16v_1 - 12v_2 - 706v_3 - 21v_4 - u_0 \leq 0$

$3812u_1 + 3939u_2 - 242v_1 - 110v_2 - 8225v_3 - 139v_4 - u_0 \leq 0$

$880u_1 + 1630u_2 - 75v_1 - 50v_2 - 2763v_3 - 93v_4 - u_0 \leq 0$

$1525u_1 + 887u_2 - 42v_1 - 34v_2 - 2489v_3 - 5v_4 - u_0 \leq 0$

$172u_1 + 230u_2 - 8v_1 - 7v_2 - 390v_3 - 4v_4 - u_0 \leq 0$

$0.1u_1 + 0.30u_2 - 1v_3 \leq 0$ (Judgement 3-Model 6.11)

$1u_2 - 0.2v_4 \leq$ (Judgement 4-Model 6.17)

$1u_1 - 1u_2 \leq 0$ (Judgement 5-Model 6.19)

$-1u_1 + 0.8u_2 \leq 0$ (Judgement 6-Model 6. 21)

$-1v_1 + 0.9v_2 \leq 0$ (Judgement 7-Model 6.23)

$1v_1 - 1.5v_2 \leq 0$ (Judgement 8-Model 6.25)

$-0.45u_1 - 0.01u_2 + 1v_3 \leq 0$ (Judgement 9-Model 6.27)

$-1u_2 + 0.001v_4 \leq 0$ (Judgement 10-Model 6.29)

$u_1, u_2, v_1, v_2, v_3, v_4 \geq 0$, u_0 is sign free

6.6. Limitations of the DEATOB Framework

Despite having the ability to incorporate several bank specific characteristics and providing significant improvement in the discriminatory power of DEA model, the DEATOB Framework has some limitations. These limitations are mainly the limitations associated with the underlying banking models and the underlying technique of the framework i.e. the trade-off approach used in the current study.

The first limitation is that this framework cannot incorporate all the exogenous and endogenous factors in the evaluation models because these factors are incorporated with the help of variables and the relationship between these variables. In terms of selection of variables, the banking models chosen in the study cover only a limited number of variables depending on their underlying philosophy hence are unable to accommodate all the possible exogenous and endogenous factors. In terms of trade-off relationships, production trade-offs can only be established among variables selected for the banking model. Therefore, trade-offs among variables are confined to the variables included in the banking models and cannot provide any technological judgment about the relationship of these variables with the variables excluded from the model.

The second critique about the DEATOB Framework in the banking context may be that the constituent production trade-offs of the framework are based on researchers apprehension of the banking activities that can lead to the identification of dissimilar trade-offs by different researchers in the same banking system.

Lastly, values of production trade-offs in the framework are dependent on the researchers' preference of selecting more demanding or conservative values for the identified production trade-offs. This means that different researchers can use non identical values for identical trade-offs in the same banking system that may lead to different efficiency levels of the same bank.

6.7. Conclusion

This chapter has explained the conceptual framework built around the motivation of the current study. The DEATOB Framework is a combination of different trade-offs that have been developed through a multistage process in order to create a better informed DEA model. Different aspects of banking intermediation process have been covered in these trade-offs by categorising them into exogenous and endogenous factors, risk and bank specific characteristics. To clarify the purpose and importance of each trade-off a detailed explanation for the identification and evaluation of each trade-off relationship is provided. The development of trade-offs on operational realities of banking activities provided in this chapter is in line with the ideology of technological judgements behind the concept of production trade-offs.

For the incorporation of trade-offs, we have selected multiplier DEA model therefore, precise statements for trade-off relationships are described in this chapter with their translation into equivalent weight restrictions. This chapter has provided mathematical formulation and application of the trade-offs side by side in order to show the impact of trade-offs on DEA model and efficiency scores respectively. Results obtained from the incorporation of trade-offs represented that weight profile of all banks significantly improved with all positive weights assigned to inputs and outputs used in the model. Moreover, discrimination of the model also improved. These results confirm that production trade-offs meaningfully add additional information in the DEA model on one hand and improve the discrimination of the efficiency scores on the other hand.

This chapter has covered the development process of all the possible categories of trade-off relationships in a DEA model to clarify the development process of all kinds of trade-off relationships that may exist in the real life situation. Moreover, different methods of trade-offs' identification and quantification, used in the study, are also summarized in the chapter. This chapter also highlights some of the limitations associated with the DEATOB Framework. The next chapter provides the empirical application of the DEATOB Framework on the data of Pakistani commercial banks.

CHAPTER 7

EMPIRICAL ANALYSIS

7.1. Introduction

In Chapter 6 we have explained the development of the DEATOB Framework with an example of subset of banks. In this chapter, we consider complete data set of banks for the year 2012 and provide the empirical application of the proposed DEATOB Framework in order to achieve the second objective of the current study. Empirical analysis starts with the evaluation of the banking sector under the standard output oriented VRS model that provides results without our proposed framework. In this chapter we employ two different ways to assess the impact of the DEATOB Framework on the banking efficiency. In the first way, the impact of each constituent trade-off of the framework is evaluated independently by incorporating it in the standard VRS model and comparing the efficiency scores so obtained with the efficiency scores of standard VRS model. In the second way, all trade-offs of the framework are gradually incorporated in the standard VRS model and their aggregate impact is investigated by examining the variations taking place in the efficiency scores with each additional trade-off. This chapter also examines the relationship of efficiency scores with the ownership type and size of banks. Finally, we provide scale efficiency and RTS characteristics of the all the banks after application of the DEATOB Framework.

7.2. Analysis with Standard DEA Model

After developing the DEATOB Framework, the next objective is to investigate the impact of the proposed DEATOB Framework on the efficiency of banking sector. For this purpose, we have chosen output oriented standard DEA model with VRS assumption as the basic model and used it for the incorporation of trade-offs restrictions designed for the DEATOB Framework. Moreover, the results obtained with this model serve as the base efficiency scores before incorporation of the DEATOB Framework.

The summary of output improvement factor (DEA scores) and efficiency scores (represented by ϕ and $1/\phi$ respectively as explained in Chapter 4 section 4.5.1) for all banks obtained through the application of standard, output oriented, VRS model are provided in Table 7.1. The last few rows of the table show the descriptive statistics of banks such as mean, minimum, and maximum of both DEA and efficiency scores. Instead of following the alphabetical order, banks are arranged according to their ownership type in this table. The first twenty two banks are private domestic banks where the first five are Islamic banks and the rest of the seventeen are standard private commercial banks for which we have used the term private domestic banks. The next four (23-26) banks are public banks which are followed by three (27-29) foreign banks.

Table 7. 1 Standard improvement factor (DEA scores) and radial output efficiency of banks with the standard VRS model under intermediation approach

S.No.	Bank	DEA Scores	Efficiency Scores	S.No.	Bank	DEA Scores	Efficiency Scores
1	Al Baraka Bank Pakistan Ltd.	1.121	89.24%	16	NIB Bank Ltd.	1	86.33%
2	Bank Islami Ltd.	1	100%	17	Samba Bank Ltd.	1.158	100%
3	Burj Bank Ltd.	1	100%	18	Silk Bank Ltd.	1	95.57%
4	Dubai Islamic Bank Ltd.	1.235	80.99%	19	Soneri Bank Ltd.	1.046	100%
5	Meezan Bank Ltd.	1	100%	20	Standard Chartered Bank Pakistan Ltd.	1	100%
6	Allied Bank of Pakistan Ltd.	1	100%	21	Summit Bank Ltd.	1	74.97%
7	Askari Commercial Bank Ltd.	1.084	92.28%	22	United Bank Ltd.	1.334	100%
8	Bank Al Falah Ltd.	1.029	97.20%	23	Bank of Punjab	1	100%
9	Bank Al Habib Ltd.	1	100%	24	Bank of Khyber	1	100%
10	Faysal Bank Ltd.	1	100%	25	First Women Bank Ltd.	1	100%
11	Habib Bank Ltd.	1	100%	26	National Bank of Pakistan	1	100%
12	Habib Metropolitan Bank Ltd.	1	100%	27	Barclays Bank PLC Pakistan	1	100%
13	JS Bank Ltd.	1	100%	28	Citi Bank	1	100%
14	KASB Bank Ltd.	1.376	72.68%	29	HSBC	1	100%
15	Muslim Commercial Bank Ltd.	1	100%				
	Mean	1.05	96.18%		**Maximum**	1.38	100%
	Minimum	1	72.67%		**Number of Efficient Banks**	21	21

According to Table 7.1, twenty one banks are efficient in a sample of twenty nine banks indicating that standard VRS model is not sufficiently discriminating the efficiency scores of banks. DEA scores represent the existence and degree of output inefficiency that reflects the potential for banks to improve their output level given input level. Mean DEA score of 1.05 suggests that on average banks in Pakistan have to increase their outputs by 1.05 times of their current output level. The least efficient bank has to increase its outputs by 1.376 times of its existing output level in order to be as efficient as the best practices banks in the banking industry.

While solving DEA model, input-output factors attain weights that represent the bank in the best possible light in comparison to the other banks. These weights in DEA models are flexible. Therefore, DEA model tend to choose high weight for that output which is large in quantity and assign low weights to other outputs. Similarly, high weight is assigned to that input which is having small quantity and relatively low weights are assigned to the rest of the inputs. We also observe many outputs with zero weights. Assignment of zero weights to any input or output is equivalent to leaving out that particular input/output from the analysis. Table 7.2 represents a summary of zero weights assigned to inputs and outputs in the standard DEA model. In order to deal with the problem of assigning significantly low and zero weights and to include meaningful additional information in the standard VRS model, we are using the DEATOB Framework proposed by the current study. Empirical analysis with the DEATOB Framework is described in detail in the forthcoming sections.

Table 7. 2 The number of zero weights assigned to inputs and outputs with standard VRS model

Inputs/Outputs		Number of Zero Weights
Inputs	Physical Capital	13
	Labour Cost	12
	Deposits	9
	NPLs	18
Outputs	Investments	12
	Loans	8

7.3. Analysis with Independent Incorporation of Trade-Offs

7.3.1. Trade-Offs 1 and 2 – Incorporation of Liquidity Requirement and Loans Generating Capability

Trade–Off 1 is based on the banking regulation regarding the liquidity requirement in the intermediation process and represents an exogenous factor. The application of this Trade-Off does change the weight profile of few banks but does not change the number of efficient banks and efficiency scores. However, unaltered efficiency scores do not mark this trade-off useless. DEA is a data driven approach therefore, this Trade-Off can bring about changes in the efficiency scores with a different data set. This fact is obvious in the illustration provided in Chapter 6 where data are actually a subset of original banking data. Moreover, the sequential addition of this Trade-Off after Trade-Off 2 makes change in the efficiency scores as we will demonstrate in section 7.4 of this chapter.

Table 7.3 provides results with the incorporation of Trade-Off 2 related to the core intermediation function of banks (i.e. advancing of loans) considering it an endogenous factor for the banking operations. Application of this Trade-Off reduces the number of efficient banks from 21 to 20 by eliminating Bank of Punjab from the list of efficient bank. Average efficiency score declines from 96.18% to 95.86% due to the decrease in the efficiency scores of 4 banks that include: Al Baraka Bank, Dubai Islamic Bank, Bank Al Falah and Bank of Punjab. Highest decline of 3.46 percentage points occurs in the efficiency scores of Dubai Islamic Bank.

Table 7. 3 Efficiency scores with and without Trade-Off 2

Bank	Efficiency Scores without TO	Efficiency Scores with TO 2	Percentage Points Change
Al Baraka Bank Pakistan Ltd.	89.24%	88.53%	0.70%
Bank Islami Ltd.	100.00%	100.00%	0%
Burj Bank Ltd.	100.00%	100.00%	0%
Dubai Islamic Bank Ltd.	80.99%	77.53%	3.46%
Meezan Bank Ltd.	100.00%	100.00%	0%
Allied Bank of Pakistan Ltd.	100.00%	100.00%	0%
Askari Commercial Bank Ltd.	92.28%	92.28%	0%
Bank Al Falah Ltd.	97.20%	94.04%	3.16%
Bank Al Habib Ltd.	100.00%	100.00%	0%
Faysal Bank Ltd.	100.00%	100.00%	0%
Habib Bank Ltd.	100.00%	100.00%	0%
Habib Metropolitan Bank Ltd.	100.00%	100.00%	0%
JS Bank Ltd.	100.00%	100.00%	0%
KASB Bank Ltd.	72.68%	72.68%	0%
Muslim Commercial Bank Ltd.	100.00%	100.00%	0%
NIB Bank Ltd.	86.33%	86.33%	0%
Samba Bank Ltd.	100.00%	100.00%	0%
Silk Bank Ltd.	95.57%	95.57%	0%
Soneri Bank Ltd.	100.00%	100.00%	0%
Standard Charted Bank Pakistan Ltd.	100.00%	100.00%	0%
Summit bank Ltd.	74.97%	74.97%	0%
United Bank Ltd.	100.00%	100.00%	0%
Bank of Punjab	100.00%	97.88%	2.12%
Bank of Khyber	100.00%	100.00%	0%
First Women Bank Ltd.	100.00%	100.00%	0%
National Bank of Pakistan	100.00%	100.00%	0%
Barclays Bank PLC Pakistan	100.00%	100.00%	0%
Citi Bank	100.00%	100.00%	0%
HSBC	100.00%	100.00%	0%
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	21	20	4
Average Efficiency Score	96.18%	95.86%	

7.3.2. Trade-Off 3 – Liquidity Requirement and Loans Generating Capability Combined in One Statement

Results of the analysis, performed by incorporating loans generating capability (endogenous factors) and liquidity requirement (exogenous factors) together in one equation (for detail see section 6.3.2.1 (3) of Chapter 6) are provided in Table 7.4. Results indicate that after accounting for endogenous and exogenous factors the number of efficient banks has reduced from 21 to 20. Bank of Punjab becomes an inefficient bank with highest decrease of 5.66 percentage points in the efficiency score. Moreover, three inefficient banks (Al Baraka Bank, Dubai Islamic Bank and Bank Al Falah) have observed a decline in their efficiency scores. However, Trade-Off 3 brings about a larger decrease in the efficiency scores of all four banks as compared to Trade-Off 2, despite the fact that Trade-Off 1 alone does not change efficiency scores. There are two main reasons for this change in efficiency scores. First, the standard model assigns zero weight to one or more from deposits (input), investments and loans that transform to positive weights with this Trade-Off, as seen in the Dubai Islamic Bank, Bank Al Falah and Bank of Punjab. The second reason is the adjustment of weight profile according to the condition of Trade-Off 3 as observed in case of Al Baraka Bank. Efficiency scores of the rest of the banks remain unchanged as their weight profile is already consistent with the condition defined for Trade-Off 3.

The introduction of Trade-Off 3 in the standard VRS model ensures the observance of intermediation process in DEA model by tackling the problem of ignoring deposits, investments or loans in the production process that arises due to the assignment of zero weights to one or more of them by the standard VRS model. Another outcome of this Trade-Off appears in the form of improved discrimination of DEA model.

Table 7. 4 Efficiency scores with and without Trade-Off 3

Bank	Efficiency Scores without TO	Efficiency Scores with TO 3	Percentage Points Change
Albarka Bank Pakistan Ltd.	89.24%	87.79%	1.45%
Bank Islami Ltd.	100%	100.00%	0%
Burj Bank Ltd.	100%	100.00%	0%
Dubai Islamic Bank Ltd.	80.99%	77.17%	3.82%
Meezan Bank Ltd.	100%	100.00%	0%
Allied Bank of Pakistan Ltd.	100%	100.00%	0%
Askari Commercial Bank Ltd.	92.28%	92.28%	0%
Bank Al Falah Ltd.	97.20%	93.72%	3.48%
Bank Al Habib Ltd.	100%	100.00%	0%
Faysal Bank Ltd.	100%	100.00%	0%
Habib Bank Ltd.	100%	100.00%	0%
Habib Metropolitan Bank Ltd.	100%	100.00%	0%
JS Bank Ltd.	100%	100.00%	0%
KASB Bank Ltd.	72.68%	72.68%	0%
Muslim Commercial Bank Ltd.	100%	100.00%	0%
NIB Bank Ltd.	86.33%	86.33%	0%
Samba Bank Ltd.	100%	100.00%	0%
Silk Bank Ltd.	95.57%	95.57%	0%
Soneri Bank Ltd.	100%	100.00%	0%
Standard Chartered Bank Pakistan Ltd.	100%	100.00%	0%
Summit Bank Ltd.	74.97%	74.97%	0%
United Bank Ltd.	100%	100.00%	0%
Bank of Punjab	100%	94.34%	5.66%
Bank of Khyber	100%	100.00%	0%
First Women Bank Ltd.	100%	100.00%	0%
National Bank of Pakistan	100%	100.00%	0%
Barclays Bank PLC Pakistan	100%	100.00%	0%
Citi Bank	100%	100.00%	0%
HSBC	100%	100.00%	0%
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	21	20	4
Average Efficiency	96.18%	95.68%	

7.3.3. Trade-Off 4 – NPLs and Loans Linkage

The efficiency scores of banks before and after incorporation of Trade-Off 4 are demonstrated in Table 7.5. This table also provides percentage change in efficiency scores (column 4) and NPLs to loans ratio (column 5). According to these results, the number of efficient banks has reduced from 21 to 14. The list of inefficient banks is populated with seven more banks which include: Faysal Bank, Samba Bank, Soneri Bank, Standard Chartered Bank, United Bank, Bank of Punjab, and National Bank. Overall, efficiency scores of 15 banks have declined. Highest decline of 39.82 percentage points has been observed in the efficiency score of Silk Bank whose efficiency score dropped from 95.57% to 55.75%. Some other banks such as: Faysal Bank, Samba Bank, Soneri Bank and Standard Chartered Bank have observed a decline of more than 20 percentage points. There may be a good reason for this decline in efficiency scores. Banks with high NPLs to loans ratio have observed a decrease in their efficiency scores. This fact indicates that efficiency scores are negatively related to NPLs to loans ratio that is also evident from the correlation of -0.45 between efficiency scores and NPLs to loan ratio.

The differences in efficiency scores obtained before and after incorporation of Trade-Off 4 suggest that mere inclusion of NPLs in the intermediation model is not enough to account for the risk factor. This is so because, NPLs may be ignored in the calculation of efficiency scores and lead to overestimated efficiency scores as shown by the results with standard VRS model in Table 7.5 (column 2). After incorporation of Trade-Off 4 efficiency scores of those banks decline that either assign zero weight to NPLs or have high NPLs to loans ratio. This fact indicates that the DEATOB Framework has the capability to assign efficiency ranks to banks after accounting for risk. This is so because this framework evaluates the efficiency of banks by considering the quality as well as quantity of banking assets.

Table 7. 5 Efficiency scores with and without Trade-Off 4

Bank	Efficiency Scores without TO	Efficiency Scores with TO 4	Percentage Points Change	NPLs to Loans Ratio
Al Baraka Bank Pakistan Ltd.	89.24%	75.65%	13.58%	22.98%
Bank Islami Ltd.	100%	100%	0%	3.42%
Burj Bank Ltd.	100%	100%	0%	4.47%
Dubai Islamic Bank Ltd.	80.99%	76.80%	4.19%	8.98%
Meezan Bank Ltd.	100%	100%	0%	5.56%
Allied Bank of Pakistan Ltd.	100%	100%	0%	7.41%
Askari Commercial Bank Ltd.	92.28%	73.11%	19.17%	18.59%
Bank Al Falah Ltd.	97.20%	88.43%	8.77%	9.77%
Bank Al Habib Ltd.	100%	100%	0%	2.46%
Faysal Bank Ltd.	100%	71.01%	28.99%	16.87%
Habib Bank Ltd.	100%	100%	0%	10.93%
Habib Metropolitan Bank Ltd.	100%	100%	0%	17.46%
JS Bank Ltd.	100%	100%	0%	14.07%
KASB Bank Ltd.	72.68%	70.84%	1.84%	55.77%
Muslim Commercial Bank Ltd.	100%	100%	0%	10.71%
NIB Bank Ltd.	86.33%	76.00%	10.33%	50.34%
Samba Bank Ltd.	100%	79.63%	20.37%	13.49%
Silk Bank Ltd.	95.57%	55.75%	39.82%	22.14%
Soneri Bank Ltd.	100%	74.53%	25.47%	13.33%
Standard Chartered Bank Pakistan Ltd.	100%	74.01%	25.99%	16.97%
Summit Bank Ltd.	74.97%	61.50%	13.47%	53.73%
United Bank Ltd.	100%	83.91%	16.09%	14.54%
Bank of Punjab	100%	97.88%	2.12%	64.12%
Bank of Khyber	100%	100%	0%	16.13%
First Women Bank Ltd.	100%	100%	0%	5.03%
National Bank of Pakistan	100%	99.40%	0.60%	13.64%
Barclays Bank PLC Pakistan	100%	100%	0%	4.88%
Citi Bank	100%	100%	0%	20.31%
HSBC	100%	100%	0%	6.56%
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	21	14	15	
Average Efficiency Score	96.18%	88.22%		

7.3.4. Trade-Off 5 – Loans and Investments Trade-Offs

Intermediation model in our study has two outputs: investments and loans. Banks have freedom to choose between these two outputs in the intermediation process. Keeping in view this freedom of choice in outputs, we have formulated two trade-offs which are explained in detail in Chapter 6 section 6.3.2.3. Following sections provide the empirical application of these trade-offs as Trade-Off 5a and 5b on the banking data.

7.3.4.1. Trade-Off 5a – Increase in Investments and Decrease in Loans

Efficiency scores obtained by incorporating this Trade-Off into standard VRS model are provided in Table 7.6. Results indicate that efficiency of only one bank (JS Bank) declines. JS Bank has highest investments to loans ratio of 2.22 times in the data set which means its amount of investments is 2.22 times more than amount of loans. Initially, this bank was included among efficient banks because high weight was attached to its investments. By restricting weight flexibility through Trade-Off 5a this bank is no longer efficient because its efficiency score declines from 100% to 94.18%. The large amounts of investments as compared to loans is an outcome of its risk aversion strategy. However, despite the large amounts of investments, the bank still has relatively high NPLs to loan ratio of 14.07% (see the last column of Table 7.5).

Table 7. 6 Efficiency scores with and without Trade-Off 5a

Bank	Efficiency Scores without TO	Efficiency Scores with TO 5a	Percentage Points Change	Investments to Loans Ratio
Al Baraka Bank Pakistan Ltd.	89.24%	89.24%	0%	1.03
Bank Islami Ltd.	100%	100%	0%	0.82
Burj Bank Ltd.	100%	100%	0%	0.74
Dubai Islamic Bank Ltd.	80.99%	80.99%	0%	0.77
Meezan Bank Ltd.	100%	100%	0%	1.70
Allied Bank of Pakistan Ltd.	100%	100%	0%	0.96
Askari Commercial Bank Ltd.	92.28%	92.28%	0%	1.02
Bank Al Falah Ltd.	97.20%	97.20%	0%	0.83
Bank Al-Habib Ltd.	100%	100%	0%	1.66
Faysal Bank Ltd.	100%	100%	0%	0.54
Habib Bank Ltd.	100%	100%	0%	1.55
Habib Metropolitan Bank Ltd.	100%	100%	0%	1.58
JS Bank Ltd.	100%	94.18%	5.82%	2.22
KASB Bank Ltd.	72.68%	72.68%	0%	1.61
Muslim Commercial Bank Ltd.	100%	100%	0%	1.70
NIB Bank Ltd.	86.33%	86.33%	0%	1.28
Samba Bank Ltd.	100%	100%	0%	0.49
Silk Bank Ltd.	95.57%	95.57%	0%	0.26
Soneri Bank Ltd.	100%	100%	0%	0.80
Standard Chartered Bank Pakistan Ltd.	100%	100%	0%	0.81
Summit Bank Ltd.	74.97%	74.97%	0%	1.14
United Bank Ltd.	100%	100%	0%	0.96
Bank of Punjab	100%	100%	0%	1.20
Bank of Khyber	100%	100%	0%	1.70
First Women Bank Ltd.	100%	100%	0%	0.60
National Bank of Pakistan	100%	100%	0%	0.52
Barclays Bank PLC Pakistan	100%	100%	0%	1.09
Citi Bank	100%	100%	0%	1.03
HSBC	100%	100%	0%	0.61
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	21	20	1	

7.3.4.2. Trade-Off 5b – Decrease in Investments and Increase in Loans

Results obtained through incorporation of Trade-Off 5b are presented in Table 7.7. This table shows that the number of efficient banks has declined from 21 to 17 due to the elimination of four banks (Bank Islami, Faysal Bank, Soneri Bank and United

Bank) from the set of efficient banks. Overall efficiency scores of 10 banks decline. Banks having lower investment to loans ratio has observed a decline in the efficiency scores. Banks that fall in this category include: Bank Islami, Dubai Islamic Bank, Bank Al Falah, Faysal Bank, Silk Bank, Soneri Bank, and United Bank. Silk Bank observes the highest decrease of 17.60 percentage points in efficiency score due to its lowest investments to loans ratio of 0.26. Moreover, in spite of having investments to loans ratio slightly greater than one, some banks (Al Baraka Bank, Askari Commercial Bank, and Summit Bank) observe a minor decline in efficiency scores.

Table 7. 7 Efficiency scores with and without Trade-Off 5b

Bank	Efficiency Scores without TO	Efficiency Scores with TO 5b	Percentage Points Change	Investments to Loans Ratio
Al Baraka Bank Pakistan Ltd.	89.24%	88.07%	1.16%	1.03
Bank Islami Ltd.	100%	98.43%	1.57%	0.82
Burj Bank Ltd.	100%	100%	0%	0.74
Dubai Islamic Bank Ltd.	80.99%	71.72%	9.27%	0.77
Meezan Bank Ltd.	100%	100%	0%	1.70
Allied Bank of Pakistan Ltd.	100%	100%	0%	0.96
Askari Commercial Bank Ltd.	92.28%	91.08%	1.19%	1.02
Bank Al Falah Ltd.	97.20%	89.26%	7.94%	0.83
Bank Al Habib Ltd.	100%	100%	0%	1.66
Faysal Bank Ltd.	100%	91.75%	8.25%	0.54
Habib Bank Ltd.	100%	100%	0%	1.55
Habib Metropolitan Bank Ltd.	100%	100%	0%	1.58
JS Bank Ltd.	100%	100%	0%	2.22
KASB Bank Ltd.	72.68%	72.68%	0%	1.61
Muslim Commercial Bank Ltd.	100%	100%	0%	1.70
NIB Bank Ltd.	86.33%	86.33%	0%	1.28
Samba Bank Ltd.	100%	100%	0%	0.49
Silk Bank Ltd.	95.57%	77.98%	17.60%	0.26
Soneri Bank Ltd.	100%	95.58%	4.42%	0.80
Standard Chartered Bank Pakistan Ltd.	100%	100%	0%	0.81
Summit Bank Ltd.	74.97%	73.21%	1.76%	1.14
United Bank Ltd.	100%	99.86%	0.14%	0.96
Bank of Punjab	100%	100%	0%	1.20
Bank of Khyber	100%	100%	0%	1.70
First Women Bank Ltd.	100%	100%	0%	0.60
National Bank of Pakistan	100%	100%	0%	0.52
Barclays Bank PLC Pakistan	100%	100%	0%	1.09
Citi Bank	100%	100%	0%	1.03
HSBC	100%	100%	0%	0.61
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	21	17	10	

7.3.4.3. Combined Analysis of Trade-Offs 5a and 5b

Results obtained by combining Trade-Off 5a and 5b show (see Table 7.8) that the number of efficient banks is reduced from 21 to 16 which mean that list of inefficient banks include 5 more banks (Bank Islami, Faysal Bank, JS Bank, Soneri Bank and United Bank) making a total of 13 inefficient banks. Moreover, efficiency scores of 13 banks decline. Dubai Islamic Bank is the least efficient bank with an efficiency score of 71.72% but the highest decrease of 17.60 percentage points appears in the efficiency score of Silk Bank.

Table 7. 8 Efficiency scores with and without Trade-Offs 5a and 5b

Bank	Efficiency Scores without TO	Efficiency Scores with TO 5a and 5b	Percentage Points Change
Al Baraka Bank Pakistan Ltd.	89.24%	88.08%	1.16%
Bank Islami Ltd.	100%	98.42%	1.58%
Burj Bank Ltd.	100%	100%	0%
Dubai Islamic Bank Ltd.	80.99%	71.72%	9.27%
Meezan Bank Ltd.	100%	100%	0%
Allied Bank of Pakistan Ltd.	100%	100%	0%
Askari Commercial Bank Ltd.	92.28%	91.08%	1.20%
Bank Al Falah Ltd.	97.20%	89.26%	7.94%
Bank Al Habib Ltd.	100%	100%	0%
Faysal Bank Ltd.	100%	91.75%	8.25%
Habib Bank Ltd.	100%	100%	0%
Habib Metropolitan Bank Ltd.	100%	100%	0%
JS Bank Ltd.	100%	94.19%	6%
KASB Bank Ltd.	72.68%	72.68%	0%
Muslim Commercial Bank Ltd.	100%	100%	0%
NIB Bank Ltd.	86.33%	86.33%	0%
Samba Bank Ltd.	100%	100%	0%
Silk Bank Ltd.	95.57%	77.98%	17.60%
Soneri Bank Ltd.	100%	95.58%	4.42%
Standard Chartered Bank Pakistan Ltd.	100%	100%	0%
Summit Bank Ltd.	74.97%	73.21%	1.75%
United Bank Ltd.	100%	99.86%	0.14%
Bank of Punjab	100%	100%	0%
Bank of Khyber	100%	100%	0%
First Women Bank Ltd.	100%	100%	0%
National Bank of Pakistan	100%	100%	0%
Barclays Bank PLC Pakistan	100%	100%	0%
Citi Bank	100%	100%	0%
HSBC	100%	100%	0%
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	21	16	13

7.4. Analysis and Discussion with the DEATOB Framework

7.4.1. Discussion of Efficiency Results

In order to explore the aggregate effect of multiple trade-offs formulated for the DEATOB Framework on the efficiency of commercial banks of Pakistan, we progressively add all the trade-offs in the standard output oriented VRS model and analyse their results. Table 7.9 provides a summary of results obtained before and after gradual incorporation of each trade-off into DEA model.

The standard VRS model identifies 21 efficient banks. The addition of Trade-Off 1 alone does not change the efficiency scores as observed in section 7.3.1 of this chapter. Therefore, we change the application sequence of Trade-Offs 1 and 2 in order to test, whether this switching affects the efficiency scores or not. Results indicate that this interchange works well with this data set and makes variation in the efficiency scores as a result of gradually adding both trade-offs.

The incorporation of Trade-Off 2, as the first trade-off restriction, reduces the number of efficient banks from 21 to 20 by eliminating Bank of Punjab from efficient banks. The efficiency scores of 4 banks decrease that change the average efficiency score from 96.18% to 95.86%. Trade-Off 1 is the next trade-off in the order of application. The addition of Trade-Off 1 does not change the number of efficient banks but slightly reduces the efficiency score (0.22 percentage points) of only the Bank of Punjab, as shown in column 6 of Table 7.9.

After incorporation of Trade-Off 3[58], the number of efficient banks reduces to 20 due to elimination of Bank of Punjab from the efficient banks. Efficiency scores of four banks decrease that include: Al Baraka Bank, Dubai Islamic Bank, Bank Al Falah and

[58] Trade-Off 3 is a combined form of Trade-Offs 1 and 2. Therefore, it is incorporated directly into standard VRS model without adding Trade-Offs 1 and 2. The rest of the trade-offs of the DEATOB Framework are added in standard VRS model after incorporating Trade-Off 3 only by considering it the first trade-off of the framework.

Bank of Punjab. The reduction in efficiency score of these banks decreases the average efficiency score from 96.18% to 95.68%. However, the highest decrease of 5.66 percentage points is observed in the efficiency score of Bank of Punjab. Although, these results are somewhat similar to the results obtained by sequentially adding Trade-Offs 1 and 2, but are relatively better discriminating because Trade-Off 3 is more demanding as compared to the Trade-Offs 1 and 2 (for detailed explanation of this concept, see Chapter 6 section 6.3.2.1). The introduction of Trade-Off 3 in the standard VRS model ensures the observance of intermediation process in DEA model by including all the variables of intermediation process in the efficiency evaluation.

Column 9 of Table 7.9 shows results obtained with the addition of Trade-Off 4 in the previous model (output oriented VRS model with Trade-Off 3). The number of efficient banks reduces from 20 to 14 communicating that six more banks become inefficient which include: Faysal Bank, Samba Bank, Soneri Bank, Standard Chartered Bank, United Bank, and National Bank of Pakistan. Decrease in their efficiency scores ranges from 12.82 to 29.03 percentage points. Efficiency scores of 15 banks decrease (see column 10) that reduce the average efficiency score from 95.68% to 87.24%. Highest decline of 39.82 percentage points in efficiency score is observed in Silk Bank followed by a decline of 29.03 percentage points in Faysal Bank. Lowest reduction of 1.84 percentage points is noticed in KASB Bank. Most of the banks (11 out of 15) observe a decrease of more than 10 percentage points in the efficiency scores.

These results suggest that despite including NPLs as risk variable in the efficiency estimation model, most of the banks appear efficient or nearly efficient due to assignment of zero or extremely low multipliers to NPLs. When risk factor involved in intermediation process is emphasized through the incorporation of Trade-Off 4 of the

DEATOB Framework, the resulting model not only includes NPLs but also considers their volume while evaluating the efficiency of banks. Consequently, banks with either high NPLs to loans ratio or allocation of zero weight to NPLs in the analysis, observe a decrease in the efficiency scores. Moreover, the incorporation of this trade-off improves the discriminatory power of the resulting model.

The addition of Trade-Off 5a reduces the number of efficient banks from 14 to 9 by recognizing JS Bank, Habib Metropolitan Bank, Muslim Commercial Bank, Bank of Khyber and Citi Bank as inefficient banks in the analysis. Overall efficiency scores of 13 banks change that decrease the average efficiency by 6.48 percentage points. This Trade-Off eliminates those banks from the efficient category which are having comparatively high investments to loans ratio (greater than 1). Another important fact about these banks is that these banks also have relatively high NPLs to loans ratio (greater than 10%). These facts indicate that due to the existence of comparatively large NPLs, these banks have shifted their resources from loans towards investments in pursuance of risk aversion strategy.

With the application of Trade-Off 5b, the number of efficient banks further reduces from 9 to 7 (see column 13 in Table 7.9) indicating that two more banks (Bank Islami and Allied Bank) are removed from the set of efficient banks. Overall, efficiency scores of 22 banks reduce that lead to a drop in average efficiency scores from 80.76% to 79.54%. Highest decline in efficiency score is observed in Bank of Punjab about 48.57 percentage points followed by a decline of 29.32 percentage points in NIB Bank. The decrease in efficiency scores ranges from 0.13 to 48.57 percentage points. The findings of Trade-Offs 5a and 5b show that these Trade-Offs can identify those banks that are shifting their operations from commercial banking to investment banking which is observed in the form of change in the asset mix of banks in Pakistan.

The application of DEATOB Framework on the banking sector of Pakistan identifies only seven efficient banks (shaded in grey) which are: Burj Bank, Meezan Bank, Bank Al Habib, Habib Bank, First Women Bank, Barclays Bank and HSBC.

Table 7. 9 Efficiency scores and percentage point change in the efficiency scores with gradual addition of trade-offs designed for the DEATOB Framework

Bank	Efficiency Scores without TO (2)	Efficiency Scores with TO1 (3)	Percentage Points Change (4=2-3)	Efficiency Scores with TO1 and 2 (5)	Percentage Points Change (6=5-3)	Efficiency Scores with TO 3 (7)	Percentage Points Change (8=7-2)	Efficiency Scores with TO 3 and 4 (9)	Percentage Points Change (10=9-7)	Efficiency Scores with TO 3, 4 and 5a (11)	Percentage Points Change (12=11-9)	Efficiency Scores with all TO (13)	Percentage Points Change (14=13-11)
Al Baraka Bank Pakistan Ltd.	89.24%	88.53%	-0.70%	88.53%	0%	87.79%	-0.75%	73.70%	-14.09%	63.66%	-10.04%	63.66%	-10.04%
Bank Islami Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	98.43%	-1.57%
Burj Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100.00%	0%
Dubai Islamic Bank Ltd.	80.99%	77.53%	-3.46%	77.53%	0%	77.17%	-3.82%	71.61%	-5.56%	71.61%	0.00%	68.29%	-3.32%
Meezan Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100.00%	0%
Allied Bank of Pakistan Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	96.17%	-3.83%
Askari Commercial Bank Ltd.	92.28%	92.28%	0%	92.28%	0%	92.28%	0%	73.11%	-19.17%	68.18%	-4.93%	68.18%	-4.93%
Bank Al Falah Ltd.	97.20%	94.04%	-3.16%	94.04%	0%	93.72%	-3.48%	86.04%	-7.68%	86.04%	0.00%	78.91%	-7.13%
Bank Al Habib Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100.00%	0%
Faysal Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	70.97%	-29.03%	70.97%	0.00%	64.63%	-6.34%
Habib Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100.00%	0%
Habib Metropolitan Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	94.36%	-6%	94.36%	-5.64%
JS Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	87.02%	-12.98%	87.02%	-12.98%
KASB Bank Ltd.	72.68%	72.68%	0%	72.68%	0%	72.68%	0%	70.84%	-1.84%	44.30%	-26.54%	44.30%	-26.54%
Muslim Commercial Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	99.33%	-0.67%	99.33%	-0.67%
NIB Bank Ltd.	86.33%	86.33%	0%	86.33%	0%	86.33%	0%	76.00%	-10.33%	46.68%	-29.32%	46.68%	-29.32%
Samba Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	79.63%	-20.37%	78.95%	-0.68%	78.95%	-0.68%
Silk Bank Ltd.	95.57%	95.57%	0%	95.57%	0%	95.57%	0%	55.75%	-39.82%	55.75%	0%	49.52%	-6.24%
Soneri Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	74.53%	-25.47%	74.53%	0%	74.40%	-0.13%
Standard Chartered Bank Pakistan Ltd.	100%	100%	0%	100%	0%	100%	0%	74.01%	-25.99%	73.56%	-0.45%	73.56%	-0.45%
Summit Bank Ltd.	74.97%	74.97%	0%	74.97%	0%	74.97%	0%	61.50%	-13.47%	40.03%	-21.47%	40.03%	-21.47%
United Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	83.91%	-16.09%	83.91%	0%	83.23%	-0.68%
Bank of Punjab	100%	97.88%	-2.12%	97.66%	-0.22%	94.34%	-5.66%	91.10%	-3.24%	42.53%	-48.57%	42.53%	-48.57%
Bank of Khyber	100%	100%	0%	100%	0%	100%	0%	100%	0%	89.65%	-10.35%	89.65%	-10.35%
First Women Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100.00%	0%
National Bank of Pakistan	100%	100%	0%	100%	0%	100%	0%	87.18%	-12.82%	87.18%	0.00%	81.16%	-6.02%
Barclays Bank PLC Pakistan	100%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100.00%	0%
Citi Bank	100%	100%	0%	100%	0%	100%	0%	100%	0%	83.81%	-16.19%	83.81%	-16.19%
HSBC	100%	100%	0%	100%	0%	100%	0%	100%	0%	100%	0%	100.00%	0%
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	21	20	4	0	1	20	4	14	15	9	13	7	22
Average Efficiency Score	96.18%	95.86%		95.85%		95.68%		87.24%		80.76%		79.54%	

7.4.2. Comparison of Efficiency Estimates

In order to compare the efficiency scores, before and after incorporation of DEATOB Framework, we have plotted efficiency estimates with standard VRS model and DEATOB Framework (results given in column 2 and 13 of Table 7.9) in Figure 7.1. This figure shows that Summit Bank is the least efficient bank in the banking sector of Pakistan with an efficiency score of 40.03%.

The five weakest banks, whose efficiency score dropped even below 50% include; KASB Bank, NIB Bank, Silk Bank, Summit Bank and Bank of Punjab. Among those, Bank of Punjab is efficient with the standard DEA model whereas the rest of the four banks are inefficient even with the standard DEA model. However, in spite of being efficient with standard VRS model, Bank of Punjab has the highest decrease of 57.47 percentage points in the efficiency score i.e. from 100% to 42.53%. There are two main factors that contribute towards highest inefficiency observed in all these banks. First, all these banks have high ratio of non-performing to performing loans (KASB has 56%, Silk Bank 22%, Bank of Punjab 64.12%, NIB Bank 50%, and Summit Bank 54%). Second, these banks have either comparatively high or low investment to loan ratio. For example four banks have high investment to loan ratio and include: KASB Bank with 1.60%, NIB Bank with 1.28%, Summit Bank with 1.14% and Bank of Punjab with 1.19%. Conversely, Silk bank has very low investment to loan ratio of 0.26%. This low investment to loan ratio for Silk Bank along with high NPLs to loans ratio represents that Silk bank has most of its deposit liabilities bound in risky loans i.e. NPLs which are facing non-payment problem on one hand, and might face liquidity problem due to comparatively small amount of investments on the other hand.

In addition to exploring the NPLs to loans ratio and investments to loans ratio in the least efficient banks we also investigated the financial stability indicator “Capital Adequacy Ratio (CAR) [59]” of these banks to validate the results obtained with our proposed model. Four of the least efficient banks, identified by our model have very low (CAR) as compared to the standard minimum ratio of 10% set by the SBP according to Basel Accord II requirements. For example, KASB has CAR of 1.1%, Silk Bank 5.7%, Bank of Punjab 7.7%, and Summit Bank 4.6%. This low CAR indicates that these banks have large amounts of risk weighted assets which are a threat for their stability. However, the fifth least efficient bank, NIB Bank, has CAR of 12.1% which is slightly higher than the minimum required level. Moreover, three other banks which are less efficient according to our model have this ratio just above the required standard and include: Al Baraka Bank (11.2%), Askari Commercial Bank (11.9%), and Faysal Bank (10.8%). These findings suggest that our proposed model has the capability to evaluate banks on the basis of risk attached to their asset portfolio.

[59] CAR is a ratio of bank’s capital to bank’s risk weighted credit exposure. It is an indicator of financial stability that measures the ability of bank to absorb the reasonable level of losses before becoming insolvent.

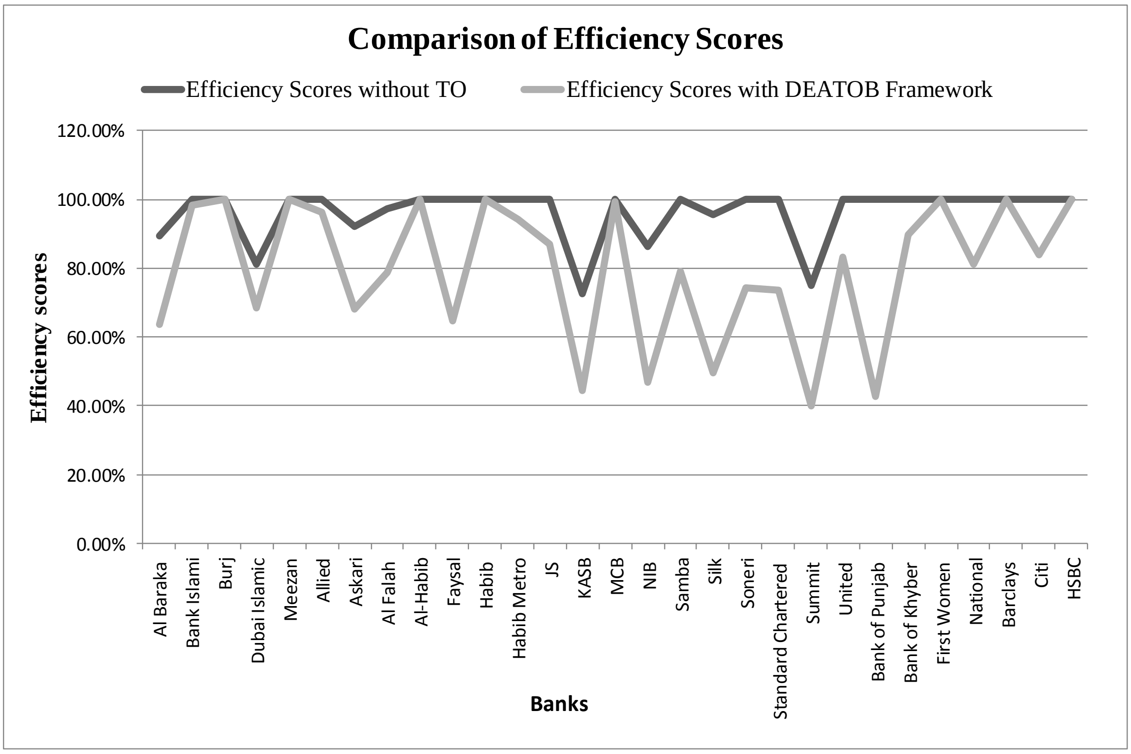


Figure 7. 1 The comparison of efficiency scores before and after application of the DEATOB Framework

7.4.3. Peer Analysis

Peer analysis provides the information on the benchmark banks that should be emulated by each inefficient bank while formulating its operational strategies, in order to enhance its efficiency. In the final analysis, obtained after incorporating all trade-offs of the DEATOB Framework, only seven banks remain efficient (Burj Bank, Meezan Bank, Bank Al Habib, Habib Bank, First Women Bank, Barclays Bank and HSBC) indicating that these banks have the best banking practices in the banking sector of Pakistan. Table 7.10 represents efficient peers (banks having $\lambda_j^* > 0$) of each inefficient bank and the number of times each efficient bank is cited as efficient target (number placed against efficient bank) for inefficient banks. Among efficient banks, Bank Al Habib is the strongest benchmark among all with 18 occurrences, whereas HSBC is the weakest benchmark that serves as reference peer for only one bank. It is also noteworthy here that for the inefficient foreign bank (Citi Bank) only two banks serve as benchmarks and both are foreign banks (Barclays Bank and HSBC).

Being one of the weakest banks in the analysis, the DEATOB Framework recommends to the Bank of Punjab to emulate the banking practices of Meezan Bank, Bank Al Habib and First Women Bank. For the remaining four weakest banks (KASB Bank, NIB Bank, Silk Bank and Summit Bank), Bank Al Habib and Burj Bank serve as the models of best practices.

Table 7. 10 Reference set of inefficient banks

S.No.	Bank	Reference Set
1	Al Baraka Bank Pakistan Ltd.	5 (0.07) 9 (0.06) 25 (0.88)
2	Bank Islami Ltd.	3 (0.86) 9 (0.08) 25 (0.07)
3	Burj Bank Ltd.	10
4	Dubai Islamic Bank Ltd.	3 (0.61) 5 (0.15) 25 (0.03) 27 (0.21)
5	Meezan Bank Ltd.	7
6	Allied Bank of Pakistan Ltd.	9 (0.86) 11 (0.14)
7	Askari Commercial Bank Ltd.	5 (0.24) 9 (0.61) 27 (0.15)
8	Bank Al Falah Ltd.	9 (0.93) 11 (0.07)
9	Bank Al Habib Ltd.	18
10	Faysal Bank Ltd.	3 (0.36) 9 (0.64)
11	Habib Bank Ltd.	5
12	Habib Metropolitan Bank Ltd.	5 (0.68) 27 (0.32)
13	JS Bank Ltd.	3 (0.91) 9 (0.09)
14	KASB Bank Ltd.	3 (0.88) 9 (0.12)
15	Muslim Commercial Bank Ltd.	9 (0.79) 11 (0.21)
16	NIB Bank Ltd.	3 (0.65) 9 (0.35)
17	Samba Bank Ltd.	3 (0.30) 25 (0.70)
18	Silk Bank Ltd.	3 (0.89) 9 (0.11)
19	Soneri Bank Ltd.	3 (0.72) 9 (0.28)
20	Standard Chartered Bank Pakistan Ltd.	5 (0.56) 9 (0.36) 27 (0.08)
21	Summit Bank Ltd.	3 (0.77) 9 (0.23)
22	United Bank Ltd.	9 (0.59) 11 (0.41)
23	Bank of Punjab	5 (0.58) 9 (0.08) 25 (0.34)
24	Bank of Khyber	5 (0.12) 9 (0.05) 25 (0.83)
25	First Women Bank Ltd.	6
26	National Bank of Pakistan	9 (0.32) 11 (0.68)
27	Barclays Bank PLC Pakistan	5
28	Citi Bank	27 (0.98) 29 (0.02)
29	HSBC	1

7.5. Relationship between Technical Efficiency and Ownership Type

This sections aims to answer the *Question 4* set in the current study by exploring the relationship between efficiency estimates and bank ownership. In terms of ownership, banks are divided into four groups: public sector banks, private domestic banks, foreign banks and Islamic banks. Islamic banks are private banks working under Islamic mode of banking but work with different underline banking ideology and offer different Islamic banking products. Islamic banks are growing rapidly since last few years (State Bank of Pakistan, 2011a). Therefore, in order to evaluate their efficiency as an independent group we have separated them from the private banks and used the name private domestic banks for the private banks other than Islamic banks.

Table 7.11 summarises the number of efficient and inefficient banks and average efficiency scores of different groups of banks before and after application of the DEATOB Framework. Results show that there is a wide variation in efficiency scores among different ownership groups and even among banks within the same ownership group before and after application of the DEATOB Framework (for individual efficiency scores reader is referred to Table 7.9 column 2 and 13). The evidence on ownership type with standard VRS model reveals that all the public sector and foreign banks are fully efficient. On the other hand, 65% of private and 40% of Islamic banks are efficient with an average efficiency score of 95.24% and 94.11% respectively. These results indicate that Islamic banks are the least efficient category of banks in terms of ownership type under standard VRS model.

After the application of the DEATOB Framework, two banks are efficient from each of Islamic (Burj Bank and Meezan Bank), private domestic (Bank Al Habib and Habib Bank) and foreign banks (Barclays Bank and HSBC) whereas from public sector banks, only one (First Women Bank) has maintained its efficient status (see Table 7.9 column 13). However, with the DEATOB Framework four different patterns of efficiency change appear in four different groups of banks. First, foreign banks remain the most efficient banks among all groups of banks with an efficiency drop of 5.4 percentage points mainly due to the transfer of Citi Bank from efficient to inefficient bank. Second, in spite of being the least efficient group under standard DEA model, Islamic banks remain comparatively efficient with an average score of approximately 86%. Third, the average efficiency of public sector banks reduces noticeably (from 100% to 78.34%). Finally, private domestic banks have the lowest average efficiency among all groups of banks with an efficiency score of 75.25%.

Table 7.11 An overview of different ownership groups of banks before and after application of the DEATOB Framework.

Category of Bank	With Standard VRS Model			With DEATOB Framework		
	Number of Efficient Banks	Number of Inefficient Banks	Average Efficiency Scores	Number of Efficient Banks	Number of Inefficient Banks	Average Efficiency Scores
Islamic Banks	3	2	94.05%	2	3	86.07%
Private Domestic Banks	11	6	95.24%	2	15	75.25%
Public Sector Banks	4	0	100%	1	3	78.34%
Foreign Banks	3	0	100%	2	1	94.60%
Total	21	8	95.78%	7	22	79.54%

Average technical efficiency scores of different banking groups indicate that all the categories of banks in Pakistan need to increase their efficiency. However, these average efficiency scores are not telling anything about the variation existing in efficiency scores within groups and main contributors in the overall inefficiency of banking sector from each group. Therefore, we have divided efficiency scores into three categories: good performers (having scores greater than 85%), average performers (with efficiency scores from 70% to 85%) and poor performers (with efficiency scores less than or equal to 70%). Table 7.12 shows the number of banks in each performance category, different banking groups (ownership), average efficiency score and cumulative efficiency score in each performance category. It is evident from the table that most of the banks are good performers. On the other hand, average performers and poor performers have 7 and 9 banks respectively.

The poor performers consist of six private domestic banks (Askari Commercial Bank, Faysal Bank, KASB Bank, NIB Bank, Silk Bank and Summit Bank) two Islamic banks (Al Baraka Bank and Dubai Islamic Bank) and one public sector bank (Bank of Punjab). The exclusion of these poor performers improves the average efficiency score from 79.54% to 90.95% reflecting that these banks are the major contributors towards the overall inefficiency of banking sector in Pakistan. Moreover, these findings indicate that private domestic banks are the least efficient group of banks as two third of the poor performers belong to this group. However, if we combine Islamic and private domestic banks together, then about 89% of the poor performers are private banks. Therefore, it can be concluded safely that private banks are the least efficient banks in Pakistan.

Table 7. 12 Different ownership groups of banks and their performance categories with the DEATOB Framework

Category/ Bank	Islamic Banks	Private Domestic Banks	Public Sector Banks	Foreign Banks	Total	Average Score	Cumulative Average Score	Big Five
Good Performers (efficiency >85%)	3	6	2	2	13	97.30%	97.30%	3
Average Performers (70<efficiency ≤85%)	0	5	1	1	7	79.15%	90.95%	2
Poor Performers (efficiency ≤70%)	2	6	1	0	9	54.20%	79.54%	0

One possible reason for highest efficiency scores of foreign banks might be the fact that foreign banks in Pakistan often target exclusively big individual and corporate clients that have less chances of default. This strategy of foreign banks refers to the *global advantage hypothesis* of Berger et al. (2000) according to which banks of some nations overcome the diseconomies of cross boarder operations due to various unspecified advantages. Foreign banks in Pakistan also tend to follow the home nation effects, described by Sturm and Williams (2008), partially according to which multinational banks of developed nations export financial practices and financial sophistication to the developing host economies. Foreign banks in Pakistan tend to operate more efficiently than their domestic counterparts because they hire local staff and train them according to their own standards, resulting in superior managerial skills and best financial practices pursued by them. Moreover, given the market size and resources, they tend to better utilize their resources as compared to local banks.

Contrarily, public and private sector banks are inefficient due to the accumulation of NPLs on their loan portfolios. Increasing cost of business in challenging economic conditions coupled with persistent energy crisis adversely affected the repayment capability of borrowers and triggered the growth of NPLs in both public and private sectors. Although, banks are actively pursuing the strategies of recovering the infectious loan and the restructuring/rescheduling of workable corporate loans still they have large quantities of NPLs (State Bank of Pakistan, 2012b), particularly public sector banks where political interference is relatively high.

It could be argued here that management of private domestic banks and public sector banks need to develop a strict scrutiny and monitoring system while advancing loans so that risk of default could be minimized and a profile of healthy assets could be created. Better position of Islamic banks on average efficiency score is attributed to their better portfolio of advances with small amount of non-performing loans and increasing amount of investments due to their risk aversion behaviour (State Bank of Pakistan, 2012a). Among the big five banks, Allied Bank, Habib Bank and Muslim

Commercial Bank (denationalized banks) are good performers whereas United Bank (denationalized bank) and National Bank of Pakistan (public sector bank) are average performers (for reference see Table 7.10 column 13).

Our findings of efficiency of banks with respect to ownership type are similar to the empirical results of many previous studies which compared the efficiency of banks across different ownership types. For example, Patti and Hardy (2005) reported that foreign banks are more efficient in Pakistan as compared to public and private banks. Isik and Hassan (2003) found that foreign banks in Turkey are more efficient than private domestic banks. Sturm and Williams (2004) provided a further support to these findings by saying that foreign banks in Australia are more efficient than domestic banks.

7.6. Relationship between Technical Efficiency and Bank Size

To answer the *Question 5* of the current study, we investigate the possible relationship between efficiency and bank size. For this purpose, we have proxied bank size by the total assets[60]. Banks in Pakistan are heterogeneous in assets size and classified into four asset groups. These asset groups are: small banks (total assets of Rupees 70 billion or less), medium sized banks (total assets greater than rupees 70 billion to 200 billion), large banks (total assets greater than Rupees 200 billion up to 500 billion), and largest banks (total assets greater than Rupees 500 billion). Upper part of Table 7.13 shows total assets of all banks arranged in descending order and efficiency scores with and without the DEATOB Framework. Four categories of banks based on assets sizes and average efficiency scores of each category, before and after application of the DEATOB Framework, are placed in the bottom part of the table. Assets sizes in the table show that Habib Bank is the largest bank and First Women Bank is the

[60] Total assets are used as a proxy for asset size by many studies such as Resti (1997), Elyasiani and Mehdian (1990), and Ataullah et al. (2004).

smallest bank. The big five banks (first five banks in Table 7.13) hold about 55.21% of the total assets of banks included in the sample. In terms of assets size most of the banks are medium sized. Only two banks have assets more than Rupees one trillion where National Bank is a public sector bank while Habib Bank is a denationalized bank.

With standard DEA model, 21 banks are efficient having almost equal distribution in each assets group. With the DEATOB Framework, only seven banks are efficient where four (Burj Bank, First Women Bank, HSBC Bank and Barclays Bank) are small, two (Meezan Bank and Bank Al Habib) are medium sized banks and one (Habib Bank) is the largest bank.

Relationship between asset size and efficiency exhibits some interesting features. In general, both the small and largest banks experienced relatively high average efficiency levels before and after application of the DEATOB Framework. Large banks are nearly efficient with standard DEA model but inefficient with the DEATOB Framework. Medium sized banks are the least efficient before and after application of the DEATOB Framework in spite of being the most populated category of banks. These trends in efficiency indicate the possibility of a U-shaped relationship between asset size and efficiency level in Pakistani context with and without the DEATOB Framework. Highest efficiency scores in small banks can be attributed to their better portfolio management and control on capital costs as compared to larger banks. Largest banks exhibit relatively high average scores because they possess high market share (Kpmg, 2012) due to their extensive branch network (see Table 5.2 in Chapter 5) in rural and urban areas that enables them to serve both individual and corporate customers providing more diversified services than smaller banks. However, all banks in this asset group except Habib Bank are inefficient with the DEATOB Framework due to their diseconomies of operations[61].

Lower efficiency levels in the middle two categories of assets can be attributed mainly to the fact that most of the banks have overall poor asset quality in spite of their reluctance to extend credit to private sector and increased inclination to invest in government securities. Moreover, most of the banks in these two categories either exhibit IRS (8 banks) or DRS (6 banks) hence, require either to increase their scale of operations or trim down their operations respectively in order to overcome their inefficiencies (RTS for all banks are explained in the next section).

Among the big five, public sector bank (National Bank) is the least efficient whereas three denationalized banks (Allied bank, Habib Bank and Muslim Commercial Bank) exhibit relatively high efficiency scores. This may be attributed to the fact that generally, public banks are overstaffed and burdened with comparatively large amounts of non-performing portfolios. On the other hand, denationalized banks effectively managed to control these issues with their better resource management strategies. These results support the trend of denationalization and privatization of public sector banks in Pakistan.

The findings of relatively higher efficiency scores in small and largest banks in Pakistan are similar to the findings of Ataullah et al. (2004) in Pakistan, Chen et al. (2005) in China and Jaffry et al. (2007) in Indian subcontinent. These assets based efficiency trends are partially observed in the banking sectors of other countries as well. For example, the trend of highest efficiency in small banks is consistent with those of Ashton (2001) for smaller British retail banks and Resti (1997) for Italian banks. Similarly, a positive relationship between bank size and efficiency was

[61] As shown by the DRS characteristics of all these banks in the next section.

concluded by the Elyasiani and Mehdian (1990), Miller and Noulas (1996) and Berger and Humphrey (1997) in U.S., Yildirim (2002) in Turkey and Drake et al. (2006) in Hong Kong banking sector. Based on these earlier findings it can be inferred that the banking sector of Pakistan resembles the banking sectors of other countries particularly, Asian economies.

Table 7. 13 Total assets and the efficiency scores of all banks with and without the DEATOB Framework

S.No.	Bank	Total Assets (in 000)	Efficiency Scores without TO	Efficiency Scores with all Trade-Offs
1	Habib Bank Ltd.	1,610,308,572	100%	100.00%
2	National Bank of Pakistan	1,316,160,457	100%	81.16%
3	United Bank Ltd.	960,210,415	100%	83.23%
4	Muslim Commercial Bank Ltd.	770,282,541	100%	99.33%
5	Allied Bank of Pakistan Ltd.	632,301,706	100%	96.17%
6	Bank Al Falah Ltd.	536,466,694	97.20%	78.91%
7	Bank Al Habib Ltd.	453,353,942	100%	100.00%
8	Standard Chartered Bank Pakistan Ltd.	399,055,450	100%	73.56%
9	Askari Commercial Bank Ltd.	353,211,274	92.28%	68.18%
10	Bank of Punjab	332,110,474	100%	42.53%
11	Faysal Bank Ltd.	313,064,332	100%	64.63%
12	Habib Metropolitan Bank Ltd.	300,739,810	100%	94.36%
13	Meezan Bank Ltd.	274,436,510	100%	100.00%
14	NIB Bank Ltd.	190,855,177	86.33%	46.68%
15	Soneri Bank Ltd.	158,618,236	100%	74.40%
16	Summit Bank Ltd.	134,289,066	74.97%	40.03%
17	KASB Bank Ltd.	90,277,626	72.68%	44.30%
18	Silk Bank Ltd.	89,061,570	95.57%	49.52%
19	Citi Bank	85,171,810	100%	83.81%
20	JS Bank Ltd.	84,018,777	100%	87.02%
21	Bank of Khyber	82,177,638	100%	89.65%
22	Bank Islami Ltd.	74,236,030	100%	98.43%
23	Al Baraka Bank Pakistan Ltd.	73,869,051	89.24%	63.66%
24	Dubai Islamic Bank Ltd.	63,500,705	80.99%	68.29%
25	HSBC	50,328,093	100%	100.00%
26	Barclays Bank PLC Pakistan	47,778,267	100%	100.00%
27	Burj Bank Ltd.	47,185,452	100%	100.00%
28	Samba Bank Ltd.	34,853,837	100%	78.95%
29	First Women Bank Ltd.	22,490,800	100%	100.00%
	Asset Category	**Number of Banks**	**Average Efficiency**	**Average Efficiency**
1	**Small**-Less than or equal to Rs.70 billion	6	96.83%	91.21%
2	**Medium**- >Rs.70 billion and ≤Rs. 200 billion	10	91.88%	67.75%
3	**Large**- >Rs.200 billion and ≤ Rs.500 billion	7	98.90%	77.61%
4	**Largest**-Greater than Rs.500 billion	6	99.53%	89.80%

7.7. Scale Efficiency of Pakistani Banks

To determine the scale efficiency of Pakistani banks, we also need to calculate the output oriented CRS efficiency scores with the DEATOB Framework. Recall from section 4.5.2 of Chapter 4 that scale efficiency is calculated as:

$$\text{Scale Efficiency (SE)} = \theta^*_{CCR} \big/ \theta^*_{BCC} \,.$$

Table 7.14 illustrates the distribution of individual efficiency scores and their RTS, average efficiency of the entire banking sector and average efficiencies for different ownership groups of banks. Results of the scale efficiency indicate that apparently, scale economies exist at the aggregate level in the banking sector of Pakistan. However, analysis of the scale efficiency by ownership type reveals a different picture. Foreign banks and Islamic banks are the most scale efficient banks. Public sector banks and private domestic banks exhibit comparatively more diseconomies of scale as depicted by their individual and average efficiency scores. It is apparent from the table that there is not much divergence between overall technical efficiency scores (OTE) and pure technical efficiency (PTE) scores. This implies that overall technical inefficiency in banking sector of Pakistan is more driven by pure technical inefficiency than scale inefficiency. The presence of scale efficiencies in banking sectors are also reported by other studies such as Berger and Humphrey (1991), Berger et al. (1993a), Berger et al. (1993b).

For investigation of RTS exhibited by all banks, we have used the method proposed by Färe et al. (1985) in order to demonstrate that the existing RTS determination methods work equally well with the production trade-offs formulated for the DEATOB Framework. According to this method we need to solve non-increasing returns to scale (NIRS) model in addition to CRS model (as described in section 4.8 of

Chapter 4) with the DEATOB Framework under output orientation. RTS findings provided in the last column of the table show that 9 banks exhibit IRS, 13 banks DRS and 7 banks exhibit CRS. This reflects that most of the banks in our sample are working at DRS which mean that they are operating at more than their optimal scale. Moreover, among seven pure technical efficient banks six are exhibiting CRS and one is operating at DRS. Note here, that RTS is the property of BCC efficient banks and RTS for inefficient banks is obtained by their output oriented BCC projection on the efficient frontier (for details see section 4.8 in Chapter 4).

These results also indicate that foreign banks, on average, are the most technical as well as scale efficient banks. These findings are similar to Sturm and Williams (2004) study on Australian banks who reported that foreign banks are more efficient than domestic banks in Australia due to their superior scale efficiencies. On the other hand, public sector banks and private banks are relatively scale inefficient. However, in spite of having the lowest technical efficiency scores, private domestic banks are slightly better than the public sector banks in scale efficiency.

It is noteworthy here that the majority of big banks, including the big five banks, are operating under DRS representing diseconomies of scale in their operations. The degree of these diseconomies is at its peak in big five banks as shown by their average scale efficiency score of 90.25%. This indicates that these banks are working far above their efficient scale and required to reduce the size of their operations to be efficient. Such diseconomies of scale in big banks have also been reported by Iimi (2004) in Pakistan, Drake and Hall (2003) and Altunbas et al. (2000) in Japan and by Sturm and Williams (2004) in Australia. Furthermore, among the big five, public sector bank is the least scale efficient whereas three denationalized banks (Allied Bank, Habib Bank, and Muslim Commercial Bank) exhibit comparatively high scale efficiency scores. These results also support the trend of denationalization and privatization of public sector banks in Pakistan. It is also worth mentioning here that nine inefficient banks are projected onto the IRS facets over the efficient frontier. This information indicates the possibility of further consolidation in the banking sector of Pakistan.

Table 7. 14 Scale efficiency scores and RTS of all banks with the DEATOB Framework

Bank	OTE	PTE	SE	RTS
Al Baraka Bank Pakistan Ltd.	62.55%	63.66%	98.25%	IRS
Bank Islami Ltd.	98.35%	98.43%	99.92%	IRS
Burj Bank Ltd.	100.00%	100.00%	100.00%	CRS
Dubai Islamic Bank Ltd.	68.01%	68.29%	99.60%	DRS
Meezan Bank Ltd.	100.00%	100.00%	100.00%	CRS
Allied Bank of Pakistan Ltd.	89.34%	96.17%	92.90%	DRS
Askari Commercial Bank Ltd.	68.05%	68.18%	99.80%	DRS
Bank Al Falah Ltd.	75.95%	78.91%	96.24%	DRS
Bank Al Habib Ltd.	100.00%	100.00%	100.00%	CRS
Faysal Bank Ltd.	64.62%	64.63%	99.97%	DRS
Habib Bank Ltd.	92.35%	100.00%	92.35%	DRS
Habib Metropolitan Bank Ltd.	92.75%	94.36%	98.29%	DRS
JS Bank Ltd.	86.96%	87.02%	99.93%	IRS
KASB Bank Ltd.	43.96%	44.30%	99.22%	IRS
Muslim Commercial Bank Ltd.	90.80%	99.33%	91.41%	DRS
NIB Bank Ltd.	46.55%	46.68%	99.73%	IRS
Samba Bank Ltd.	77.30%	78.95%	97.91%	IRS
Silk Bank Ltd.	49.50%	49.52%	99.98%	DRS
Soneri Bank Ltd.	74.40%	74.40%	100.00%	CRS
Standard Chartered Bank Pakistan Ltd.	73.20%	73.56%	99.51%	DRS
Summit Bank Ltd.	39.85%	40.03%	99.57%	IRS
United Bank Ltd.	73.68%	83.23%	88.53%	DRS
Bank of Punjab	42.49%	42.53%	99.89%	IRS
Bank of Khyber	89.24%	89.65%	99.54%	IRS
First Women Bank Ltd.	100.00%	100.00%	100.00%	CRS
National Bank of Pakistan	69.83%	81.16%	86.04%	DRS
Barclays Bank PLC Pakistan	100.00%	100.00%	100.00%	CRS
Citi Bank	82.74%	83.81%	98.73%	DRS
HSBC	100.00%	100.00%	100.00%	CRS
Average Efficiency of All Banks	77.67%	79.54%	97.84%	
Number of Efficient Banks	6	7	7	
Average Efficiency of Islamic Banks	85.78%	86.07%	99.55%	
Average Efficiency of Private Domestic Banks	72.90%	75.25%	97.37%	
Average Efficiency of Public Sector Banks	75.39%	78.34%	96.37%	
Average Efficiency of Foreign Banks	94.25%	94.60%	99.58%	
Average Efficiency of Big Five Banks	83.20%	91.98%	90.25%	

7.8. Conclusion

This chapter has attempted to achieve the second objective of the current study. Motivated by the scantiness of banking efficiency studies in Pakistan, the DEATOB Framework is empirically tested on the financial data of 29 commercial banks of Pakistan for the year 2012. The trade-offs formulated for the DEATOB Framework has been incorporated in the form of weight restrictions in output oriented DEA model with the VRS assumption. The empirical application of the DEATOB Framework has been discussed in two ways. Firstly, the empirical implication of each constituent trade-off of the DEATOB Framework has been analysed in order to evaluate its independent impact on the efficiency of all banks. Secondly, the aggregate impact of various trade-offs is studied by incorporating trade-offs in a step wise manner in the standard VRS model.

Results presented in this chapter revealed that standard DEA model provided overestimated results for most of the banks due to assigning unrealistic weight profile to different variables or just considering good aspects of their banking activities. This empirical evidence supported the need to enrich the standard DEA model with some additional information based on technological judgements so that efficiency scores of banks could be calculated by including all the variables in the transformation process while accounting for both good and bad aspects of their banking operations. This objective has been achieved through the addition of the DEATOB Framework in the standard VRS model.

This framework is a combination of different trade-offs having the capability to evaluate banks on different grounds. We formulated five trade-offs for this framework based on different exogenous and endogenous factors related to banking activities that have enriched the standard DEA model in many ways. First, they have ensured the inclusion of all the variables of intermediation process in the evaluation of banks. Second, banks are evaluated on the basis of quantity of NPLs because accumulation of NPLs has been a major problem in the banking sector of Pakistan since the nationalization of banks in 1974. Third, both investments and loans are considered in the evaluation process. Finally, the advancing of loans as the major function of commercial banks is enforced because banking sector in Pakistan has been deviating from the commercial banking activities since 2007. All these trade-offs added information on a particular aspect and ranked banks according to the criteria defined in the trade-offs.

Empirical results indicate that most of the banks which were efficient with the standard VRS model are no longer efficient. Moreover, the relative efficiencies of the most of the banks have reduced with the introduction of each trade-off of the DEATOB Framework. These facts indicate that the discrimination of DEA model has improved with the DEATOB Framework. This improvement in discriminatory power of DEA within the DEATOB Framework has been observed due to its more rigorous definition of efficient performance that takes into account aforementioned multiple aspects incorporated through trade-offs.

According to the results presented in the chapter, private banks and public banks are the least efficient banks in Pakistan. The major cause of low efficiency in these banks is the large amounts of NPLs. Banks accumulated these NPLs due to their excessive lending to only few sectors that were unable to pay back loans due to their downfall. Among private banks, privatized banks are relatively good performers and have comparatively small proportion of NPLs which is due to their diversified loan portfolio. An important policy implication that emerges by looking at this situation is that the regulatory authorities should define a maximum limit for lending portfolio extended to a particular sector with respect to total loan portfolio in order to avoid the loan losses arise due to collapse of a particular sector. However, while devising such a policy for banks, there is a need to know more about the government policy regarding the priority sector lending in Pakistan.

CHAPTER 8

EXTENSION OF THE DEATOB FRAMEWORK TO MODEL PROFIT EFFICIENCY

8.1. Introduction

This chapter aims to achieve the third objective set in the current study and extends the idea of the DEATOB Framework to the profitability model. This objective is achieved in two phases. The first phase is, the development phase of a separate framework for the profitability model because it has totally different set of inputs and outputs. For this second framework we are using the term “PDEATOB Framework” in order to differentiate it from the DEATOB Framework designed earlier. In this phase, we elaborate different aspects of banking operations that serve as foundation for the development of various trade-offs of the framework and provide their mathematical formulation in the multiplier form. In the second phase, we empirically test the PDEATOB Framework. Empirical testing of this framework is carried out in two different ways similar to Chapter 7. In the last section of this chapter we also compare and contrast the results obtained with the DEATOB and PDEATOB Frameworks.

8.2. Profitability Model

Commercial banks are profit oriented organizations that strive to maximize their profits as their main objective (as described in section 3.4 of Chapter 3). Keeping in view this objective of commercial banks, the current study has considered profitability model to estimate the profit efficiency of commercial banks in Pakistan. According to Fraser and Fraser (1990), principal dimensions of banks performance are profitability and risk. Following this concept of performance, the risk element is dealt by adding a risk variable; “loan loss provision” in the profitability model.

Profitability model was originally introduced by Leightner and Lovell (1998) and extensively used in the banking studies (Das and Ghosh, 2006, Pasiouras, 2008a, Avkiran, 2009b, Drake et al., 2009, Sufian, 2009, Avkiran, 2011) to determine the profit efficiency of banks (for the detail of this approach reader is referred to Chapter 2 section 2.7.3). If inputs and outputs of intermediation model are replaced by their costs (for inputs) and revenues (for outputs), then profit efficiency of the intermediation process can be assessed. In fact, profitability model and intermediation model both reflect the intermediation process of banks in two different dimensions. Intermediation model represents the asset generation capability whereas profitably model characterises the income generating capability of banks. Moreover, banks intermediation efficiency is tied to the profit generating ability of banks as a going concern.

The inputs set of profitability model consists of interest expenses, non-interest expenses and loan loss provision while outputs include; interest income, fee commission and brokerage income and other income (details of these variables are provided in Chapter 5 section 5.4). The third input, loan loss provision, is included in the model to account for risk. Loan loss provision is the cost of loans and is one of the variables used for measuring risk in banking studies as described in the literature review on risk and asset quality in Chapter 2 section 2.9.1.

8.3. Development of the PDEATOB Framework

In this section we provide the development process of the PDEATOB Framework. Using the concept of performance evaluation of banks given by Fraser and Fraser (1990), we define different bank specific exogenous and endogenous factors that we are using to formulate trade-offs for the PDEATOB Framework. These factors are shown in the following figure.

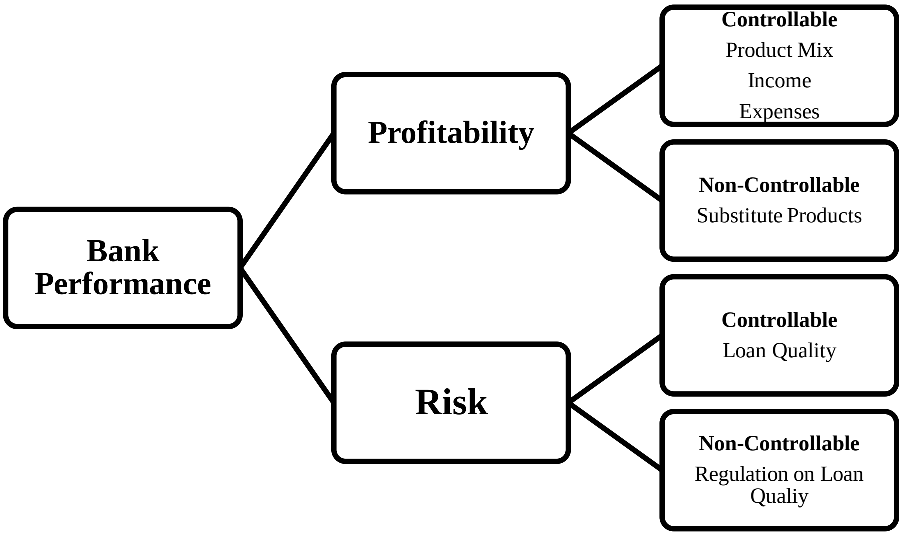


Figure 8. 1 Principal components of the bank's performance

Profitability of banks refers to the excess of recurring incomes over recurring expenses. Banks generate incomes from their asset portfolio (loans and investments) and other sources such as off-balance sheet activities. Recall from Chapter 3, section 3.4.3 and Chapter 6, section 6.3.2.3, asset mix of banks is dependent on the portfolio management strategy of banks and is a controllable bank specific factor. This implies that incomes and expenses of banks related to that asset mix are also controllable bank specific factors. Conversely, the availability of different substitutes of income generating products (loans and investments) is beyond the control of bank's management and we are not considering them in the current study. In case of risk, we consider loan quality and the regulation on loan quality imposed by the SBP in the form of loan loss provision. Bank can control the loan quality up to some extent by scrutinizing loans carefully. However, the rate of loan loss provision varies with different categories of loans and is set by the SBP. Commercial banks are required to maintain the amount of loan loss provision against their loan portfolio according to the SBP's specified rate. Therefore, the rate of loan loss provision is an exogenous factor. We have already included loan quality in the development of trade-offs for intermediation model (see Chapter 6 section 6.3.2.2). In profitability model we are including loan loss provision as a risk variable and will use the rate of loan loss provision as a base for developing trade-off in order to ensure the inclusion of risk variable in the efficiency evaluation.

Recall from Chapter 6, development of the DEATOB Framework is a five stage process consisting of identification, validation, evaluation, application and review stages. Following these stages we explain the development of various trade-offs for the PDEATOB Framework in the following sections.

8.3.1. Trade-Off 1 – Linking Interest Expense and Interest Income

For developing trade-offs for profitability model we again refer to Figure 6.4 in Chapter 6 describing intermediation process, where increase in deposits leads to increase in investments and loans. In real life banking, some costs and revenues are attached to this intermediation process. Deposits represents the liability of banks having cost in the form of interest expenses which is payable by banks to the deposit holders. In contrast, loans and investments are the assets of bank and act as the main source of income for banks in the form of interest income earned on both loans and investments. If we translate the intermediation process provided in Figure 6.4 of Chapter 6 in terms of costs and revenues, then increase in interest expenses brings about a subsequent increase in interest income from loans and investments (because more loans and investments are generated from the increased amount of deposits after maintaining CRR). This process is explained in the following figure.

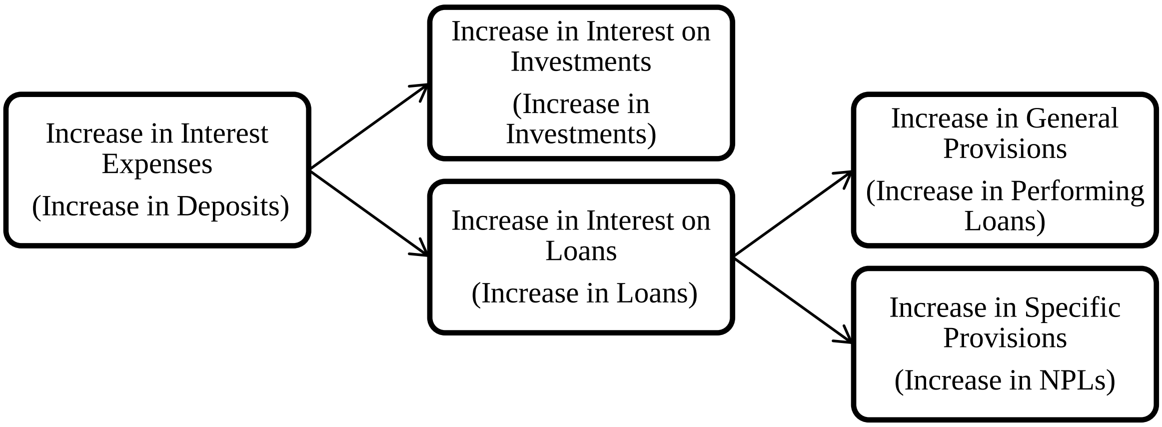


Figure 8. 2 Profitability model in terms of costs and revenues of the intermediation process

Banks charge different rate of interests for lending and borrowing. Generally, rate of interest on loans is higher than the rate of interest on deposits. In banking terminology the difference between these two rates is called interest rate spread[62]. The greater the difference between these two rates, the more is the interest rate spread and more income is generated by bank. Current interest rate spread, prevailing in Pakistan, is approximately 5.38% (SBP 2013) whereas a minimum return on saving deposits is 6% [63](declared by SBP). This information represents that on average the interest rate on loans is almost double the interest rate on deposits. On the other hand, the rate of interest on investments is also higher than the rate of interest on deposits. Since last few years, the rate of interest on government securities is almost similar to the rate of interest on loans (State Bank of Pakistan, 2014). Therefore, we assume that the difference between interest rate on deposits and investments is equal to interest rate spread.

Keeping in view the above mentioned facts, we have used interest rate spread as a base for developing one of the trade-offs for our PDEATOB Framework. However,

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[62] Interest rate spread is the gap between interest rate, a bank charges on loans, securities, and other interest-earning assets and the interest rate paid on deposits and other interest-bearing liabilities.

[63]Banking Policy and Regulation Department Circular No. 1 April 13, 2012.

while defining this trade-off we are considering the real life banking practices that all the deposits are not converted into loans and investments due to CRR imposed by the SBP. Moreover, all the loans and advances do not generate interest income due to their non performing portion. In order to verify the practicability of our identified trade-off in the real life situation, we consulted banking experts to get their opinion in this regard. The information was collected by asking the following question.

Q1. What should be the minimum interest rate spread that would be sufficient to meet the cost of deposits and average operating expenses of banks?

Most of the experts were of the opinion that interest rate spread should be at least 2%-5%. This interest rate spread is also consistent with the average interest rate spread provided in Table 8 of the SBP working paper NO. 45[64] that provides information on average interest rate spreads, bank type and borrowers' type. Moreover, we confirmed these rates from the banking survey of commercial banks by KPMG (2012). We here assume a spread of 3% to be realistic as according to some bankers a spread of 2% is very low in terms of meeting operating costs after paying for the cost of deposits. If we compare this spread of 3% with the rate on saving deposit of 6% (i.e. 9% on loan and 6% on deposits makes a spread of 3%), it means interest rate on loans is 50% greater than the interest rate on deposits which imply that interest income should be 50% greater than the interest expense. Considering a difference of 50% between interest income and interest expenses we formulate the following trade-off.

Judgement 8.1. Without demanding any additional resources, an increase of one million in interest expenses, increases the interest income by 1.5 million (equal to 150% of the increase in the interest expenses).

[64] SBP working paper No. 45 titled" Bank Lending and Monetary Shocks: Evidence from Developing Economy". We are considering this table because it contains the actual data submitted to SBP directly by different commercial banks.

If the weight of interest income and interest expense is represented by u_1 and v_1 respectively, then this trade-off can be translated into the following weight restriction:

$$1.5\,u_1 - 1v_1 \leq 0 \qquad (8.1)$$

8.3.2. Trade-Off 2 – Non-Interest Income Generating Process

An increase in deposits plays an important role in the income generating process of banks. On one hand, it increases the interest income by increasing loans and investments and on the other hand, it contributes towards raising non-interest income of banks as a result of increased clientele of the banks in the form of increased number of depositors and borrowers. This indirect process of income generation is shown in the following diagram.

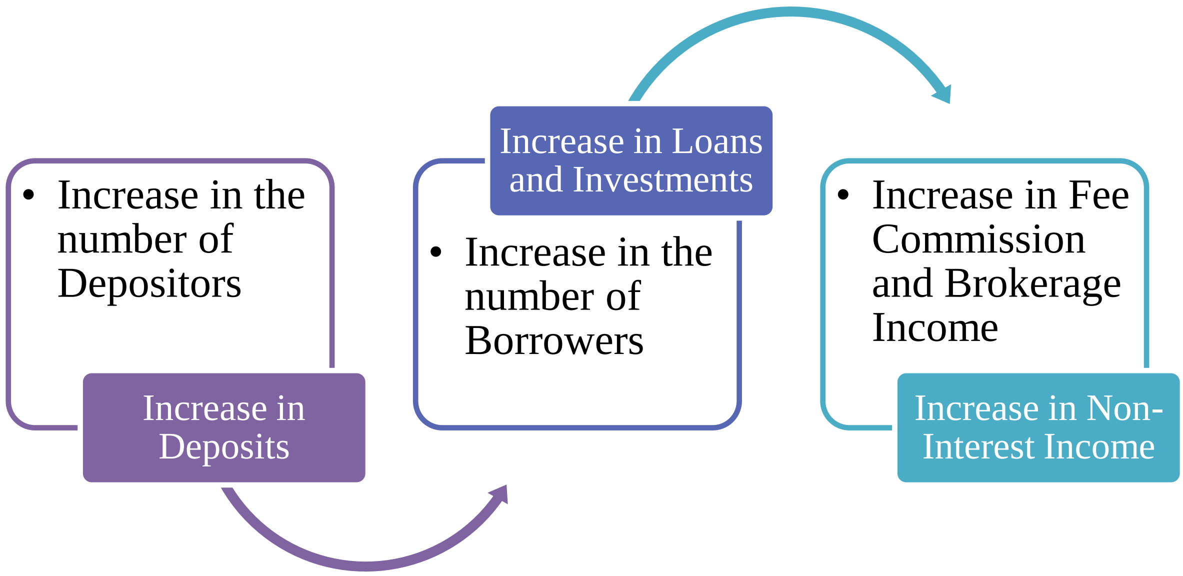

Figure 8. 3 Non-interest income generation process

This non-interest income is generated in the form of fee, commission and brokerage income earned by banks through providing a variety of account related and other service to their customers (both depositors and borrowers) and is mentioned as income from off-balance sheet items in the literature. Fama (1980) investigated commercial banking in the light of finance theory and concluded that banks should focus their efforts on earning fees rather than managing their portfolios structure efficiently because from investors' point of view only profit is important. Inclusion of off-balance sheet income in the efficiency studies has been emphasized in banking efficiency literature (Altunbaş et al., 2001, Isik and Hassan, 2003, Pasiouras, 2008a) as well. Considering the importance of income from off-balance sheet items[65], we have considered them as a basis for trade-off in the PDEATOB Framework. To formulate a realistic trade-off, we discussed this aspect with banking experts and collected the information on the value of trade-off by asking the following question.

Q2. *What is the percentage of fee, commission and brokerage income in relation to the interest expenses?*

It was easy for the experts to assess the percentage of fee commission and brokerage income in total income but was comparatively difficult to relate fee commission and brokerage income to interest expenses. However, based on the fee, commission and brokerage income to interest expenses ratio, derived from their monthly and quarterly financial reports they suggested a very broad range that varies from 5% to 20%. To make it acceptable for all banks we have considered a middle value of 10% and translated this non-interest income generating process of banks into the following trade-off:

Judgement 8.2. Without demanding any additional resources, an increase of one million in interest expenses, increases fee, commission and brokerage income by 0.1 million (equivalent to 10% of increase in interest expenses).

If we represent the weight of fee, commission and brokerage income by u_2, the resulting weight restriction for this trade-off can be written as:

[65] Off-balance sheet activities are not recorded in the balance sheets of banks but generate fee income for banks that improve their earnings ratios.

$$0.1u_2 - 1v_1 \leq 0 \tag{8.2}$$

8.3.3. Trade-Off 3 – Combined form of Trade-Offs 1 and 2

In the previous two trade-offs, interest expenses are related to only one output at a time i.e. interest income or fee, commission and brokerage income. In the real banking practice, an increase in the interest income and fee, commission and brokerage income are triggered simultaneously by an increase in interest expenses. Therefore, instead of stating two separate trade-offs, a single trade-off can be developed in the form of the following statement which appears to be entirely plausible:

Judgement 8.3. Without demanding any additional resources, an increase of one million in interest expenses, increases interest income by 1.5 million and fee, commission and brokerage income by 0.1 million.

Judgement 8.3 can be translated in the following weight restriction expression:

$$1.5\, u_1 + 0.1\, u_2 - 1v_1 \leq 0 \tag{8.3}$$

This expression is more complex as compared to expressions (8.1) and (8.2). While constructing expression (8.1) we assume that increase in the interest expenses only increases interest income without having any detrimental effect on other outputs. Changes in inputs (P_1) and outputs (Q_1) as a result of this trade-off can be expressed as follows:

$$P_1 = (1, 0, 0) \text{ and } Q_1 = (1.5, 0, 0) \tag{8.4}$$

Similarly, expression (8.2) links the increase in interest income with the increase in fee commission and brokerage income and can be expressed as:

$$P_2 = (1,0,0) \text{ and } Q_2 = (0,0.1,0) \tag{8.5}$$

P_2 and Q_2 represent changes in inputs and outputs respectively as a result of Trade-Off 2. According to expressions (8.4) and (8.5) two million units of interest expenses increase both the outputs by the amount specified in Trade-Offs 1 and 2 and result in the following expression:

$P_1 + P_2 = (2, 0, 0)$ and $Q_1 + Q_2 = (1.5, 0.1, 0)$ (8.6)

However, trade-off condition becomes more demanding if we consider that increase in the interest income and fee commission and brokerage income are actually the outcome of increase in interest expense. The resulting changes in inputs (P_3) and outputs (Q_3) are:

$P_3 = (1, 0, 0)$ and $Q_3 = (1.5, 0.1, 0)$ (8.7)

The expression (8.7) is more demanding than the expression (8.6) because it increases the same amount of outputs by using only half of the amount of input. This demanding effect has been explained with the help of empirical analysis in sections 8.4.2.2 and 8.4.3.1 of this Chapter.

8.3.4. Trade-Off 4 – Interest Income and Loan Loss Provision Linkage

All of the loans advanced by banks do not turn into good quality loans due to their risk of default. Therefore, according to SBP regulations, it is mandatory for banks to maintain a certain amount of profit as loan loss provision on both performing (general provision) and NPLs (specific Provision) in order to mitigate their future risk. However, the rate of provision varies with different categories of performing and non-performing loans that is communicated to banks from time to time through prudential regulations and different banking circulars of SBP. Generally, these rates are very nominal for performing loans and very high for different categories of NPLs as shown in Table 8.1.

Table 8.1 Rates of provision for different categories of loans

Performing Loans			Non-Performing Loans		
All Loans except Consumer Loans	Consumer Loans (Secured)	Consumer Loans (Unsecured)	Substandard Loans	Doubtful Loans	Losses
0.10%	1.50%	5.00%	25%	50%	100%

Source: (State Bank of Pakistan, 2011b)

The rate of loan loss provision has a broad range from 0 .1% of loans to 100%. As in profitability model we are dealing with revenues generated from loans therefore, we need to describe loan loss provision as a percentage of interest income in order to formulate trade-off between risk and income. To decide values for this trade-off based on the real life practice, we discussed this aspect with credit experts of the banks. For making this idea more comprehensible for them, we asked same question in different ways. The most effectively answered questions were:

Q3. *How much of the interest income is normally consumed for making loan loss provision against loans and advances?*

or

Q4. *What is the loan loss provision to interest income ratio for the bank?*

As the amount of provision is maintained on the amount of loans that vary with the categories of loans therefore, it was comparatively difficult for banking experts to relate it with the interest income. However, based on the responses collected from different banks we identified a range of 5% to 10%. As expected, banks with smaller amount of NPLs provided a lower estimate while banks with comparatively large amounts of NPLs provided comparatively larger estimate. For our trade-off we selected a more conservative limit of this range i.e. 10% in order to make it acceptable for every bank. This information is expressed in the form of trade-off as follows:

Judgement 8.4. Without demanding any additional resources, it is possible to increase the interest income by one million and increase the loan loss provision by 0.1 million (equivalent to 10% of increase in interest income).

If the weight of loan loss provision is represented by v_3 then the respective weight restriction is:

$$1\, u_1 - 0.1 v_3 \leq 0 \tag{8.8}$$

8.4. Empirical Analysis

For the empirical application of the PDEATOB Framework, we have selected output oriented DEA model with VRS assumption. The discussion of the empirical results on the profit efficiency is following the structure of Chapter 7. According to this structure, first we calculate the efficiency results with standard VRS model and use them as a base for comparison with the efficiency results obtained after application of trade-offs formulated for the PDEATOB Framework. For studying the impact of the PDEATOB Framework on the efficiency estimates, we first analyse the individual trade-offs of the PDEATOB Framework. Then, we incorporate all the trade-offs gradually to analyse their aggregate impact. The following sections provide the discussion of results according to the above mentioned scheme of analysis.

8.4.1. Analysis with Standard VRS Model

Table 8.2 provides output augmentation (ϕ), efficiency scores ($1/\phi$), and the summary statistics of profitability model obtained through the application of standard output oriented DEA model with VRS assumption. These results demonstrate that 17 out of 29 banks are efficient under profitability model. The average DEA score of 1.14 represents that, on average, banks in Pakistan require increasing their output level by 1.14 times more than what they are currently producing. Silk Bank is the least efficient bank with an efficiency score of 58.39%. Inefficient banks include: Al Baraka Bank, Burj Bank, Dubai Islamic Bank, Askari Commercial Bank, Bank Al Falah, Faysal Bank, KASB Bank, NIB Bank, Silk Bank, Soneri Bank, Summit Bank, and Barclays Bank.

Table 8. 2 Standard improvement factor (DEA scores) and radial output efficiency of banks with the standard VRS model under profitability approach

S.NO.	Bank	Efficiency Scores	DEA Scores
1	Al Baraka Bank Pakistan Ltd.	77.26%	1.29
2	Bank Islami Ltd.	100%	1
3	Burj Bank Ltd.	77.12%	1.30
4	Dubai Islamic Bank Ltd.	91.32%	1.10
5	Meezan Bank Ltd.	100%	1
6	Allied Bank of Pakistan Ltd.	100%	1
7	Askari Commercial Bank Ltd.	84.48%	1.18
8	Bank Al Falah Ltd.	85.84%	1.16
9	Bank Al Habib Ltd.	100%	1
10	Faysal Bank Ltd.	73.59%	1.36
11	Habib Bank Ltd.	100%	1
12	Habib Metropolitan Bank Ltd.	100%	1
13	JS Bank Ltd.	100%	1
14	KASB Bank Ltd.	90.58%	1.10
15	Muslim Commercial Bank Ltd.	100.0%	1
16	NIB Bank Ltd.	67.20%	1.49
17	Samba Bank Ltd.	100.0%	1
18	Silk Bank Ltd.	58.39%	1.71
19	Soneri Bank Ltd.	79.54%	1.26
20	Standard Chartered Bank Pakistan Ltd.	100.0%	1
21	Summit Bank Ltd.	60.99%	1.64
22	United Bank Ltd.	100.0%	1
23	Bank of Punjab	100.0%	1
24	Bank of Khyber	100.0%	1
25	First Women Bank Ltd.	100.0%	1
26	National Bank of Pakistan	100.0%	1
27	Barclays Bank PLC Pakistan	73.26%	1.37
28	Citi Bank	100.0%	1
29	HSBC	100.0%	1
	Average Efficiency Score	90.33%	1.14
	Number of Efficient Banks	17	17
	Max	100.00%	1.71
	Min	58.39%	1.00

8.4.2. Analysis with Application of Individual Trade-Offs

8.4.2.1. Efficiency Estimates with Trade-Offs 1 and 2

Table 8.3 summarizes the efficiency estimates before and after application of Trade-Off 1. Results indicate that the number of efficient banks reduce from 17 to 15 due to the transfer of two banks (Bank of Punjab and Bank of Khyber) from efficient to inefficient status. Summit Bank is the least efficient bank with an efficiency score of 55.73%. The decrease in efficiency score of eleven banks is observed where 7 banks are inefficient under standard VRS model with an efficiency score of less than 80%. This decrease ranges from 0.2 to 14.8 percentage points and reduces average efficiency score from 90.33% to 88.62%. This change in efficiency scores of banks is observed mainly due to low interest income in comparison to interest expense or allocation of zero or less weight to interest expense in comparison to other inputs or interest income. Highest decrease of 14.8 percentage points is observed in the efficiency score of Bank of Punjab. This decrease in its efficiency score is attributed to its relatively low interest income due to existence of large non income generating portion of loans (in the form of NPLs) in its asset portfolio.

Table 8. 3 Efficiency scores of banks with and without Trade-Off 1

Bank	Efficiency Scores without TO	Efficiency Scores with TO 1	Percentage Points Change
Al Baraka Bank Pakistan Ltd.	77.26%	65.93%	11.3%
Bank Islami Ltd.	100%	100%	0%
Burj Bank Ltd.	77.12%	76.93%	0.2%
Dubai Islamic Bank Ltd.	91.32%	91.32%	0%
Meezan Bank Ltd.	100%	100%	0%
Allied Bank of Pakistan Ltd.	100%	100%	0%
Askari Commercial Bank Ltd.	84.48%	76.76%	7.7%
Bank Al Falah Ltd.	85.84%	85.33%	0.5%
Bank Al Habib Ltd.	100.00%	100%	0%
Faysal Bank Ltd.	73.59%	73.06%	0.5%
Habib Bank Ltd.	100%	100%	0%
Habib Metropolitan Bank Ltd.	100%	100%	0%
JS Bank Ltd.	100%	100%	0%
KASB Bank Ltd.	90.58%	90.58%	0%
Muslim Commercial Bank Ltd.	100%	100%	0%
NIB Bank Ltd.	67.20%	66.68%	0.5%
Samba Bank Ltd.	100%	100%	0%
Silk Bank Ltd.	58.39%	58.12%	0.3%
Soneri Bank Ltd.	79.54%	76.31%	3.2%
Standard Chartered Bank Pakista	100%	100%	0%
Summit Bank Ltd.	60.99%	55.73%	5.3%
United Bank Ltd.	100%	100%	0%
Bank of Punjab	100%	85.16%	14.8%
Bank of Khyber	100%	94.67%	5.3%
First Women Bank Ltd.	100%	100%	0%
National Bank of Pakistan	100%	100%	0%
Barclays Bank PLC Pakistan	73.26%	73.26%	0%
Citi Bank	100%	100%	0%
HSBC	100%	100%	0%
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	17	15	11
Average Efficiency Score	90.33%	88.62%	

Incorporation of Trade-Off 2 does not change efficiency scores of banks as shown in Table 8.4. However, some changes are observed in the weight profile of the variables according to the new condition added to the standard VRS model. We are not increasing the value of fee, commission and brokerage income used in the trade-off just for the sake of making differences in the efficiency scores. Moreover, increasing the value of fee, commission and brokerage income in trade-off may make this trade-off unacceptable for those banks that have comparatively low portion of their income in the form of off-balance sheet activities.

Table 8.4 Efficiency scores of banks with and without Trade-Off 2

Bank	Efficiency Scores without TO	Efficiency Scores with TO 2	Percentage Points Change
Al Baraka Bank Pakistan Ltd.	77.26%	77.26%	0%
Bank Islami Ltd.	100%	100%	0%
Burj Bank Ltd.	77.12%	77.12%	0%
Dubai Islamic Bank Ltd.	91.32%	91.32%	0%
Meezan Bank Ltd.	100%	100%	0%
Allied Bank of Pakistan Ltd.	100%	100%	0%
Askari Commercial Bank Ltd.	84.48%	84.48%	0%
Bank Al Falah Ltd.	85.84%	85.84%	0%
Bank Al Habib Ltd.	100.00%	100.00%	0%
Faysal Bank Ltd.	73.59%	73.59%	0%
Habib Bank Ltd.	100%	100%	0%
Habib Metropolitan Bank Ltd.	100%	100%	0%
JS Bank Ltd.	100%	100%	0%
KASB Bank Ltd.	90.58%	90.58%	0%
Muslim Commercial Bank Ltd.	100%	100%	0%
NIB Bank Ltd.	67.20%	67.20%	0%
Samba Bank Ltd.	100%	100%	0%
Silk Bank Ltd.	58.39%	58.39%	0%
Soneri Bank Ltd.	79.54%	79.54%	0%
Standard Chartered Bank Pakistan Lt	100%	100%	0%
Summit Bank Ltd.	60.99%	60.99%	0%
United Bank Ltd.	100%	100%	0%
Bank of Punjab	100%	100%	0%
Bank of Khyber	100%	100%	0%
First Women Bank Ltd.	100%	100%	0%
National Bank of Pakistan	100%	100%	0%
Barclays Bank PLC Pakistan	73.26%	73.26%	0%
Citi Bank	100%	100%	0%
HSBC	100%	100%	0%
Average Efficiency Score	90.33%	90.33%	
Number of Efficient Banks	17	17	

8.4.2.2. *Efficiency Estimates with Trade-Off 3*

Table 8.5 presents the efficiency estimates before and after application of Trade-Off 3 (combined form of Trade-Offs 1 and 2). The count of efficient banks reduces from 17 to 13 as Bank Al Habib, Habib Metropolitan Bank, Bank of Punjab and Bank of Khyber are removed now from the list of efficient banks. Average efficiency score drops from 90.33% to 88.05% due to the decrease in efficiency scores of thirteen banks. Although, Trade-Off 2 alone does not change the efficiency scores but the combination of Trade-Offs 1 and 2 as Trade-Off 3 reduces both the count of efficient banks and efficiency scores. Similar to Trade-Off 1, Summit Bank is the least efficient bank with efficiency score of 54.26% and Bank of Punjab observes the highest drop of 17.03 percentage points in efficiency score.

Table 8. 5 Efficiency scores of banks with and without Trade-Off 3

Bank	Efficiency Scores without TO	Efficiency Scores with TO 3	Percentage Points Change
Al Baraka Bank Pakistan Ltd.	77.26%	65.93%	11.33%
Bank Islami Ltd.	100%	100%	0%
Burj Bank Ltd.	77.12%	76.93%	0.19%
Dubai Islamic Bank Ltd.	91.32%	91.32%	0%
Meezan Bank Ltd.	100%	100%	0%
Allied Bank of Pakistan Ltd.	100%	100%	0%
Askari Commercial Bank Ltd.	84.48%	76.76%	7.72%
Bank Al Falah Ltd.	85.84%	85.33%	0.51%
Bank Al Habib Ltd.	100.00%	96.43%	3.57%
Faysal Bank Ltd.	73.59%	73.06%	0.54%
Habib Bank Ltd.	100%	100%	0%
Habib Metropolitan Bank Ltd.	100%	93.00%	7.00%
JS Bank Ltd.	100%	100%	0%
KASB Bank Ltd.	90.58%	90.58%	0%
Muslim Commercial Bank Ltd.	100%	100%	0%
NIB Bank Ltd.	67.20%	64.73%	2.47%
Samba Bank Ltd.	100%	100%	0%
Silk Bank Ltd.	58.39%	58.12%	0.27%
Soneri Bank Ltd.	79.54%	76.09%	3.46%
Standard Chartered Bank Pakistan Ltd.	100%	100%	0%
Summit Bank Ltd.	60.99%	54.26%	6.73%
United Bank Ltd.	100%	100%	0%
Bank of Punjab	100%	82.97%	17.03%
Bank of Khyber	100%	94.59%	5.41%
First Women Bank Ltd.	100%	100%	0%
National Bank of Pakistan	100%	100%	0%
Barclays Bank PLC Pakistan	73.26%	73.26%	0%
Citi Bank	100%	100%	0%
HSBC	100%	100%	0%
Average Efficiency Score	90.33%	88.05%	
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	17	13	13

8.4.2.3. Efficiency Estimates with Trade-Off 4

Results generated by independent application of Trade-Off 4 are presented in Table 8.6. The number of efficient banks decreases from 17 to 15. Similar to Trade-Off 1, two inefficient banks are: Bank of Punjab and Bank of Khyber. Al Baraka Bank is the least efficient bank with an efficiency score of 46.21%. Overall, efficiency scores of 13 banks decrease that reduced the average efficiency scores from 90.33% to 85.99%.

Table 8. 6 Efficiency scores of banks with and without Trade-Off 4

Bank	Efficiency Scores without TO	Efficiency Scores with TO 4	Percentage Points Change
Al Baraka Bank Pakistan Ltd.	77.26%	46.21%	31.05%
Bank Islami Ltd.	100%	100%	0%
Burj Bank Ltd.	77.12%	73.07%	4.06%
Dubai Islamic Bank Ltd.	91.32%	90.65%	0.67%
Meezan Bank Ltd.	100%	100%	0%
Allied Bank of Pakistan Ltd.	100%	100%	0%
Askari Commercial Bank Ltd.	84.48%	63.48%	21.00%
Bank Al Falah Ltd.	85.84%	83.04%	2.80%
Bank Al Habib Ltd.	100.00%	100.00%	0%
Faysal Bank Ltd.	73.59%	66.01%	7.58%
Habib Bank Ltd.	100%	100%	0%
Habib Metropolitan Bank Ltd.	100%	100%	0%
JS Bank Ltd.	100%	100%	0%
KASB Bank Ltd.	90.58%	90.58%	0%
Muslim Commercial Bank Ltd.	100%	100%	0%
NIB Bank Ltd.	67.20%	64.47%	2.73%
Samba Bank Ltd.	100%	100%	0%
Silk Bank Ltd.	58.39%	53.28%	5.11%
Soneri Bank Ltd.	79.54%	67.75%	11.80%
Standard Chartered Bank Pakistan Ltd.	100%	100%	0%
Summit Bank Ltd.	60.99%	51.06%	9.93%
United Bank Ltd.	100%	100%	0%
Bank of Punjab	100%	85.16%	14.84%
Bank of Khyber	100%	97.52%	2.48%
First Women Bank Ltd.	100%	100%	0%
National Bank of Pakistan	100%	100%	0%
Barclays Bank PLC Pakistan	73.26%	61.55%	11.71%
Citi Bank	100%	100%	0%
HSBC	100%	100%	0%
Average Efficiency Score	90.33%	85.99%	
Number of Efficient Banks/ Number of Banks with Change in Efficiency Scores	17	15	13

The highest decline of 31.05 percentage points occurs in Al Baraka Bank followed by a decline of 21 percentage points in Askari Commercial Bank. The major contributing factor to this decline in their efficiency scores is the large quantities of loan loss provision charged for the year due to existence of large amount of NPLs in these banks.

8.4.3. Analysis with the Complete PDEATOB Framework

This section provides the discussion of results obtained through the implementation of the complete PDEATOB Framework introduced in the stepwise manner.

8.4.3.1. Discussion of Efficiency Estimates

Efficiency estimates of profitability approach calculated with standard VRS model, Trade-Off 1, Trade-Offs 1 and 2, Trade-Offs 3 and the complete PDEATOB Framework are reported in Table 8.7. Results indicate that without any trade-off, 17 banks are efficient. After application of Trade-Off 1, Bank of Punjab and Bank of Khyber become inefficient and the count of efficient banks reduces to 15. Efficiency scores of 11 banks decline where highest decline is observed in Bank of Punjab which is an efficient bank under standard VRS model. Column 5 of the table provides results with the sequential addition of Trade-Off 2. These results indicate that this addition reduces the efficiency score of only the Bank of Punjab by 2.19 percentage points without changing the efficiency scores of the rest of the banks. An interesting fact to note here is that Trade-Off 2 alone does not change the efficiency scores, but its progressive addition after Trade-Off 1 changes the efficiency score of one bank.

The results obtained by applying Trade-Off 3 (Trade-Offs 1 and 2 combined in one statement) are provided in column 7 of the table. The incorporation of this Trade-Off in standard VRS model reduces the number of efficient banks from 15 to 13, due to switching of Bank Al Habib and Habib Metropolitan Bank from efficient to inefficient status. Moreover, efficiency scores of 7 banks further decline which include: Bank Al Habib, Habib Metropolitan Bank, NIB Bank, Soneri Bank, Summit Bank, Bank of Punjab and Bank of Khyber. The highest drop of 7 percentage points appears in Habib Metropolitan Bank. It is interesting to note here that the sequential addition of Trade-Off 2 reduces the efficiency score of only one bank, but Trade-Off 3 reduces the number of efficient banks from 15 to 14 along with a decline in the efficiency scores of 7 banks.

The efficiency estimates with the complete PDEATOB Framework (with Trade-Off 3 and Trade-Off 4 only as Trade-Off 3 is the combined form of Trade-Off 1 and Trade-Off 2) are reported in Column 9 of the table. These results indicate that only 11 banks are efficient in comparison to 17 efficient banks obtained through standard VRS model. Meezan Bank and Habib Bank switch from the efficient to inefficient set of banks. The efficiency scores of 14 banks drop that change the average efficiency score from 90.33% to 83.15%. The highest drop of 26.90 percentage points in the efficiency scores of Al Baraka Bank makes it the least efficient bank with the profit efficiency of 39.03%.

The PDEATOB Framework is dealing with the additional information related to the major constituents of profit and loss of a bank, such as interest expenses, loan loss provision, interest income and non-interest income. On the basis of this additional information, it has the capability to differentiate the bad performers with problematic operational areas in a set of banks and rank them by taking into account their strengths as well as weaknesses, which is not possible with the use of standard VRS model.

Table 8. 7 Efficiency scores of banks with all Trade-Offs of the PDEATOB Framework added in sequential manner

Bank	Column 2 Efficiency Scores without TO	Column 3 Efficiency Scores with TO 1	Column 4 Percentage Points Change	Column 5 Efficiency Scores with TO 1 and 2	Column 6 Percentage Points Change	Column 7 Efficiency Scores with TO 3	Column 8 Percentage Points Change	Column 9 Efficiency Scores with all Trade-Offs	Column 10 Percentage Points Change
Al Baraka Bank Pakistan Ltd.	77.26%	65.93%	11.33%	65.93%	0%	65.93%	0%	39.03%	26.90%
Bank Islami Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%
Burj Bank Ltd.	77.12%	76.93%	0.19%	76.93%	0%	76.93%	0%	72.48%	4.46%
Dubai Islamic Bank Ltd.	91.32%	91.32%	0%	91.32%	0%	91.32%	0%	90.65%	0.67%
Meezan Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	98.88%	1.12%
Allied Bank of Pakistan Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%
Askari Commercial Bank Ltd.	84.48%	76.76%	7.72%	76.76%	0%	76.76%	0%	58.09%	18.67%
Bank Al Falah Ltd.	85.84%	85.33%	0.51%	85.33%	0%	85.33%	0%	80.63%	4.70%
Bank Al Habib Ltd.	100%	100%	0%	100%	0%	96.43%	3.57%	95.99%	0.44%
Faysal Bank Ltd.	73.59%	73.06%	0.54%	73.06%	0%	73.06%	0%	65.31%	7.74%
Habib Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	88.28%	11.72%
Habib Metropolitan Bank Ltd.	100%	100%	0%	100%	0%	93.00%	7.00%	93.00%	0%
JS Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%
KASB Bank Ltd.	90.58%	90.58%	0%	90.58%	0%	90.58%	0%	90.58%	0%
Muslim Commercial Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%
NIB Bank Ltd.	67.20%	66.68%	0.52%	66.68%	0%	64.73%	1.95%	56.76%	7.97%
Samba Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%
Silk Bank Ltd.	58.39%	58.12%	0.27%	58.12%	0%	58.12%	0%	51.79%	6.33%
Soneri Bank Ltd.	79.54%	76.31%	3.24%	76.31%	0%	76.09%	0.22%	60.96%	15.13%
Standard Chartered Bank Pakistan Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%
Summit Bank Ltd.	60.99%	55.73%	5.26%	55.73%	0%	54.26%	1.47%	40.97%	13.29%
United Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%
Bank of Punjab	100%	85.16%	14.84%	82.97%	2.19%	82.97%	2.19%	82.97%	0%
Bank of Khyber	100%	94.67%	5.33%	94.67%	0%	94.59%	0.08%	83.74%	10.85%
First Women Bank Ltd.	100%	100%	0%	100%	0%	100%	0%	100%	0%
National Bank of Pakistan	100%	100%	0%	100%	0%	100%	0%	100%	0%
Barclays Bank PLC Pakistan	73.26%	73.26%	0%	73.26%	0%	73.26%	0%	61.15%	12.11%
Citi Bank	100%	100%	0%	100%	0%	100%	0%	100%	0%
HSBC	100%	100%	0%	100%	0%	100%	0%	100%	0%
Average Efficiency Score	90.33%	88.62%		88.54%		88.05%		83.15%	
Number of Efficient Banks/Number of Banks with Change in Efficiency Scores	17	15	11	15	1	13	7	11	14

8.4.3.2. *Comparison of Efficiency Estimates*

In order to compare the efficiency scores before (column 2 of Table 8.7) and after incorporation of the complete PDEATOB Framework (column 9 of Table 8.7), we have graphically plotted them in Figure 8.4. This figure shows that Al Baraka Bank, Askari Commercial Bank, NIB Bank, Silk Bank, Soneri Bank, Summit Bank and Barclays Bank are the seven least efficient banks with efficiency scores below 62%.

An investigation of the financial data of least efficient banks, identified by the PDEATOB Framework, supports the results obtained through the incorporation of the PDEATOB Framework. The financial data reveals that Al Baraka Bank, Silk Bank, Summit Bank and Barclays Bank suffer losses for the year 2012. Moreover, all the banks except Barclays Bank have relatively large quantities of NPLs and resultantly charged comparatively large amounts of loan loss provision in the year 2012. Although, NIB Bank has small amount of profit for the year 2012, but has accumulated huge amounts of losses from previous years. Moreover, all least efficient banks except NIB Bank have relatively low non-interest income in the form of fee, commission and brokerage income as compared to interest income. This fact indicates that these banks are less involved in off-balance sheet activities and require improving this area in order to compete with other banks.

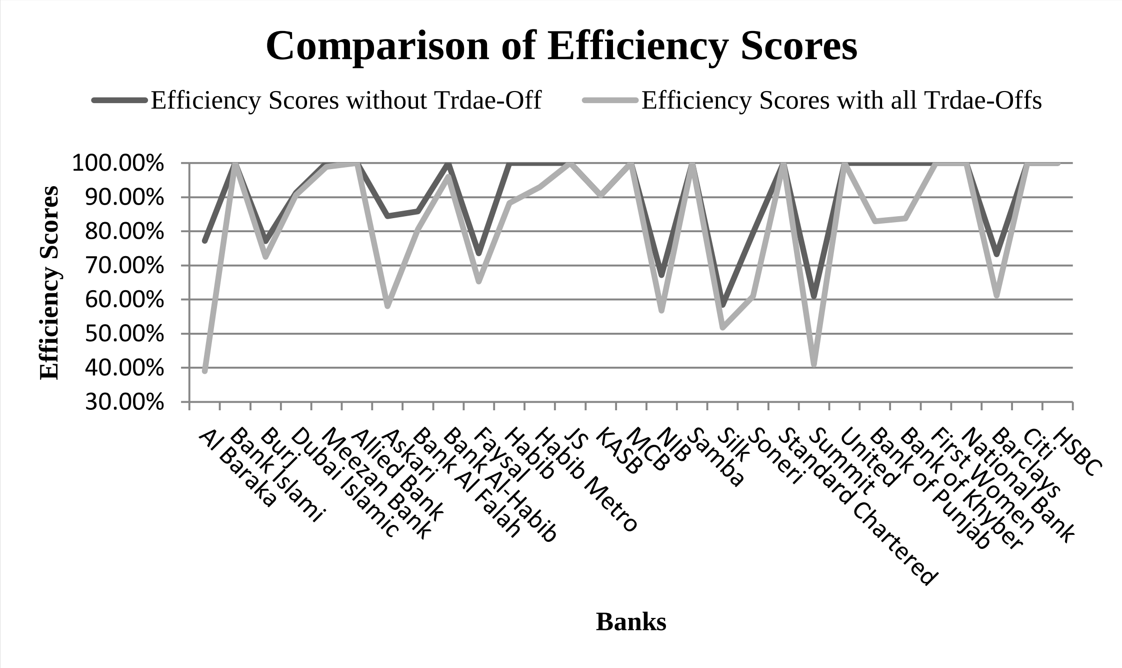

Figure 8. 4 The comparison of efficiency estimates before and after incorporation of the PDEATOB Framework

8.4.3.3. Peer Analysis

An important feature of DEA is that it provides efficient peers that serve as model of best practices for inefficient banks. Table 8.8 provides information about the benchmarks and the number of times each efficient bank is cited as benchmark for inefficient banks. After incorporation of the PDEATOB Framework only eleven banks are efficient out of which 10 banks serve as benchmarks for other banks while one bank is not selected as efficient peer for any of the bank. Moreover, three banks appear as benchmark only once. This table also reveals that Allied Bank is the most frequently selected benchmark that appears 15 times. Other frequently identified benchmarks include JS Bank (10 times), United Bank (7 times), Samba Bank (6 times), and First Women Bank (5 times) where only First Women Bank is public sector bank while the rest of the efficient peers are private domestic banks. An interesting point to note here is that inefficient foreign bank i.e. Barclays Bank (foreign bank) is suggested by the PDEATOB Framework to emulate the banking practices of Allied Bank, JS Bank and Samba Bank (all are private domestic banks) to increase its profit efficiency.

Above mentioned information indicates that because of the similarity in their input/output mix most of the inefficient banks form a dense cloud under the facets of efficient frontier defined by the private banks. Therefore, inefficient banks are radially projected onto those facets to be efficient and most of the private domestic banks serve as their benchmarks. On the other hand, some of the banks are 100% efficient due to their unique input/output mix but those banks seldom appear as benchmarks for inefficient banks due to their very large or very small size as compared to the majority of the banks. The extreme sizes of these banks lead them to define those facets of efficient frontier where the radial projection of inefficient banks is not possible.

Table 8. 8 Reference set of inefficient banks

S.No.	Bank	Reference Set
1	Al Baraka Bank Pakistan Ltd.	13 (0.19) 15 (0.04) 17 (0.51) 25 (0.26)
2	Bank Islami Ltd.	3
3	Burj Bank Ltd.	6 (0.04) 17 (0.47) 25 (0.49)
4	Dubai Islamic Bank Ltd.	15 (0.05) 22 (0.01) 25 (0.94)
5	Meezan Bank Ltd.	2 (0.73) 6 (0.10) 17 (0.17)
6	Allied Bank of Pakistan Ltd.	15
7	Askari Commercial Bank Ltd.	2 (0.54) 6 (0.46)
8	Bank Al Falah Ltd.	6 (0.43) 13 (0.53) 22 (0.04)
9	Bank Al Habib Ltd.	2 (0.89) 6 (0.11)
10	Faysal Bank Ltd.	6 (0.32) 13 (0.57) 22 (0.11)
11	Habib Bank Ltd.	6 (0.67) 22 (0.28) 26 (0.04)
12	Habib Metropolitan Bank Ltd.	6 (0.21) 13 (0.77) 22 (0.02)
13	JS Bank Ltd.	10
14	KASB Bank Ltd.	13 (0.76) 20 (0.09) 29 (0.15)
15	Muslim Commercial Bank Ltd.	2
16	NIB Bank Ltd.	6 (0.02) 13 (0.88) 22 (0.09)
17	Samba Bank Ltd.	6
18	Silk Bank Ltd.	6 (0.01) 13 (0.70) 17 (0.28)
19	Soneri Bank Ltd.	6 (0.05) 13 (0.91) 17 (0.04)
20	Standard Chartered Bank Pakis	1
21	Summit Bank Ltd.	6 (0.04) 13 (0.93) 22 (0.03)
22	United Bank Ltd.	7
23	Bank of Punjab	6 (0.26) 25 (0.74)
24	Bank of Khyber	6 (0.07) 25 (0.93)
25	First Women Bank Ltd.	5
26	National Bank of Pakistan	1
27	Barclays Bank PLC Pakistan	6 (0.01) 13 (0.16) 17 (0.83)
28	Citi Bank	0
29	HSBC	1

8.4.4. Relationship between Technical Efficiency and Ownership Type

Table 8.9 shows the number of efficient banks and average efficiency scores for different categories of banks with and without the PDEATOB Framework. The table indicates that there is no change in the number of efficient banks in case of foreign banks with or without the PDEATOB Framework (two in both cases). However, the number of efficient Islamic banks reduced from 2 to 1, private domestic banks reduced from 9 to 6 and the number of public sector banks declined from 4 to 2 after implementation of the PDEATOB Framework. It is also evident from the average efficiency scores that public sector banks, is the most efficient category of banks both with and without the PDEATOB Framework followed by foreign banks. These results are in contrast to the common perception that public firms use resources of the economy inefficiently. It is likely that the public banks have exclusive access to most of the government businesses. Consequently, they generate significant fee based income and tend to be more efficient. The higher efficiency scores for public sector banks as compared to private sector banks is reported in by Hauner (2005) in Austria and Germany. These results are further supported by studies in India (Sathye, 2003), Turkey (Isik and Hassan, 2003), and Brazil (Staub et al., 2010) which reported that public sector banks are efficient from both private and foreign banks.

Islamic banks, is the least efficient category with the average efficiency score of 80.12% after the application of the PDEATOB Framework. Al Baraka Bank is the main contributor towards low profit efficiency in Islamic banks. Major reasons for its profit inefficiency are: the large gap between the return on financing and return on deposits due to low spread[66] and the large quantities of loan loss provisions due to

[66] For details of spread rate of commercial banks reader is referred to Banking Survey by KPMG (2012).

higher proportion of NPLs. However, a possible reason for overall low efficiency scores in Islamic banks is their relatively small size with limited branch network due to which they have less business activity and less amount of income earning opportunities. Private domestic banks are slightly better than Islamic banks with the average efficiency score of 81.31%.

Table 8.9 An overview of different ownership groups of banks before and after application of the PDEATOB Framework

Category of Bank	With Standard VRS Model			With PDEATOB Framework		
	Number of Efficient Banks	Number of Inefficient Banks	Average Efficiency Scores	Number of Efficient Banks	Number of Inefficient Banks	Average Efficiency Scores
Islamic Banks	2	3	89.14%	1	4	80.21%
Private Domestic Banks	9	8	88.27%	6	11	81.31%
Public Sector Banks	4	0	100%	2	2	91.68%
Foreign Banks	2	1	91.09%	2	1	87.05%
Total	17	12	90.33%	11	18	83.15%

However, on the basis of these average efficiency scores it is difficult to tell about the major contributors in the profit inefficiency of banking sector, from a particular ownership group. Therefore, we divide all banks into three categories on the basis of their efficiency scores which are: good performers (having score greater than 85%), average performers (with efficiency scores between 70% and 85%) and poor performers (with efficiency scores less than or equal to 70%). Table 8.10 shows different performance categories of banks, the number of banks in each category from different ownership groups, average efficiency scores, average improvement factor in each performance category and cumulative efficiency scores. This table reveals that 17 banks are good performers, 4 banks are average performers and 8 banks are poor performers. The poor performers include six private domestic banks, one Islamic bank and one foreign bank. Average efficiency scores improve from 83.15% to 94.15% if we eliminate poor performers from the calculations. About 75% of the poor performers are private domestic banks indicating that private domestic bank is the least efficient category of banks. As Islamic banks and private domestic banks are the sub categories of private banks therefore it is concluded that private banks are the least efficient banks in Pakistan in terms of profitability.

Table 8. 10 Segregation of banks from different ownership groups into three performance categories

Category/ Bank	Islamic Banks	Private Domestic Banks	Public Sector Banks	Foreign Banks	Total	Average Efficiency Score	Average Improvement Factor	Cumulative Average Efficiency Score	Big Five
Good Performers (Efficiency >85%)	3	10	2	2	17	97.49%	1.03	97.49%	5
Average Performers (70<Efficiency ≤85%)	1	1	2	0	4	79.95%	1.25	94.15%	0
Poor Performers (Efficiency ≤70%)	1	6	0	1	8	54.26%	1.90	83.15%	0

The low mean efficiency score of both Islamic and private banks is due to the fact that these two categories of banks are adversely affected by the energy short fall and increasing infection in few economic sectors such as textile, chemical and pharmaceutical resulting in the deterioration of asset quality of these banks. However, to cope with this situation these banks have adopted the risk aversion strategy by subsiding the flow of funds to private sector and heavily investing in government securities which also improved their liquidity (State Bank of Pakistan, 2012a). Another contributing factor towards their low profitability is the decline in the return on government securities and advances that decreased the overall interest income of these banks (State Bank of Pakistan, 2012b).

This table also reveals that all the big five banks are good performers. This is due to the reason that these banks have extensive branch networks all over the country (see Table 5.2 in Chapter 5) that enable them to serve both retail and corporate sector while providing more diversified services as compared to the small banks that only cater the localized markets.

8.4.5. Relationship between Efficiency Estimates and Bank Size

Average efficiency estimates on the basis of asset size are presented in Table 8.11. It is evident from the average efficiency scores that largest banks are the most efficient and medium sized banks are the least efficient category, with and without the PDEATOB Framework. Large banks occupy the second place in average efficiency score with standard VRS model and third place with the PDEATOB Framework. Small banks have smaller average efficiency score than large banks with standard VRS model but become the second efficient bank category next to largest banks after the application of the PDEATOB Framework. On the basis of these results efficiency estimates seem to exhibit a U-shaped relationship with asset size which is consistent with the findings of Ataullah et al. (2004) in Pakistan, Chen et al. (2005) in China and Jaffry et al. (2007) in Indian subcontinent.

Largest banks are relatively efficient because they have extensive branch network (see Table 5.2 in Chapter 5) in both rural and urban areas and have comparatively more clientele ranging from individual customers to corporate customers that provide them more coverage of business activity across geographical regions in the country. Therefore, these banks have more opportunities to earn revenues in the form of interest as well as non-interest income. These results are also consistent with the results of State Bank of Pakistan (2012b).

Our findings on size also resemble to the banking sector of other countries partially. For example, the findings of high efficiency score in extremely large banks is similar to the findings of Drake et al. (2006) on Hong Kong’s banking system, Yildirim (2002) in Turkey, Elyasiani and Mehdian (1990), Miller and Noulas (1996) and

Berger and Humphrey (1997) in U.S. banking. Small banks are efficient because they mostly deal with exclusive big corporate clients having minimal risk of default. They charge comparatively high interest rates and service charges by providing exclusively customized services enabling them to earn more income with fewer amounts of losses. Moreover, due to their small size they have control over their costs particularly, operating costs.

Our findings of high efficiency scores in small banks is consistent with the findings of Ashton (2001) in the smaller UK retail banking and Resti (1997) for Italian banks. In contrast, most of the medium sized banks are inefficient due to existence of large quantities of NPLs which result in low interest income on one hand and increase in the expense of banks in the form of loan loss provision on the other hand. Moreover, many banks in this category such as Faysal Bank, NIB Bank, Silk Bank, Summit Bank and JS Bank have passed through a series of mergers and acquisitions as a result of minimum capital requirement imposed under Basel Accord I and II.

Table 8. 11 Total assets and efficiency scores of all banks with and without the PDEATOB Framework

S.No.	Bank	Total Assets (in 000)	Efficiency Scores without TO	Efficiency Scores with PDEATOB Framework
1	Habib Bank Ltd.	1,610,308,572	100%	88.28%
2	National Bank of Pakistan	1,316,160,457	100%	100.00%
3	United Bank Ltd.	960,210,415	100%	100.00%
4	Muslim Commercial Bank Ltd.	770,282,541	100%	100.00%
5	Allied Bank of Pakistan Ltd.	632,301,706	100%	100.00%
6	Bank Al Falah Ltd.	536,466,694	85.84%	80.63%
7	Bank Al Habib Ltd.	453,353,942	100.00%	95.99%
8	Standard Chartered Bank Pakistan Ltd.	399,055,450	100%	100.00%
9	Askari Commercial Bank Ltd.	353,211,274	84.48%	58.09%
10	Bank of Punjab	332,110,474	100%	82.97%
11	Faysal Bank Ltd.	313,064,332	73.59%	65.31%
12	Habib Metropolitan Bank Ltd.	300,739,810	100%	93.00%
13	Meezan Bank Ltd.	274,436,510	100%	98.88%
14	NIB Bank Ltd.	190,855,177	67.20%	56.76%
15	Soneri Bank Ltd.	158,618,236	79.54%	60.96%
16	Summit Bank Ltd.	134,289,066	60.99%	40.97%
17	KASB Bank Ltd.	90,277,626	90.58%	90.58%
18	Silk Bank Ltd.	89,061,570	58.39%	51.79%
19	Citi Bank	85,171,810	100%	100.00%
20	JS Bank Ltd.	84,018,777	100%	100.00%
21	Bank of Khyber	82,177,638	100%	83.74%
22	Bank Islami Ltd.	74,236,030	100%	100.00%
23	Al Baraka Bank Pakistan Ltd.	73,869,051	77.26%	39.03%
24	Dubai Islamic Bank Ltd.	63,500,705	91.32%	90.65%
25	HSBC	50,328,093	100%	100.00%
26	Barclays Bank PLC Pakistan	47,778,267	73.26%	61.15%
27	Burj Bank Ltd.	47,185,452	77.12%	72.48%
28	Samba Bank Ltd.	34,853,837	100%	100.00%
29	First Women Bank Ltd.	22,490,800	100%	100.00%
	Asset Category	**Number of Banks**	**Average Efficiency**	**Average Efficiency**
1	**Small**-Less than or equal to Rs.70 billion	6	90.28%	87.38%
2	**Medium**- >Rs.70 billion and ≤Rs. 200 billion	10	83.40%	72.38%
3	**Large**- >Rs.200 billion and ≤ Rs.500 billion	7	94.01%	84.89%
4	**Largest**-Greater than Rs.500 billion	6	97.64%	94.82%

8.4.6. Scale Efficiency

To isolate the scale effect from the overall inefficiency we need to estimate scale efficiency (SE). For the calculation of scale efficiency we already have pure technical efficiency (PTE) results (VRS efficiency with the PDEATOB Framework) and require overall technical efficiency (OTE) results. Once overall technical efficiency is calculated by using CRS output oriented model with the PDEATOB Framework, then scale efficiency can be derived by dividing the overall technical efficiency with pure technical efficiency.

Scale efficiency estimates are presented in Table 8.12. Out of the total 20.14% average inefficiency of banking sector, scale efficiency component is only 3.61% which is smaller than pure technical inefficiency. Our findings on scale efficiency support the earlier findings on scale efficiency suggesting that scale inefficiency is not an issue in the inefficiency of banking sector (Berger and Humphrey, 1991, Berger et al., 1993a, Berger et al., 1993b). Among seven the most scale efficient banks, six are private domestic banks and one is foreign bank. No public sector bank is 100% scale efficient. Five least scale efficient banks include 3 public sector banks and one each from private domestic and foreign bank category. Average scale efficiency scores show that public sector banks are most scale inefficient banks in spite of being most technically efficient banks followed by foreign banks in this trend.

For the investigation of returns to scale (RTS) characteristics of all banks we have followed the method proposed by Färe et al. (1985). According to this method we need to calculate output oriented non-increasing returns to scale (NIRS) scores with the PDEATOB Framework in addition to CRS and VRS scores. The details of this method are provided in section 4.8 of Chapter 4. RTS findings reveal that 7 banks exhibit CRS, 14 banks exhibit DRS and 8 banks exhibit IRS. Three out of four public sector banks exhibit IRS indicating that they need to expand their operational activities to increase their profitability and reap the benefits of productivity gain. In contrast, despite being less efficient, private domestic banks and Islamic banks are more scale efficient. This can be attributed to severe market competition between these two categories of banks. Although, Islamic banking is a relatively new concept however, the share of Islamic banks in the overall banking assets is growing rapidly since last few years. Due to increasing popularity of Islamic banking products most of the private domestic banks are also providing Islamic banking services through their special Islamic banking windows and branches. This competition drives both these categories of banks to take the advantage of cost saving by diversifying their business.

Table 8. 12 Scale efficiency and RTS of all banks with the PDEATOB Framework

Bank	OTE	PTE	SE	RTS
Al Baraka Bank Pakistan Ltd.	38.48%	39.03%	98.58%	IRS
Bank Islami Ltd.	98.60%	100%	98.60%	DRS
Burj Bank Ltd.	70.00%	72.48%	96.58%	IRS
Dubai Islamic Bank Ltd.	84.60%	90.65%	93.32%	IRS
Meezan Bank Ltd.	97.46%	98.88%	98.56%	DRS
Allied Bank of Pakistan Ltd.	100%	100%	100%	CRS
Askari Commercial Bank Ltd.	57.90%	58.09%	99.68%	DRS
Bank Al Falah Ltd.	79.73%	80.63%	98.88%	DRS
Bank Al-Habib Ltd.	93.54%	95.99%	97.45%	DRS
Faysal Bank Ltd.	64.08%	65.31%	98.11%	DRS
Habib Bank Ltd.	85.44%	88.28%	96.79%	DRS
Habib Metropolitan Bank Ltd.	92.51%	93.00%	99.47%	DRS
JS Bank Ltd.	100%	100%	100%	CRS
KASB Bank Ltd.	77.95%	90.58%	86.06%	IRS
Muslim Commercial Bank Ltd.	100%	100%	100%	CRS
NIB Bank Ltd.	56.25%	56.76%	99.10%	DRS
Samba Bank Ltd.	100%	100%	100%	CRS
Silk Bank Ltd.	51.66%	51.79%	99.76%	DRS
Soneri Bank Ltd.	60.79%	60.96%	99.71%	DRS
Standard Chartered Bank Pakistan Ltd.	100%	100%	100%	CRS
Summit Bank Ltd.	40.44%	40.97%	98.70%	DRS
United Bank Ltd.	100%	100%	100%	CRS
Bank of Punjab	74.25%	82.97%	89.49%	IRS
Bank of Khyber	79.27%	83.74%	94.67%	IRS
First Women Bank Ltd.	80.93%	100%	80.93%	IRS
National Bank of Pakistan	90.59%	100%	90.59%	DRS
Barclays Bank PLC Pakistan	61.05%	61.15%	99.83%	DRS
Citi Bank	100%	100%	100%	CRS
HSBC	80.33%	100%	80.33%	IRS
Average Efficiency Score	79.86%	83.15%	96.39%	
Number of Efficient Banks	7	11	7	
Average Efficiency of Islamic Banks	77.83%	80.21%	97.13%	
Average Efficiency of Private Domestic Banks	80.02%	81.31%	98.45%	
Average Efficiencyof Public Sector Banks	81.26%	91.68%	88.92%	
Average Efficiency of Foreign Banks	80.46%	87.05%	93.39%	

8.5. Comparative Analysis of the DEATOB and PDEATOB Frameworks

8.5.1. Comparison of Efficiency Estimates

This section explores the similarities and differences existing in the efficiency estimates of banks, obtained with intermediation and profitability models before and after application of their respective Frameworks (DEATOB for intermediation and PDEATOB for profitability model). For this purpose, we have arranged the summary of results under both models before and after application of the proposed frameworks in Table 8.13[67]. Efficiency estimates suggest a large asymmetry between banks with different banking approaches mainly due to the selection of different input and output set under each approach. Efficiency estimates with standard VRS intermediation model indicate that 21 banks are efficient with an overall average efficiency score of 96.18%. KASB Bank and Summit Bank are the two least efficient banks with efficiency score of 72.68% and 74.97% respectively.

On the other hand, standard VRS profitability model identifies 17 efficient banks. Average efficiency score of the banking sector is 90.33%. Silk Bank and Summit Bank are the two least efficient banks with efficiency score of 58.39% and 60.99% respectively. The efficiency scores of standard VRS model under both banking approaches highlight some interesting facts. First, the number of efficient banks is larger with intermediation model as compared to profitability model. Second, individual efficiency scores of all banks and the average efficiency score are far higher under intermediation approach vis-à-vis profitability approach. Third, the banks which are efficient with profitability model are also efficient under intermediation model but

[67] Efficiency scores of fully efficient banks are shaded in dark grey colour and least efficient banks are shaded with light grey colour.

not vice versa. Finally, Summit bank is the poor performer under both models due to having large proportion of NPLs and high operating costs.

The results after application of the proposed frameworks show that the number of efficient banks and average efficiency score are higher with the PDEATOB as compared to the DEATOB Framework. First Women Bank and HSBC are among the efficient banks under both frameworks. Similarly, both the frameworks have six of the poor performers in common which are: Al Baraka Bank, Askari Commercial Bank, Faysal Bank, NIB Bank, Silk Bank and Summit Bank. This finding suggests that these six banks are weak in both intermediation activities and the profit generation and need to improve both these dimensions of their banking operations for increasing their efficiency.

In addition, there are some banks which are good in one of the aspect and require improvement in the other dimension in order to be efficient in all respects. For example Burj Bank, Meezan Bank, Bank Al Habib, Habib Bank, and Barclays Bank are fully efficient in intermediating financial resources but require improving their profitability. Most of their profit inefficiency stems from high operating costs and low interest and non-interest incomes. However, among all these banks Barclays Bank is the only bank that transformed from fully efficient under the DEATOB Framework to one of the least efficient banks under the PDEATOB Framework due to the losses in its business for the year 2012. Moreover, Burj Bank is less profitable due to its very low interest rate spread of 2.6% (Kpmg, 2012). This is likely that charging low rate of return on financing is a strategy of bank to penetrate into the market and increasing its clientele in future.

On the other hand, Bank Islami, Allied Bank, JS Bank, Muslim Commercial Bank, Samba Bank, Standard Chartered Bank, United Bank, National Bank and Citi Bank are good in profit generation but need to improve their intermediation activities up to the level of best practices commercial banks. In these banks the main cause of inefficiency are NPLs and the diversion of assets from commercial banking to investment banking as risk averting strategies. This trend reflects that, by deviating from the SBP objective they have attained their own objective and maintained their profitability to be sustainable in the banking sector.

Our findings of higher efficiency scores under intermediation model compared to the profitability model with standard DEA appraisal are similar to the findings of Das and Ghosh (2006) in India, and Drake and Hall (2003) and Drake et al. (2009) in Japan. On the other hand, higher efficiency level with the profitability model as compared to the intermediation model after application of the proposed frameworks contradicts the results obtained with the standard VRS model but are similar to the results observed by Sufian and Habibullah (2009) in Korean Banks.

Table 8. 13 Efficiency Scores and average efficiency scores of all banks before and after application of the DEATOB and PDEATOB Frameworks.

Bank	Intermediation Model		Profitability Model	
	Efficiency Scores without TO	Efficiency Scores with DEATOB Framework	Efficiency Scores without TO	Efficiency Scores with PDEATOB Framework
Al Baraka Bank Pakistan Ltd.	89.24%	63.66%	77.26%	39.03%
Bank Islami Ltd.	100%	98.43%	100%	100.00%
Burj Bank Ltd.	100%	100.00%	77.12%	72.48%
Dubai Islamic Bank Ltd.	80.99%	68.29%	91.32%	90.65%
Meezan Bank Ltd.	100%	100.00%	100%	98.88%
Allied Bank of Pakistan Ltd.	100%	96.17%	100%	100.00%
Askari Commercial Bank Ltd.	92.28%	68.18%	84.48%	58.09%
Bank Al Falah Ltd.	97.20%	78.91%	85.84%	80.63%
Bank Al Habib Ltd.	100%	100.00%	100.00%	95.99%
Faysal Bank Ltd.	100%	64.63%	73.59%	65.31%
Habib Bank Ltd.	100%	100.00%	100%	88.28%
Habib Metropolitan Bank Ltd.	100%	94.36%	100%	93.00%
JS Bank Ltd.	100%	87.02%	100%	100.00%
KASB Bank Ltd.	72.68%	44.30%	90.58%	90.58%
Muslim Commercial Bank Ltd.	100%	99.33%	100%	100.00%
NIB Bank Ltd.	86.33%	46.68%	67.20%	56.76%
Samba Bank Ltd.	100%	78.95%	100%	100.00%
Silk Bank Ltd.	95.57%	49.52%	58.39%	51.79%
Soneri Bank Ltd.	100%	74.40%	79.54%	60.96%
Standard Chartered Bank Pakistan Ltd.	100%	73.56%	100%	100.00%
Summit Bank Ltd.	74.97%	40.03%	60.99%	40.97%
United Bank Ltd.	100%	83.23%	100%	100.00%
Bank of Punjab	100%	42.53%	100%	82.97%
Bank of Khyber	100%	89.65%	100%	83.74%
First Women Bank Ltd.	100%	100.00%	100%	100.00%
National Bank of Pakistan	100%	81.16%	100%	100.00%
Barclays Bank PLC Pakistan	100%	100.00%	73.26%	61.15%
Citi Bank	100%	83.81%	100%	100.00%
HSBC	100%	100.00%	100%	100.00%
Number of Efficient Banks	21	7	17	11
Average Efficiency of all Banks	96.18%	79.54%	90.33%	83.15%
Average Efficiency of Islamic Banks	94.05%	86.07%	89.14%	80.21%
Average Efficiency of Private Domestic Banks	95.24%	75.25%	88.27%	81.31%
Average Efficiency of Public Sector Banks	100.00%	78.34%	100.00%	91.68%
Average Efficiency of Foreign Banks	100.00%	94.60%	91.09%	87.05%

8.5.2. Relationship between Efficiency Estimates and Ownership Type with the DEATOB and PDEATOB Frameworks

The bottom part of the Table 8.13 shows the average efficiency scores of different banking ownership groups with both intermediation and profitability models before and after application of the proposed frameworks. Results of intermediation model with standard VRS model show that foreign and public sector banks are fully efficient whereas Islamic banks are the least efficient banks. However, after application of the DEATOB Framework none of the banking group is 100% efficient. Moreover, the results of all banking groups change tremendously. Foreign banks appear as the most efficient banking group with an average efficiency score of 94.60% whereas private domestic group becomes the least efficient group having average efficiency score of 75.25%. Islamic banks appear relatively efficient with efficiency score of 86.07%.

With standard VRS profitability model only public sector banks are 100% efficient which are followed by the foreign banks with an average efficiency of 91.09%. Private domestic banks are the least efficient banks with an average efficiency score of 88.27% whereas Islamic banks are slightly better with efficiency score of 89.14%. As expected, after application of the PDEATOB Framework average efficiency scores decline however the order of average efficiency ranking does not change except Islamic banks become the least efficient group. As Islamic banks and private domestic banks are the sub category of private banks therefore, with both frameworks overall private banks are the least efficient banks.

An interesting point to note here is that public sector banks are one of the least efficient group of banks with the DEATOB Framework but most efficient ownership group with the PDEATOB Framework. This contrast in results indicates that public banks are good in generating incomes but are comparatively poor in intermediation process. The major reason of generating more income is their privileged access to government businesses that provides them the opportunity to earn more income particularly, non-interest income. However, they are poor in intermediation process due to existence of large quantities of NPLs in their asset portfolios. There could be multiple reasons for this accumulation of NPLs. For example, despite the alternative lending opportunities, management of these banks pursue the government policy objectives of advancing loans to priority sectors even at below market lending rates. It also seems likely that these banks face a lot of political pressure while advancing loans. Among public sector banks, First Women Banks is the only efficient bank under both frameworks whereas National Bank of Pakistan is efficient only with the PDEATOB Framework.

Among foreign banks, only HSBC is efficient with both the DEATOB and PDEATOB Frameworks. On the other hand, Barclays Bank is efficient only with the DEATOB Framework whereas Citi Bank is efficient only under the PDEATOB Framework. Conversely, no common set of efficient banks is identified from among the private domestic and Islamic banks under the DEATOB and PDEATOB Frameworks.

Although, average efficiency scores identify the weak ownership group however, they do not provide the information about the major contributors to the poor performance of that particular group. To overcome this limitation of average efficiency estimates, we have segregated banks from various ownership groups into different performance categories after the application of the DEATOB and PDEATOB Frameworks and presented them in Table 8.14. These results indicate that nine poor performers are identified with intermediation model where one belongs to public sector, six to private domestic and two to Islamic banks. In case of profitability model eight poor performers consist of one Islamic, one foreign and six private domestic banks.

However, one Islamic (Al Baraka Bank) and five private domestic banks (Askari Commercial Bank, Faysal Bank, NIB Bank, Silk Bank, and Summit Bank) are poor performers under both frameworks indicating that private banks are the least efficient ownership group in the banking sector of Pakistan. It is noteworthy here that both frameworks have almost similar average efficiency scores for each performance category despite having different number of banks in each category. For example, good performers, average performers and poor performers have average efficiency scores of around 97%, 79% and 54% respectively under both frameworks.

Table 8. 14 Summary of banks' performance from different ownership groups under the DEATOB and PDEATOB Frameworks

Category/ Bank	DEATOB FRAMEWORK			PDEATOB FRAMEWORK		
	Good Performers	Average Performers	Poor Performers	Good Performers	Average Performers	Poor Performers
Islamic Banks	3	0	2	3	1	1
Private Domestic Banks	6	5	6	10	1	6
Public Sector Banks	2	1	1	2	2	0
Foreign Banks	2	1	0	2	0	1
Total	13	7	9	17	4	8
Average Efficiency Score	97.30%	79.15%	54.20%	97.49%	79.95%	54.26%

8.5.3. Comparison of Relationship between Efficiency Estimates and Bank Size

It is evident from Table 8.15 that relationship of efficiency estimates with size exhibits similar structure under both banking approaches (intermediation and profitability) with standard VRS model. Largest banks are the most efficient banks with highest average efficiency scores followed by the large banks. The least efficient category is medium sized banks. However, small banks are relatively efficient than medium sized banks.

In case of intermediation approach with the DEATOB Framework, small banks have the highest average efficiency scores of 91.21% whereas largest banks have a slightly lower average efficiency score (89.80%) than small banks. Under profitability model with the PDEATOB Framework, largest banks possess the highest average efficiency score of 94.82% followed by small banks with relatively lower efficiency score of 87.38%. However, small banks are relatively efficient than large and medium sized banks. Medium sized banks are still the least efficient banks under both banking approaches. These findings suggest that efficiency estimates follow almost similar pattern that seems to exhibit a U-shaped relationship with the bank size under both banking models after application of the proposed frameworks.

Table 8. 15 Average efficiency of different asset sizes categories of banks before and after application of the DEATOB and PDEATOB Frameworks

S.No.	Asset Category	Number of Banks	Intermediation Model		Profitability Model	
			Average Efficiency without TO	Average Efficiency with DEATOB Framework	Average Efficiency without TO	Average Efficiency with PDEATOB Framework
1	**Small**-Less than or equal to Rs.70 billion	6	96.83%	91.21%	90.28%	87.38%
2	**Medium**- >Rs.70 billion and ≤Rs. 200 billion	10	91.88%	67.75%	83.40%	72.38%
3	**Large**- >Rs.200 billion and ≤ Rs.500 billion	7	98.90%	77.61%	94.01%	84.89%
4	**Largest**-Greater than Rs.500 billion	6	99.53%	89.80%	97.64%	94.82%

8.5.4. Comparison of Scale Efficiencies

Scale efficiency results of all banks and different banking ownership groups with the DEATOB and PDEATOB Frameworks are provided in Table 8.16. These results indicate that seven banks are scale efficient with each of the DEATOB and PDEATOB Framework which are totally dissimilar banks. Average efficiency scores indicate that banks are more scale efficient with the DEATOB Framework (97.84%) than the PDEATOB Framework (96.39%). However, higher average scale efficiency with both frameworks indicates that banks in Pakistan have scale economies at the aggregate level.

Among seven DEATOB technical efficient banks, six are scale efficient whereas among eleven PDEATOB technical efficient banks only seven are scale efficient. On the other hand, all the least efficient banks are relatively scale efficient with efficiency scores ranging from 98.11% to 99.98% under both frameworks.

In terms of banking ownership groups, foreign banks are the most scale efficient banks followed by the Islamic banks under the DEATOB Framework. On the other hand, with the PDEATOB Framework, private domestic banks are the most scale efficient banks whereas Islamic banks come next in this trend. Public sector banks are the least scale efficient banks with both the DEATOB and PDEATOB Frameworks. However, their level of scale inefficiency is relatively high with the PDEATOB Framework in spite of the fact that they are the most technically efficient banks with the PDEATOB Framework. These findings indicate that public sector banks need to improve (either increase or decrease) their scale of operations in both intermediation and profitability terms to be more efficient.

Scale efficiency scores of both frameworks revealed that in terms of size, mostly small and large banks are more scale inefficient however scale inefficiencies are not large in magnitude. Existence of comparatively large scale inefficiencies in small and large banks were also reported by Drake and Hall (2003) in Japan. The scale efficiency results of big five banks vary significantly under both frameworks. These banks are more scale efficient with the PDEATOB Framework (97.48%) as compared to the DEATOB Framework (90.25%).

The RTS results with both frameworks show that most of the small to medium size banks exhibit IRS or CRS and large banks exhibit DRS or CRS. These findings are similar to the findings of earlier studies among others by Mcallister and Mcmanus (1993) and Noulas et al. (1990). Almost all big five banks are operating at DRS reflecting that these banks need to trim down their operations to be efficient. Among seven DEATOB Framework technical efficient banks, six are operating at CRS and one at DRS. On the other hand, among eleven technically efficient banks under the PDEATOB Framework, seven are operating at CRS, while two each are operating at IRS and DRS. Results on RTS imply that banks that have been working at IRS could achieve cost savings and productivity gain through internal growth (by efficiently utilizing their inputs) or further consolidation in the banking sector of Pakistan. In a competitive market, banks with IRS are the prime target for acquirers who can create value by, streamlining the operations and eliminating the inefficiencies of such underperforming banks (Evanoff and Israilevich, 1991). On the other hand, the management of the banks with DRS ought to be cautious about further increasing their size particularly through mergers and acquisitions.

Table 8. 16 Scale efficiency and RTS of all banks with the DEATOB and PDEATOB Frameworks

Bank	DEATOB FRAMEWORK			PDEATOB FRAMEWORK			Total Assets (in 000)
	TE	SE	RTS	TE	SE	RTS	
Habib Bank Ltd.	100.00%	92.35%	DRS	88.28%	96.79%	DRS	1,610,308,572
National Bank of Pakistan	81.16%	86.04%	DRS	100.00%	90.59%	DRS	1,316,160,457
United Bank Ltd.	83.23%	88.53%	DRS	100.00%	100%	CRS	960,210,415
Muslim Commercial Bank Ltd.	99.33%	91.41%	DRS	100.00%	100%	CRS	770,282,541
Allied Bank of Pakistan Ltd.	96.17%	92.90%	DRS	100.00%	100%	CRS	632,301,706
Bank Al Falah Ltd.	78.91%	96.24%	DRS	80.63%	98.88%	DRS	536,466,694
Bank Al Habib Ltd.	100.00%	100%	CRS	95.99%	97.45%	DRS	453,353,942
Standard Chartered Bank Pakistan Ltd.	73.56%	99.51%	DRS	100.00%	100%	CRS	399,055,450
Askari Commercial Bank Ltd.	68.18%	99.80%	DRS	58.09%	99.68%	DRS	353,211,274
Bank of Punjab	42.53%	99.89%	IRS	82.97%	89.49%	IRS	332,110,474
Faysal Bank Ltd.	64.63%	99.97%	DRS	65.31%	98.11%	DRS	313,064,332
Habib Metropolitan Bank Ltd.	94.36%	98.29%	DRS	93.00%	99.47%	DRS	300,739,810
Meezan Bank Ltd.	100.00%	100%	CRS	98.88%	98.56%	DRS	274,436,510
NIB Bank Ltd.	46.68%	99.73%	IRS	56.76%	99.10%	DRS	190,855,177
Soneri Bank Ltd.	74.40%	100%	CRS	60.96%	99.71%	DRS	158,618,236
Summit Bank Ltd.	40.03%	99.57%	IRS	40.97%	98.70%	DRS	134,289,066
KASB Bank Ltd.	44.30%	99.22%	IRS	90.58%	86.06%	IRS	90,277,626
Silk Bank Ltd.	49.52%	99.98%	DRS	51.79%	99.76%	DRS	89,061,570
Citi Bank	83.81%	98.73%	DRS	100.00%	100%	CRS	85,171,810
JS Bank Ltd.	87.02%	99.93%	IRS	100.00%	100%	CRS	84,018,777
Bank of Khyber	89.65%	99.54%	IRS	83.74%	94.67%	IRS	82,177,638
Bank Islami Ltd.	98.43%	99.92%	IRS	100.00%	98.60%	DRS	74,236,030
Al Baraka Bank Pakistan Ltd.	63.66%	98.25%	IRS	39.03%	98.58%	IRS	73,869,051
Dubai Islamic Bank Ltd.	68.29%	99.60%	DRS	90.65%	93.32%	IRS	63,500,705
HSBC	100.00%	100%	CRS	100.00%	80.33%	IRS	50,328,093
Barclays Bank PLC Pakistan	100.00%	100%	CRS	61.15%	99.83%	DRS	47,778,267
Burj Bank Ltd.	100.00%	100%	CRS	72.48%	96.58%	IRS	47,185,452
Samba Bank Ltd.	78.95%	97.91%	IRS	100.00%	100%	CRS	34,853,837
First Women Bank Ltd.	100.00%	100%	CRS	100.00%	80.93%	IRS	22,490,800
Number of Efficient Banks	7	7		11	7		
Average Efficiency of All Banks	79.54%	97.84%		83.15%	96.39%		
Average Efficiency of Islamic Banks	86.07%	99.55%		80.21%	97.13%		
Average Efficiency of Private Domestic Banks	75.25%	97.37%		81.31%	98.45%		
Average Efficiency of Public Sector Banks	78.34%	96.37%		91.68%	88.92%		
Average Efficiency of Foreign Banks	94.60%	99.58%		87.05%	93.39%		
Average Efficiency of Big Five Banks	91.98%	90.25%		97.66%	97.48%		

8.6. Conclusion

This chapter has extended the idea of production trade-offs on the profitability banking model, in the form of the PDEATOB Framework, and provided the empirical support on the benefits of employing the proposed PDEATOB Framework in the banking sector.

Initially, the PDEATOB Framework has been empirically tested on the basis of its individual trade-offs in order to judge whether the additional information provided in the particular trade-off is serving its purpose or not. The areas evaluated through trade-offs include: the interest incomes and non interest incomes earned by banks in relation to interest expenses and the quantity of loan loss provision set aside each year to mitigate the risk of NPLs in relation to the interest income.

Results show that banks having large amounts of interest and non-interest incomes as compared to interest expenses are profitable. Similarly, banks with large quantities of interest income in comparison to the provision amount for that year have relatively high profit efficiency. These results indicated that the formulated trade-offs successfully identified the weaknesses of banks existing in the areas addressed through these trade-offs. After getting the satisfactory results from the independent application of trade-offs, we studied their aggregate impact by adding them gradually in the standard VRS model. Efficiency scores of banks reduced with the addition of every new trade-off indicating that these banks were not performing up to the standard of the best practices banks. The model also identified the best practices banks for each inefficient bank so that they could emulate their practices to be efficient.

The PDEATOB Framework also proved to be well discriminating despite considering a small data set of 29 banks. This framework has imposed four trade-offs with moderate values originated from the actual banking practices. Consequently, smaller efficiency scores are allocated to the most of the banks with a reduction in the count of efficient banks.

This chapter has also performed the comparative analysis of the results obtained through the application of two frameworks proposed by the current study. The empirical findings clearly bring forth the higher degree of inefficiency with the proposed frameworks as compared to standard VRS models. A set of six common banks is identified as poor performers by both of the frameworks and all these banks are working under private ownership. The reason of their poor performance under both frameworks is the existence of the large amounts of NPLs and the subsequent maintenance of the large amounts of provisions for mitigating the risk of future losses. These results support the policy implication suggested in Chapter 7. The comparison of both frameworks has highlighted another important fact about private banks that some banks are poor under the DEATOB Framework but relatively better performers under the PDEATOB Framework. This result shows that the deviation of these banks from intermediation to investing activities has made them profitable. This trend of commercial banks is indicating an informal beginning of the universal banking in Pakistan. Keeping in view this trend one suggestion is that the regulatory authorities should formally start planning for the universal banking in Pakistan by formulating prudential regulations for it. Another possible policy suggestion is that if the regulatory authorities want to maintain the current banking structure then they should limit the investing activities of the commercial banks in order to carry out the objective of economic development set by the SBP and to differentiate them from investment banks which pursue a completely different objective.

CHAPTER 9
CONCLUSION

9.1. Introduction

Efficient and profitable banks have always been vital for the sustainable economic growth and development. However, the sustainability of banks was threatened due to the growing competition witnessed in most of the countries after the introduction of the deregulation, liberalization and innovative technological changes. This competition among banks led to the prevalence of survival of the financially fittest philosophy in the domestic markets. Recognizing these facts researchers spent a considerable time studying and modelling bank efficiency and productivity that increased the banking efficiency literature in the last few decades drastically. Banking efficiency assessment is a mode of identifying the best and worst performing banks leading to the appropriate and timely policy formulation in order to avoid any future failures.

Profitability and risk are considered two principal dimensions for the performance evaluation of banks (Fraser and Fraser, 1990). The most efficient banks will have a competitive advantage by having a long although uneven aspect of financial soundness and profitability. Realizing this fact the current study has incorporated risk factor into the DEA based efficiency evaluation and proposed the DEATOB Framework to ensure its inclusion in the evaluation process. In addition to risk, this framework has also provided the way of incorporating different bank specific endogenous and exogenous factors into the DEA based banking behaviour models to create a better informed DEA model.

For the empirical application of the DEATOB Framework, this study has used the data from the commercial banks of Pakistan. Banks constitute the largest segment of the financial system in Pakistan and serve as the backbone of the financial sector due to their largest share in the total assets of financial sector (73%) and strong backward and forward linkage with the rest of the sectors of the economy (State Bank of Pakistan, 2012a). Although this study has developed the DEATOB Framework considering the banking sector of Pakistan, this framework is equally applicable to the banking systems of other countries.

9.2. Summary of Research

This entire thesis has focused on how to add additional information of different banking aspects into the DEA based banking behaviour models to create a better informed DEA model. For this purpose, the current study has proposed a novel combination of DEA with production trade-offs in the banking context named “DEATOB Framework”. This methodology is based on the innovative non-parametric DEA based concept of production trade-offs introduced by Podinovski (2004) who showed that additional information can be incorporated into a DEA model without distorting the technical meaning of efficiency. This framework has been developed for two different banking behaviour approaches, named intermediation and profitability approaches, to show its applicability on the real life banking.

To develop the proposed framework, this thesis has reviewed the banking literature in detail and found that the importance of different factors, such as risk and bank specific endogenous and exogenous factors was well established in the banking literature. However, variation existed in the specification of variables used as proxy for these factors and the way of using them in studies for the analysis purposes.

In terms of variables’ specification, we have provided a detailed literature review on risk. We found that in DEA based efficiency studies only limited studies have considered risk factor in the evaluation of efficiency scores. In these studies, loan loss provision was the most commonly used risk variable in the banking models whereas only few studies had considered NPLs. However, for studying exogenous and endogenous factors no specific variable was added into the DEA model.

In the empirical analysis, efficiency estimates were calculated by including only risk variables directly in the DEA model. On the other hand, generally, a two stage analysis procedure is followed in the literature to investigate the impact of exogenous and endogenous variables. At the first stage, efficiency scores are calculated using standard banking variables in standard DEA models. Then at the second stage, different exogenous and endogenous variables commonly selected according to the need of the study, based on the areas of interest of researcher, are regressed against the efficiency scores to study their impact on the efficiency scores.

This study distinguishes itself from the literature in a way that it provides a different way of including additional information such as risk attached to poor quality assets and bank specific exogenous and endogenous factors in the efficiency estimation. For considering risk, the current study has not only used risk variables in the DEA model at the first stage but also ensured their inclusion in the efficiency estimation by linking them with the good output through the application of production trade-offs. However, unlike previous studies which used the information about exogenous and endogenous factors at the second stage analysis, the current study has incorporated such information into DEA model at the first stage with the help of production trade-offs without introducing any additional variable.

For the specification of model variables, this study has considered both NPLs and loan loss provision but included one at a time into one banking model according to its nature. NPLs are poor quality assets therefore these are used in the input/output set of the asset based intermediation model. On the other hand, loan loss provision is treated as expense therefore this has been used as risk variable in the profitability model.

In this study, a sample of 29 banks is selected from the total of 34 commercial banks because 5 banks (4 foreign banks and 1 public sector bank) do not meet the sample selection criteria set by the researcher. The selection criteria are based on two conditions. First, the bank should have at least five branches in Pakistan and second, it had been involved in the banking operations for three consecutive years preceding the year 2012.

Data used in the current study were both primary and secondary in nature. Secondary data provided the amounts of variables selected for two banking behaviour models used in the study and sourced from annual reports of individual banks for the year 2012. Secondary data were also cross-validated with the similar data provided in the statistical reports published by the State Bank of Pakistan.

The primary data were required for the development of productions trade-offs for the DEATOB Framework and collected through elite interview technique by interviewing many banking experts from treasury, credit and operations departments of banks. Moreover, the information on banking regulations and specific banking rates (such as interest rates on deposits and loans, rate of provisions on different categories of performing and NPLs etc.) has also been collected from different banking circulars issued from time to time, and statistical reports published regularly, by the SBP.

For empirical analysis, DEA has been selected as the main technique for the estimation of banking sector efficiency due to its ability to handle multiple inputs and outputs without specifying any functional form. To estimate the output augmented efficiency of banks, output oriented standard VRS model was used. To model the banking behaviour in Pakistan, intermediation and profitability models were considered to evaluate banks according to the objectives set for commercial banks by SBP and commercial banks themselves respectively. As different set of variable are used in intermediation and profitability approaches therefore the study explained the development process of two different DEATOB Frameworks with two different sets of trade-offs depending on the nature of variables included in each model. Trade-offs development process for the framework passed through five stages marked as identification, validation, evaluation, application and review. Realistic and practical trade-offs were finalized with the approval of the banking experts and used in the construction of the final DEATOB Frameworks presented in Chapter 6 for intermediation approach and Chapter 8 for profitability approach. Key findings of these frameworks are described in the following subsections.

9.3. Key Research Findings

9.3.1. DEATOB and PDEATOB Frameworks

Empirical results with the DEATOB Framework for intermediation model are provided in Chapter 7. To investigate the impact of the DEATOB Framework on the efficiency scores first, the efficiency scores were calculated using standard output oriented DEA model with VRS technology. Then these scores were compared with the efficiency scores obtained with progressive application of different trade-offs finalized for the DEATOB Framework. According to the results provided by standard VRS model 21 banks were efficient with an average efficiency score of 96.18%. KASB Bank and Summit Bank were the least efficient banks with an efficiency score of 72.68% and 74.97% respectively.

Liquidity requirement and credit expansion capability of banks was used as Trade-Offs 1 and 2 to ensure the inclusion of all the variables of intermediation process in the efficiency evaluation. Keeping in view the real process of intermediation, these two factors were combined in the form of Trade-Off 3. The application of Trade-Off 3 reduced the number of efficient banks from 21 to 20 with a decline in the efficiency scores of 4 banks. Trade-Off 4 incorporated risk factor into the model which reduced the number of efficient banks from 20 to 14. This indicated that without consideration of risk, efficiency scores were overstated and not reflecting the actual performance of banks in terms of advancing loans.

The disintermediation behaviour of banks in the form of deviation from the core banking objective of resource allocation in the economy was identified with the application of Trade-Off 5. This Trade-Off reduced the number of efficient banks from 14 to 7 and highlighted the important fact that the banks which were removed from the list of efficient banks were having large amounts of investments as compared to advances. This indicated that these banks had deviated from the basic objective of intermediation process by shifting their resources from loans towards investments. Further investigation into their financial data revealed that these banks still had relatively large amounts of NPLs therefore these banks had subdued their credit to the private sector and shifted their resources towards the secure investments particularly high yielding government papers in order to minimize their risk in future. In other words, these banks deviated from the socio-economic goal of financial deepening and outreach set by the SBP for commercial banks. So this is concluded that the DEATOB Framework under the intermediation approach provided the efficiency scores by considering the banking behaviours towards portfolio management and risk taking.

The development of the DEATOB Framework for profitability model (the PDEATOB Framework) with empirical analysis is provided in Chapter 8. The efficiency scores calculated with standard VRS model show that 17 banks are efficient with an average radial improvement factor of 1.14 indicating that overall banking output required an increase of 1.14 times in their current production level. Incorporation of Trade-Offs 1 and 2 reduced the number of efficient banks from 17 to 15. The number of efficient banks further reduced to 13 as a result of application of Trade-Off 3 with a decline in the efficiency scores of 7 banks. This reduction in the efficiency scores of banks, as a result of these three Trade-Offs, was mainly due to fewer amounts of interest income as compared to interest expenses and less proportion of fee commission and brokerage income in their total income. Application of Trade-Off 4 reduced the number of efficient banks to 11 with a decline in the efficiency scores of 14 banks. Large amounts of loan loss provision in these banks were the major cause of this decline in efficiency scores. Actually, large amounts of NPLs at the asset portfolio of these banks necessitated the need to set aside comparatively large amounts of loan loss provision from their annual income in order to mitigate the future risk of default. In short, the PDEATOB Framework evaluated banks by taking into account their income generating capability and risk cover.

The comparative analysis of both approaches with their respective DEATOB Frameworks revealed that First Women Bank and HSBC remained 100% efficient under both models. On the other hand, Al Baraka Bank, Askari Commercial Bank, Faysal Bank, NIB Bank, Silk Bank, and Summit Bank were the six least efficient banks under both frameworks indicating that these banks need to improve both the intermediation and profitability dimensions of their banking operations in order to survive in the competitive banking environment. KASB Bank and the Bank of Punjab were poor in terms of asset generation therefore appeared as least efficient banks under intermediation approach but they were comparatively better in their income generation process with efficiency scores of 90.58% and 82.97% respectively. On the other hand, Barclays Bank was 100% efficient in terms of asset generation but was among the least efficient (61.15%) banks in income generating capability.

Based on these results, it is concluded that the trade-offs of the DEATOB Frameworks derived from the real life banking practices, have enabled the standard DEA model to evaluate each bank by virtue of strengths and weaknesses existing in its banking practices. Consequently, these strengths and weaknesses are reflected in the efficiency scores obtained by the evaluation of the transformation process through DEA.

9.3.2. Relationship between Efficiency and Ownership Type

Question 4 of the thesis provided evidence on the relationship between bank performance and bank ownership type. Distinction of study lies in the investigation of the impact of these factors in two different dimensions of banking operations; intermediation and profitability.

In terms of ownership, all banks were classified into 4 public, 22 private (17 private domestic and 5 Islamic banks) and 3 foreign banks. Analysis of efficiency in relation to ownership type revealed partially similar results under intermediation and profitability approaches. Under intermediation approach public sector banks and foreign banks were 100% efficient with standard VRS model. However, after the application of the DEATOB Framework, foreign banks appeared to be the most efficient group as compared to their domestic counterparts whereas public sector banks turned into one of the least efficient categories of banks. This shift of public sector banks to least efficient banks with the DEATOB Framework was mainly due to the fact that these banks have large quantities of NPLs and the proposed framework accounted for the risk attached to poor quality assets in the efficiency estimation which was initially ignored by standard VRS model. In contrast private domestic banks were least efficient category of banks with and without the DEATOB Framework.

Under profitability approach public banks appeared to be the most efficient banks followed by the foreign banks with and without the application of the PDEATOB Framework. Private domestic banks and the Islamic banks were the least efficient categories.

The selection of foreign banks as most efficient group under intermediation model and appearance of public sector banks as most efficient category under profitability approach led to the conclusion that on average public sector banks were efficient in income generating process (profitability) but inefficient in asset generation (intermediation) whereas foreign banks were better in both these aspects. In contrast, the private sector banks were identified as the least efficient category of banks in terms of both intermediation and profitability signifying the need to improve both these dimensions of their operations. Six common poor performers (Al Baraka Bank, Askari Commercial Bank, Faysal Bank, NIB Bank, Silk Bank, and Summit Bank) were identified in the private sector under both frameworks concluding that these banks need to improve both the dimensions of their operations for their sustainability in the banking sector.

9.3.3. Relationship between Efficiency and Bank Size

On the basis of asset size banks were classified into four groups: small (less than or equal to 70 billion), medium (greater than 70 billion but less than or equal to 200 billion), large (greater than 200 billion but less than or equal to 500 billion) and largest (greater than 500 billion). The analysis of bank size concluded that largest and small banks were the most efficient categories of banks in terms of average efficiency scores with both the DEATOB and PDEATOB Frameworks. Our findings on bank size are similar to the findings of Chen et al. (2005) in China and Jaffry et al. (2007) in the Indian subcontinent. Moreover, these results partially resembled with the results of other banking studies. For example, our results of highest efficiency scores in small banks were in line with the results of Ashton (2001) in UK and Resti (1997) in Italy. Similarly, the results of high efficiency in large banks were found to be consistent with the findings of Miller and Noulas (1996) and Drake et al. (2006). High efficiency scores in small banks were observed due to their better control over the operating costs and efficient asset management whereas high efficiency scores in the largest banks were mainly attributed to their large market share due to their extensive branch networks. Among the largest banks, the highest efficiency scores were observed in case of privatized banks that supported the decision of privatization of these banks in Pakistan.

9.3.4. Scale Efficiency and RTS Investigation

For the estimation of scale efficiency, output oriented CRS models with the DEATOB Frameworks were calculated in addition to VRS models. Scale efficiency scores of 97.84% and 96.39% under intermediation and profitability approaches respectively represent that banks in Pakistan are operating relatively at the optimal scale of operations. However, they are managerially inefficient up to some extent in utilizing their resources and controlling their operating costs. It is concluded from the results that pure technical inefficiency outweighs the scale inefficiency in the total inefficiency of the banking sector therefore scale inefficiency is not a big problem in the banking sector of Pakistan.

Among different banking ownership groups, foreign banks were the most scale efficient banks under the DEATOB Framework and private banks were most scale efficient with the PDEATOB Framework. On the other hand, public sector banks are the least scale efficient banks with both frameworks. These findings indicate that public banks require more improvement (either increase or decrease) in their scale of operations as compared to other ownership groups.

In terms of asset size mostly, small and large banks are more scale inefficient under both frameworks. Overall, the big five banks are the least scale efficient however their average scale efficiency is higher with the PDEATOB Framework (97.48%) as compared to the DEATOB Framework (90.25%).

For the investigation of RTS properties of banks, scale efficiency index method proposed by Färe et al. (1985) has been chosen from among the existing methods to show that the DEATOB Framework is equally applicable to existing standard methods in DEA domain. Mostly, small banks tend to operate at IRS or CRS and large banks tend to operate at DRS or CRS under both frameworks. RTS characteristics of all the least technical efficient banks revealed that these banks are relatively scale efficient in spite of working at the DRS or IRS. Among the technical efficient banks, most of the banks are operating at CRS under both frameworks. The big five banks are mostly working on DRS under both frameworks indicating that these banks need to trim down their operations to be efficient. However, the existence of IRS in most of the inefficient and small banks indicate that there is a possibility of merger and acquisition of these banks in future if they fail to overcome their inefficiencies.

9.3.5. Improved Discrimination

It was the research motivation of the current study to propose a rigorous framework capable of dealing with the curse of dimensionality mainly caused by the small data set. The application of the DEATOB Framework on banking sector of Pakistan provided empirical support for the improvement in the discriminatory power of the DEA assessment. The current study considered the efficiency evaluation of 29 commercial banks for the year 2012. Analyses were performed by comparing the results with the proposed frameworks against the results of standard VRS models.

Under intermediation approach, efficiency estimates with standard VRS model indicated that 21 banks were efficient with average efficiency score of 95.63%. After the application of the DEATOB Framework only 7 banks were efficient and the average efficiency scores declined to 79.54%. In case of profitability model, 17 banks were efficient with standard VRS model where average efficiency of banking sector was 90.33%. The number of efficient banks declined to 11 with the application of the PDEATOB Framework while average efficiency scores dropped to 83.15%. These results indicate that efficiency scores and the count of efficient banks reduced considerably with the application of both frameworks. This concludes that the proposed frameworks have improved the discriminatory power of the standard DEA model significantly.

9.4. Core Contributions

This thesis has made several contributions to the literature of DEA and banking. The key contributions in this respect are:

1. The novel application of DEA with the production trade-offs applied on the banking sector in the form of the DEATOB Framework is proposed to add bank specific additional information into the efficiency appraisal through DEA which otherwise is not possible to incorporate in the efficiency evaluation. From the DEA methodological perspective, the proposed DEATOB Framework is a novel DEA Framework because it is tested for the first time on the real life data from the banking sector. Being the first application in the banking context, the current study has provided different ways of developing simple and complex trade-offs that include: knowledge of production process, banking practices, information

conveyed by the data set, experts' opinion, researchers' intuition, accounting concepts of different variables and information on different regulations and rates collected from banking circulars and statistical reports. Moreover, the study has also contributed by explaining the way of collecting information about different trade-offs from non DEA persons. In this regard, various questions are provided in the study asked from different banking professionals for the validation and quantification of identified trade-offs.

2. It provides the nexus between bank efficiency and risk by linking risk variables (NPLs and loan loss provision) with their relevant risk free variables (performing loans and interest income). We have estimated the efficiency not only by including the risk variables in the input/output set but also have provided an innovative methodological approach that makes possible to quantify the negative impact of these variables on the efficiency scores. Moreover, the information on endogenous and exogenous factors is incorporated into the standard DEA model through the DEATOB Framework without introducing any variable in the model. All these factors in aggregation enrich the DEA model with the risk taking and portfolio management behaviour/income generating capability of banks.
3. It is extending the banking efficiency literature to an Asian developing economy, "Pakistan" since the literature on banking efficiency is dominated by developed countries. In the context of developing economy, the study is extending the DEA based banking efficiency literature in Pakistan in many ways. It is providing DEA based empirical application as most of the previous notable studies in banking sector have used parametric techniques. It is also expanding the dimensions of banking efficiency studies in Pakistan by considering both intermediation and profitability aspect of banking sector in the year 2012 in contrast to the previous

studies that have studied mostly the intermediation aspect of banks in late 1990's and early 2000. Moreover, it is contributing towards extending the risk based banking efficiency literature because this is the first study on the banking sector of Pakistan that examined the impact of credit risk on the efficiency of commercial banks by incorporating it in the intermediation and profitability approaches using DEA.

4. The development of specific DEATOB Frameworks for intermediation and profitability approaches illustrates that the idea of production trade-offs can be extended to multiple banking models. Furthermore, the universal nature of the DEATOB Frameworks suggests that their applicability is not just confined to the developing economies like Pakistan. The same set of trade-offs could be applied on the banking sector of other economies with variation in the values of trade-offs depending on the banking practices. The development process of the DEATOB Framework also provides guidelines to develop new trade-offs in the banking sector. Moreover, these frameworks can be helpful to develop the logic for identifying production trade-offs in the production process of other industries of the economy.
5. DEATOB Frameworks has improved the discrimination of the efficiency scores of banks by compensating for the small data set.
6. This thesis has illustrated through practical application that the idea of production trade-offs is equally applicable to existing standard methods of RTS investigation in the DEA domain.

9.5. Directions for Future Research

This research provides the DEATOB Frameworks that transforms standard DEA models into better informed DEA models by enabling them to incorporate additional information in the evaluation process. However, there are certain areas that can be considered for future research with these frameworks.

The current study has considered the DEATOB Frameworks over a small data set considering only commercial banks. It can be extended to a large data set including all kinds of banks such as commercial banks, microfinance banks, cooperative banks and specialized financial institutions by defining realistic values of trade-offs depending on the regulations governing these institutions, nature of products and the operational requirements to handle the non-homogeneity of these banks due to their different specializations.

We have considered the DEATOB Frameworks for the banking efficiency at the institutional level and were unable to apply them at the branch level due to the unavailability of branch level data. The DEATOB Frameworks can be extended to the branch level banking studies.

The DEATOB Frameworks can be extended to Malmquist Productivity Index (MPI) to calculate the productivity change over a number of years which would be helpful to study the pre and post event impacts on banking efficiency such as crisis, management change, restructuring etc.

APPENDIX A

Appendix A. 1 Literature review of banking studies in Asia

Author (Publication Year)	Technique	Country	Sample	Period	Inputs	Outputs	Measures	Banking Approach	Orientation
Al shammari and Salimi (1998)	DEA	Jordan	16	1991-1994	No Input	Return on Investments, Return on Equity, Earnings Per Share, Creditors to Total Assets, Creditors to Deposits, Cash and Portfolio Investments to Deposits.	TE=0.49-1	-	Output
Arif and Can (2008)	DEA and Tobit	China	28	1995-2004	Labour Cost, Physical Capital, Loanable Funds, TC=Interest and Operating Cost	Loans , Investments,Profit=Total Income-Total costs	CE =0.798 PE=0.505	Intermediation	Input and Output
Asmild and Matthew (2012)	DEA MEA	China	14	1997-2008	Fixed Assets, No of Labor, Deposits, NPL	Net Interest Income, Fee Income	Av Eff JSB=0.50-0.77. Av Eff SOB=0.24-0.62	Intermediation/ Profitability	Input and Output
Assaf et al (2011)	DEA, Bootstrap	Saudi Arabia	9	1999-2007	Labour Cost, Capital and Deposits	Customers Loans, OBS, Securities and Interbank Loans	TE=0.92-0.97	Intermediation	Output
Ataullah and Le (2006)	DEA, OLS and GLS	India	43-47	1992-1998	Interest Expenses, Operating Expenses	Loans , Investments, Interest Income, and Operating Income	TE=0.68	Intermediation/ Profitability	Output
Avkiran (2009)	DEA SBM and NSBM	UAE	15	2005	Interest Expenses, Non interest Expenses	Interest Income, and Non Interest Income	PE 0.02-16.5	Intermediation	Output
Avkiran (2011)	DEA and Ratio Analysis	China	32	2007-2008	Interest Expenses, Non Interest Expenses	Interest Income, Non Interest Income	SSBM-C-NO=0.05-1.21. SSBM-V-NO=0.27-1.30. SSBM-C-I=0.55-1.22. SSBM-V-I=0.56-1.48. SSBM-C-O=0.05-1.29. SSBM-V-O=0.27-1.63.	Profitability	Input, Output, Non Oriented
Bhattacharyya et al (1997)	DEA and SFA	India	67-74	1986-1992	Interest Expenses, Operating Expenses	Advances, Deposits, Investments	TE=0.79-0.83	Production	Output
Chang (1999)	DEA	Taiwan	283	1994	No of Employees, Capital, Loanable Funds.	Non Subsidized Loans, Government Subsidized Loans, Deposits with Domestic Banks, Non Interest Income	TE=0.617-1	Intermediation	Input
Chiu and Chen (2009)	DEA, SBM and SFA	Taiwan	29	2002-2004	Total Deposits,No of Labor, Fixed Assets	Loans, investments and Non Interest Revenue	TE=0.71-0.94	Intermediation	Input/ Output

Author (Publication Year)	Technique	Country	Sample	Period	Inputs	Outputs	Measures	Banking Approach	Orientation
Das and Ghosh (2006)	DEA	India	74-98	1992-2002	Demand Deposits, Saving Deposits, Fixed Deposits, Operating Expenses, Labor. Labor, Interest Expenses, Operating Expenses.Interest Expenses,Employee Expenses, Operating Expenses.	Advances, Investments. Demand Deposits, Saving Deposits, Fixed Deposits, Investments, Advances. Interest Income, Non Interest Income.	TE=0.73-0.95	Intermediation, Value-added , Operating	Input
Drake and Hall (2003)	DEA	Japan	149	1997	Physical Capital, Deposits, General Expenses, Loan Loss Provision	Loans &Bills, Liquid Assets & Investments, Other Incomes	TE=0.72 SE=0.93	Intermediation	Input
Drake et al (2006)	DEA SBM and Tobit	Hong Kong	413	1995-2001	Employee Expenses, Other Non Interest Expenses , Loan Expenses , Loan Loss Provision. Physical Capital, Deposits, No of Employees, Loan Loss Provision	Net Interest Income, Net Commission Income, Other Income. Loans, Other Earning Assets	TE=0.61 TE=0.52 SBM	Intermediation/ Profitability	Input and Output
Drake et al (2009)	DEA SBM	Japan	1109	1995-2002	Deposits, Operating Expenses, Loan Loss Provision, Non Interest Expenses, Other Operating Expenses	Loans, Other Earning Assets, Net Commission Fee and Trading Income, Other Operating Income, Net Interest Income	TE(I)=0.67-0.78 TE(P)=0.24-0.33 TE(PR)=0.55-0.69	Intermediation, Production , Profitability	Input
Gilbert and Wilson (1998)	MPI	Korea	15-24	1980-1994	Labour Cost, Physical Capital and Loanable Funds	Demand Deposits, Loans with Domestic Currency, Loans with Foreign Currency, Loans by Trust Account.	TE=0.57-1. PC=0.76-1.86. PTE=0.53-2.10. TC=0.19-0.94	Intermediation	Output
Harada (2005)	DEA	Indonesia	10	1999-2003	Labor Cost,Interest Expenses ,General Administrative Expenses	Interest Income, Non Interest Income	T.E=0.51-1	Intermediation	Input
Kao and Liu (2004)	DEA	Taiwan	24	2000	Total Deposits, Interest Expenses, Non Interest Expenses	Total Loans, Interest Income, Non Interest Income	TE=0.73-1	Intermediation	Input/ Output
Leightner and Lovell (1998)	DEA	Thailand	31	1989-1994	Personnel Expenses, Premise and Equipment Expenses, Provision for Loan Losses	Net Interest Income, Non Interest Income. Loans, Invesytments.	IB=0.21-0.95. AB=0.0.9819	Income Based, Asset Based	Input
Liu and Tone (2008)	DEA SBM and SFA	Japan	660	1997-2001	Interest Cost, Credit Cost, General and Administrative Expenses	Loans, Interest Income	TE=0.80-0.88	-	Input/ Output

Author (Publication Year)	Technique	Country	Sample	Period	Inputs	Outputs	Measures	Banking Approach	Orientation
Mostafa (2009)	DEA, Probabilistic Neural Network	Arab	85	2005	Assets, Equity	Net Profit, ROA, ROE	TE=0.31-0.43	Profitability	Output
Ray and Das (2010)	DEA, 2nd Stage KDE	India	68-73	1997-2003	Labour Cost, Physical Capital, Loanable Funds, Quasi-Fixed Input=Equity	Investments, Earning Advances, Other Income	CE =0.9-0.94 PE=0.43-0.64	Asset	Input and Output
Sathye (2003)	DEA	India	94	1997-1998	Labour Cost, Physical Capital and Loanable Funds	Loans, Deposits	TE=0.62, 0.83	Intermediation	Input
Sufian (2009)	DEA and Tobit	Malaysia	171	1995-1997	Deposits, Labour, Capital. Labour, Capital, Interest Expenses. Interest Expenses, Labor, Operating Expenses.	Loans, Investments. Deposits, Loans, Investments. Interest Income, Non Interest Income.	TE=0.33-0.97	Intermediation, Value-added , Operating	Input
Sufian (2011)	MPI	Malaysia	23-36	1995-2004	Deposits, Labour, Capital	Loans, Investments, Non Interest Income	PC=0.92-1.05. TC=0.53-1.09. EC=0.81-1.75. PTC=0.95-1.09.	Intermediation	Input/ Output
Sufian and Habibullah (2009)	DEA and FEM	Korea	31	1992-2003	Total Deposits, Labor Cost, Fixed Assets Labor, Interest Expenses	Total Loans, Investments, Interest Income, Non Interest Income	TE=0.61-0.97. PTE=0.71-1. SE=0.70-0.98	Intermediation, Value-added , Operating	Input
Sufian and Habibullah (2012)	DEA and FEM	Indonesia	33	1997-2007	Total Deposits, Fixed Assets	Total Loans, Investments, Off-Balance Sheet Income	TE=0.66-0.94. PTE=0.88-0.97. SE=0.75-0.97	Intermediation	Input
Sufian and Majid (2007)	DEA and Tobit	Singapore	5	2001	Deposits, Interest Expenses, Non Interest Expenses	Interest Income, Non Interest Income, Loans.	TE=0.75-1. SE=0.75-1	Intermediation	Input
Tayebeh and Khansoz (2014)	DEA	Iran	24	2010-2011	No of ATMs and Pos, Bank Size,Index of Market Concentration	Return on Asset, Return on Equity, Mean of E-Payments	Av Eff CRS=0.31-0.34. Av Eff VRS=0.70-0.78	-	Input
Thoraneenitiyan and Avkiran (2009)	DEA SBM and SFA	Indonesia ,Malaysia , Korea, Thailand, Philippine	110	1998-2001	Total Deposits, Labour Cost, Physical Capital	Loans, Investment and Other Earning Assets, Fee Income, Off Balance Sheet Income	TE=0.04-0.97	Intermediation	Input/Output
Wang et al (2014)	Network DEA	China	16	2003-2011	Fixed Assets, Labor. Deposits	Non Interest Income, Interest Income, NPLS,	TE-P=0.26-1. TE-I=0.30-1. OE-Add=0.20-1	Intermediation/ Production	Input/ Output

Appendix A. 2 Literature review of banking studies in Pakistan

Author (Publication Year)	Technique	Country	Sample	Period	Inputs	Outputs	Measures	Banking Approach	Orientation
Akhtar (2002)	DEA	Pakistan	40	1998	Deposits, Capital	Loans, Investments	TE0.52-1 AE 0.75-1 OE 0.5-1	Intermediation	Input / Output
Akhtar (2010)	DEA	Pakistan	N/A	2001-2006	Deposits, Capital, Labour	Loans, Investments, Non Interest Income	TE 0.37-0.79 AE 0.22-0.55 OE 0.14-0.40	Intermediation	Input / Output
Ataullah and Le (2004)	DEA	Pakistan, India	N/A	1987-1998	Operating Exenses, Interest Expenses	Deposits, Loans,Investments	TE DB 80.6-98.4 FB 74.2-94.6	Intermediation	Input
Burki and Ahmad (2010)	SFA and Technical Inefficiency Model	Pakistan	N/A	1991-2005	Prices of Labour, Capital and Operating Costs	Loans, Investments	TE -P 0.26866 TE -F 0.26767 TE -S 0.11777	Intermediation	Input / Output
Iimi (2004)	SFA and SUR	Pakistan	N/A	1998-2001	Personnel Expenses,Depreciation Cost and Deposit interest	Commercial & Industrial Loans, Agriculture Loans, Public Sector Loans, Non Lending Accounts, Demand Deposits, and Time Deposits	TE 0.834-0.856 SUR SE 1.649 SC 6.485 SFA SE 1.773 SC 7.293	Intermediation	Input / Output
Jaffry et al. (2007)	DEA, Malmaquist Index, 2nd Stage Tobbit Regression	Bangladesh, India and Pakistan	898 Observations for Panel data	1993-2001	Interest Expenses, Non-Interest Expenses	Interest Income, Non-Interest Income	TE 0.519-1	Intermediation	Output
Jaffry et al. (2008)	SFA	Pakistan, India	N/A	1985-2003	Wages, Fixed Assets, Time	Loans, Deposits Government Securities, Investments, Number of Branches	TE 0.377-0.82	Intermediation	Input / Output
Jaffry et al. (2013)	DEA, Bootstrap, 2nd Stage	Pakistan, India	114	1985-2004	Number of Employees, Capital, Fixed Assets	Time Deposits, Saving Deosits, Current Deposits, Loans, Investments, Number of Branches	IDF 1.032-2.402	Intermediation	Input
Patti and Hardy (2005)	DFA, OLS, GLS, LAD	Pakistan	N/A	1981-2002	Interest Expenses, Operating Costs, Money Market Rate, Fixed Assets, Equity Capital	Loans and Other Earning Assets	PE OLS 0.01-0.65 GLS -0.02-0.66 LAD 0.03-0.60 CE OLS 0.77-0.83 GLS 0.74-0.83 LAD 0.76-0.82	Intermediation	Input / Output
Rizvi (2001)	DEA, Malmaquist Index	Pakistan	37	1993-1998	Labour Cost, Interest Expenses, Operating Expenses	Deposits, Loans,Investments	TE- 0.733-0.871	Intermediation	Input and Output

APPENDIX B

Appendix B. 1 Data of variables used in the intermediation banking model

(Data of 2012-in million Rupees)

Name of Bank	Input Variables				Output Variables	
	Physical Capital	Labour Cost	Deposits	NPLs	Investments	Loans
Al Baraka Bank Pakistan Ltd.	1090.095	835.838	65270.39	6093.026	27421.461	26516.1
Bank Islami Ltd.	1842.55	967.528	65837.9	1205.222	28994.462	35204.28
Burj Bank Ltd.	755.126	672.276	39009.19	1029.984	17156.398	23047.33
Dubai Islamic Bank Ltd.	1148.25	1114.233	69110.05	2494.271	21334.833	27789.1
Meezan Bank Ltd.	4236.729	3389.609	248887.5	5000.028	152459.855	89902.24
Allied Bank of Pakistan Ltd.	17296.83	8313.837	553618.6	20667.56	267682.679	278974.1
Askari Commercial Bank Ltd.	7610.632	4510.329	315306.5	26518.45	145354.253	142678.6
Bank Al Falah Ltd.	12582.53	7279.143	478346.6	22181.55	189486.762	227041.3
Bank Al Habib Ltd.	10748.45	4108.008	410008.6	3705.73	249923.504	150742.1
Faysal Bank Ltd.	7528.378	5024.688	276280.9	27549.73	87995.224	163301.5
Habib Bank Ltd.	19710.19	17764.16	1411544	56236.49	797094.548	514379.9
Habib Metropolitan Bank Ltd.	2976.428	2968.55	259240	17729.49	160733.315	101570.2
JS Bank Ltd.	1619.054	1205.921	70639.47	3037.264	47884.719	21584.33
KASB Bank Ltd.	2313.19	1563.024	83845.41	13868.07	39968.886	24865.79
Muslim Commercial Bank Ltd.	21885.41	9582.481	624052.4	25561.77	405601.313	238561.3
NIB Bank Ltd.	32921.5	2577.599	167273.5	32921.5	83802.727	65399.18
Samba Bank Ltd.	543.51	678.171	25231.11	2451.481	8894.957	18168.62
Silk Bank Ltd.	4110.672	2228.528	80427.23	10816.96	12734.898	48864.23
Soneri Bank Ltd.	3690.711	1765.343	141229.1	9927.397	59517.18	74450.03
Standard Chartered Bank Pakistan Ltd.	6252.803	5105.433	289998	27473.85	131741.003	161861.2
Summit Bank Ltd.	4733.084	1570.174	125715.8	23409.95	49777.088	43571.01
United Bank Ltd.	24173.65	11002.51	822479.5	57450.16	381245.903	395197.7
Bank of Punjab	3340.841	2424.429	310739.6	69328.7	129552.044	108118.1
Bank of Khyber	1211.014	969.474	67463.2	4334.605	45671.7	26875.18
First Women Bank Ltd.	205.132	425.014	19266.68	612.714	7263.885	12180.39
National Bank of Pakistan	26642.11	26061.22	1089207	89159.41	342964.635	653471
Barclays Bank PLC Pakistan	290.288	921.626	39249.63	866.541	19402.553	17759.18
Citi Bank	287.443	1179.141	64435.23	6207.49	31339.172	30556.9
HSBC	131.31	1603.445	39651.16	1441.219	13433.74	21979.93

Appendix B. 2 Data of variables used in the profitability banking model

(Data of 2012-in million Rupees)

Name of Bank	Input Variables			Output Variables		
	Interest Expenses	Non Interest Expenses	Loan Loss Provision	Interest Income	Fee, Commission and Brokerage Income	Other Income
Al Baraka Bank Pakistan Ltd.	4725.249	2102.545	1066.032	6271.14	243.01	163.145
Bank Islami Ltd.	3506.965	2279.759	134.44	5975.306	181.24	352.695
Burj Bank Ltd.	2594.187	1605.828	237.759	3603.352	104.54	351.606
Dubai Islamic Bank Ltd.	2807.792	2875.816	409.342	5682.122	436.74	258.608
Meezan Bank Ltd.	11384.534	7169.611	854.789	21836.97	969.52	1429.073
Allied Bank of Pakistan Ltd.	31180.99	15778.911	3253.01	49512.01	2,942.19	11302.71
Askari Commercial Bank Ltd.	22973.385	9315.577	3542.261	32404.35	1,173.56	3142.658
Bank Al Falah Ltd.	27500.056	15519.468	3264.302	46079.92	2,536.72	4744.623
Bank Al Habib Ltd.	26105.028	9032.511	800.812	41474.03	1,520.77	1538.061
Faysal Bank Ltd.	19838.745	11004.203	3089.354	28802.15	1,857.69	3424.031
Habib Bank Ltd.	59012.392	32062.123	7928.965	116772.7	6,785.69	9174.419
Habib Metropolitan Bank Ltd.	18821.766	6059.044	3835.022	27154.88	2,138.35	3319.318
JS Bank Ltd.	3731.733	2864.677	488.31	6168.31	818.79	1329.394
KASB Bank Ltd.	4252.011	3877.476	2176.51	6594.769	903.43	551.052
Muslim Commercial Bank Ltd.	27503.496	17823.496	4898.921	68443.74	6,384.76	3156.398
NIB Bank Ltd.	11125.821	5397.479	2858.015	13989.31	1,166.21	1229.279
Samba Bank Ltd.	1721.825	1413.28	39.283	3054.034	73.85	80.654
Silk Bank Ltd.	6681.338	4076.652	995.083	8583.566	492.41	572.256
Soneri Bank Ltd.	9224.135	4459.278	1452.32	14068.17	803.54	1053.396
Standard Chartered Bank Pakistan Ltd.	12337.997	14287.244	7869.073	32214.23	3,509.41	3802.558
Summit Bank Ltd.	10133.076	4032.501	1939.342	10262.5	652.58	773.073
United Bank Ltd.	35736.985	26577.953	6234.109	75379.86	9,449.63	7745.202
Bank of Punjab	22522.918	4565.509	3300.774	24662.36	762.49	2428.255
Bank of Khyber	4611.172	1822.549	449.827	7204.937	241.01	735.107
First Women Bank Ltd.	1037.893	716.92	69.406	1798.231	43.60	51.979
National Bank of Pakistan	56552.485	37295.445	10893.803	101125.9	11,145.57	13658.99
Barclays Bank PLC Pakistan	2733.763	1976.361	416.019	4492.307	159.81	238.401
Citi Bank	3030.151	4546.244	1255.687	8262.997	583.25	1872.751
HSBC	2326.385	3109.212	482.037	4555.975	483.70	433.827

REFERENCES

Afriat, S. N. 1972. Efficiency estimation of production functions. *International Economic Review,* 13**,** 568-598.

Aigner, D., Lovell, C. a. K. & Schmidt, P. 1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics,* 6**,** 21-37.

Akhtar, M. H. 2002. X-efficiency analysis of commercial banks in pakistan:A preliminary investigation. *European journal of Scientific Research,* 10**,** 78-91.

Akhtar, M. H. 2010a. Are saudi banks productive and efficient? *International Journal of Islamic and Middle Eastern Finance and Management,* 3**,** 95-112.

Akhtar, M. H. 2010b. X-efficiency analysis of pakistani commercial banks. *International Management Review,* 6**,** 12-23,109.

Al-Shammari, M. & Salimi, A. 1998. Modeling the operating efficiency of banks: A nonparametric methodology. *Logistics Information Management,* 11**,** 5-17.

Al-Sharkas, A. A., Hassan, M. K. & Lawrence, S. 2008. The impact of mergers and acquisitions on the efficiency of the us banking industry: Further evidence. *Journal of Business Finance & Accounting,* 35**,** 50-70.

Ali, A. I. & Seiford, L. M. 1993. The mathematical programming approach to efficiency analysis. *In:* FRIED, H. O., LOVELL, S. S. & SCHMIDT, S. S. (eds.) *The measurement of productive efficiency.* New York: Oxford University Press.

Allen, R., Athanassopoulos, A., Dyson, R. G. & Thanassoulis, E. 1997. Weights restrictions and value judgements in data envelopment analysis: Evolution, development and future directions. *Annals of Operations Research,* 73**,** 13-34.

Altunbaş, Y., Gardener, E. P. M., Molyneux, P. & Moore, B. 2001. Efficiency in european banking. *European Economic Review,* 45**,** 1931-1955.

Altunbas, Y., Liu, M.-H., Molyneux, P. & Seth, R. 2000. Efficiency and risk in japanese banking. *Journal of Banking & Finance,* 24**,** 1605-1628.

Aly, H. Y., Grabowski, R., Pasurka, C. & Rangan, N. 1990. Technical, scale, and allocative efficiencies in u.S. Banking: An empirical investigation. *The Review of Economics and Statistics,* 72**,** 211-218.

Anthanassopoulos, A. D. 1998. Nonparametric frontier models for assessing the market and cost efficiency of large-scale bank branch networks. *Journal of Money, Credit and Banking,* 30**,** 172-192.

Ariff, M. & Can, L. 2008. Cost and profit efficiency of chinese banks: A non-parametric analysis. *China Economic Review,* 19**,** 260-273.

Ashton, J. K. 2001. Cost efficiency characteristics of british retail banks. *The Service Industries Journal,* 21**,** 159-174.

Asmild, M. & Matthews, K. 2012. Multi-directional efficiency analysis of efficiency patterns in chinese banks 1997–2008. *European Journal of Operational Research,* 219**,** 434-441.

Asmild, M., Paradi, J., Aggarwall, V. & Schaffnit, C. 2004. Combining dea window analysis with the malmquist index approach in a study of the canadian banking industry. *Journal of Productivity Analysis,* 21**,** 67-89.

Assaf, G. A., Barros, C. P. & Matousek, R. 2011. Technical efficiency in saudi banks. *Expert Systems with Applications,* 38**,** 5781-5786.

Ataullah, A. 2004. *Financial repression and liability of foreignness in developing countries*, Taylor and Francis Journals.

Ataullah, A., Cockerill, T. & Le, H. 2004. Financial liberalization and bank efficiency: A comparative analysis of india and pakistan. *Applied Economics,* 36**,** 1915-1924.

Ataullah , A., Cockerill, T. & Le, H. 2004. Financial liberalization and bank efficiency: A comparative analysis of india and pakistan. *Applied Economics,* 36**,** 1915-1924.

Ataullah, A. & Le, H. 2006. Economic reforms and bank efficiency in developing countries: The case of the indian banking industry. *Applied Financial Economics,* 16**,** 653-663.

Athanassopoulos, A. D. 1998. Nonparametric frontier models for assessing the market and cost efficiency of large-scale bank branch networks. *Journal of Money, Credit and Banking,* 30**,** 172-192.

Avkiran, N. 2000. Rising productivity of australian trading banks under deregulation 1986–1995. *Journal of Economics and Finance,* 24**,** 122-140.

Avkiran, N. K. 1997. Models of retail performance for bank branches: Predicting the level of key business drivers. *International Journal of Bank Marketing,* 15**,** 224-237.

Avkiran, N. K. 1999. The evidence on efficiency gains: The role of mergers and the benefits to the public. *Journal of Banking & Finance,* 23**,** 991-1013.

Avkiran, N. K. 2006. Developing foreign bank efficiency models for dea grounded in finance theory. *Socio-Economic Planning Sciences,* 40**,** 275-296.

Avkiran, N. K. 2009a. Opening the black box of efficiency analysis: An illustration with uae banks. *Omega,* 37**,** 930-941.

Avkiran, N. K. 2009b. Removing the impact of environment with units-invariant efficient frontier analysis: An illustrative case study with intertemporal panel data. *Omega,* 37**,** 535-544.

Avkiran, N. K. 2011. Association of dea super-efficiency estimates with financial ratios: Investigating the case for chinese banks. *Omega,* 39**,** 323-334.

Banker, R. D. 1984. Estimating most productive scale size using data envelopment analysis. *European Journal of Operational Research,* 17**,** 35-44.

Banker, R. D., Charnes, A. & Cooper, W. W. 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science,* 30**,** 1078-1092.

Banker, R. D., Cooper, W. W., Seiford, L. M., Thrall, R. M. & Zhu, J. 2004. Returns to scale in different dea models. *European Journal of Operational Research,* 154**,** 345-362.

Banker, R. D. & Thrall, R. M. 1992. Estimation of returns to scale using data envelopment analysis. *European Journal of Operational Research,* 62**,** 74-84.

Banking Statistics of Pakistan 2002-2012. Reporting scheduled banks and their branches by group. Karachi: State bank of Pakistan.

Banking Statistics of Pakistan 2012. Reporting scheduled banks and their branches by group. Karachi: State Bank of Pakistan.

Barnett, W. A. 1980. Economic monetary aggregates an application of index number and aggregation theory. *Journal of Econometrics,* - 14**,** 11- 48.

Barr, R. S. & Siems, T. F. 1994. Predicting bank failure using dea to quantify management quality. Federal Reserve Bank of Dallas.

Barrow, M. & Wagstaff, A. 1989. Efficiency measurement in the public sector: An appraisal. *Fiscal Studies,* 10**,** 72-97.

Bauer, P. W., Berger, A. N., Ferrier, G. D. & Humphrey, D. B. 1998. Consistency conditions for regulatory analysis of financial institutions: A comparison of frontier efficiency methods. *Journal of Economics and Business,* 50**,** 85-114.

Beccalli, E., Casu, B. & Girardone, C. 2006. Efficiency and stock performance in european banking. *Journal of Business Finance & Accounting,* 33**,** 245-262.

Benston, G. J. 1965. Branch banking and economies of scale. *Journal of Finance,* 20**,** 312-331.

Berg, S. A., Førsund, F. R. & Jansen, E. S. 1992. Malmquist indices of productivity growth during the deregulation of norwegian banking, 1980-89. *The Scandinavian Journal of Economics,* 94**,** 211-228.

Berg, S. A. & Kim, M. 1998. Banks as multioutput oligopolies: An empirical evaluation of the retail and corporate banking markets. *Journal of Money, Credit and Banking,* 30**,** 135-153.

Bergendahl, G. 1998. Dea and benchmarks - an application to nordic banks. *Annals of Operations Research,* 82**,** 233-249.

Berger, A. 1993. “Distribution-free” estimates of efficiency in the u.S. Banking industry and tests of the standard distributional assumptions. *Journal of Productivity Analysis,* 4**,** 261-292.

Berger, A. N. 2007. International comparisons of banking efficiency. *Financial Markets, Institutions & Instruments,* 16**,** 119-144.

Berger, A. N. & Deyoung, R. 1997. Problem loans and cost efficiency in commercial banks. *Journal of Banking & Finance,* 21**,** 849-870.

Berger, A. N., Deyoung, R., Genay, H. & Udell, G. 2000. Globalization of financial institutions: Evidence from cross-border banking performance. *Brookings-Wharton Papers on Financial Services,* 3**,** 23-120.

Berger, A. N., Hancock, D. & Humphrey, D. B. 1993a. Bank efficiency derived from the profit function. *Journal of Banking & Finance,* 17**,** 317-347.

Berger, A. N. & Hannan, T. H. 1997. Using efficiency measures to distinguish among alternative explanations of the structure-performance relationship in banking. *Managerial Finance,* 23**,** 6-31.

Berger, A. N., Hanweck, G. A. & Humphrey, D. B. 1987. Competitive viability in banking - scale, scope, and product mix economies. *Journal of Monetary Economics,* 20**,** 501-520.

Berger, A. N. & Humphrey, D. B. 1991. The dominance of inefficiencies over scale and product mix economies in banking. *Journal of Monetary Economics,* 28**,** 117-148.

Berger, A. N. & Humphrey, D. B. 1992a. Measurement and efficiency issues in commercial banking. *Output Measurement in the Service Sectors,* 56**,** 245-300.

Berger, A. N. & Humphrey, D. B. 1992b. Measurement and efficiency issues in commercial banking. *In:* GRILICHES, Z. (ed.) *Output Measurement in the Service Sectors.* University of Chicago Press.

Berger, A. N. & Humphrey, D. B. 1997. Efficiency of financial institutions: International survey and directions for future research. *European Journal of Operational Research,* - 98.

Berger, A. N., Hunter, W. C. & Timme, S. G. 1993b. The efficiency of financial institutions: A review and preview of research past, present and future. *Journal of Banking & Finance,* - 17.

Berger, A. N. & Mester, L. J. 1997. Inside the black box: What explains differences in the efficiencies of financial institutions? *Journal of Banking & Finance,* 21**,** 895-947.

Bessent, A., Bessent, W., Elam, J. & Clark, T. 1988. Efficiency frontier determination by constrained facet analysis. *Operations Research,* 36**,** 785-796.

Bhattacharyya, A., Lovell, C. a. K. & Sahay, P. 1997. The impact of liberalization on the productive efficiency of indian commercial banks. *European Journal of Operational Research,* 98**,** 332-345.

Boles, J. N. Efficiency squared - efficiency computation of efficiency indexes. 39th Annual Meeting of the Western Farm Economics Association, 1966. 137-142.

Bonin, J. P., Hasan, I. & Wachtel, P. 2005. Bank performance, efficiency and ownership in transition countries. *Journal of Banking & Finance,* 29**,** 31-53.

Boufounou, P. V. 1995. Evaluating bank branch location and performance: A case study. *European Journal of Operational Research,* 87**,** 389-402.

Brockett, P. L., Charnes, A., Cooper, W. W., Huang, Z. M. & Sun, D. B. 1997. Data transformations in dea cone ratio envelopment approaches for monitoring bank performances. *European Journal of Operational Research,* 98**,** 250-268.

Burki, A. A. & Ahmad, S. 2010. Bank governance changes in pakistan: Is there a performance effect? *Journal of Economics and Business,* 62**,** 129-146.

Camanho, A. S. & Dyson, R. G. 2005. Cost efficiency, production and value-added models in the analysis of bank branch performance. *The Journal of the Operational Research Society,* 56**,** 483-494.

Canbas, S., Cabuk, A. & Kilic, S. B. 2005. Prediction of commercial bank failure via multivariate statistical analysis of financial structures: The turkish case. *European Journal of Operational Research,* 166**,** 528-546.

Casu, B. & Girardone, C. 2004. Large banks' efficiency in the single european market. *The Service Industries Journal,* 24**,** 129-142.

Casu, B. & Girardone, C. 2005. An analysis of the relevance of off-balance sheet items in explaining productivity change in european banking. *Applied Financial Economics,* 15**,** 1053-1061.

Casu, B. & Girardone, C. 2010. Integration and efficiency convergence in eu banking markets. *Omega,* 38**,** 260-267.

Casu, B., Girardone, C. & Molyneux, P. 2004. Productivity change in european banking: A comparison of parametric and non-parametric approaches. *Journal of Banking & Finance,* 28**,** 2521-2540.

Chang, C.-C. 1999. The nonparametric risk-adjusted efficiency measurement: An application to taiwan's major rural financial intermediaries. *American Journal of Agricultural Economics,* 81**,** 902-913.

Charnes, A. & Cooper, W. W. 1962. Programming with linear fractional functionals. *Naval Research Logistics Quarterly,* 9**,** 181-186.

Charnes, A. & Cooper, W. W. 1985. Preface to topics in data envelopment analysis. *Annals of Operations Research,* 2**,** 59-94.

Charnes, A., Cooper, W. W., Huang, Z. M. & Sun, D. B. 1990. Polyhedral cone-ratio dea models with an illustrative application to large commercial banks. *Journal of Econometrics,* 46**,** 73-91.

Charnes, A., Cooper, W. W., Lewin, A. Y. & M., S. L. 1994. *Data envelopment analysis: Theory, methodology, and applications,* Springer Netherlands, Kluwer Academic Publishers.

Charnes, A., Cooper, W. W. & Rhodes, E. 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research,* 2**,** 429-444.

Charnes, A., Cooper, W. W. & Rhodes, E. 1981. Evaluating program and managerial efficiency - an application of data envelopment analysis to program follow through. *Management Science,* 27**,** 668-697.

Charnes, A., Cooper, W. W., Wei, Q. L. & Huang, Z. M. 1989. Cone ratio data envelopment analysis and multi-objective programming. *International Journal of Systems Science,* 20**,** 1099-1118.

Chen, W.-H. & Shih, J.-Y. 2006. A study of taiwan's issuer credit rating systems using support vector machines. *Expert Systems with Applications,* 30**,** 427-435.

Chen, X., Skully, M. & Brown, K. 2005. Banking efficiency in china: Application of dea to pre- and post-deregulation eras: 1993–2000. *China Economic Review,* 16**,** 229-245.

Chiu, Y.-H. & Chen, Y.-C. 2009. The analysis of taiwanese bank efficiency: Incorporating both external environment risk and internal risk. *Economic Modelling,* 26**,** 456-463.

Chu, S. F. & Lim, G. H. 1998. Share performance and profit efficiency of banks in an oligopolistic market: Evidence from singapore. *Journal of Multinational Financial Management,* 8**,** 155-168.

Clement, J. N. 2007. *Financial institutions and productive efficiency: A redefinition and extension* PHD, Texas Tech University.

Coelli, T. J., Prasada Rao, D. S., O'donnell, C. J. & Battese, G. E. 2005. *An introduction to efficiency and productivity analysis,* New York, Springer.

Conaty, F. J. 2012. Performance management challenges in hybrid npo/public sector settings: An irish case. *International Journal of Productivity and Performance Management,* 61**,** 290-309.

Cook, W. D. & Seiford, L. M. 2009. Data envelopment analysis (dea) – thirty years on. *European Journal of Operational Research,* 192**,** 1-17.

Cook, W. D. & Zhu, J. 2008. *Data envelopment analysis modeling operational processes and measuring productivity,* Create Space.

Cooper, W., Seiford, L. & Zhu, J. 2011. Data envelopment analysis: History, models, and interpretations. *In:* COOPER, W. W., SEIFORD, L. M. & ZHU, J. (eds.) *Handbook on data envelopment analysis.* Springer US.

Cooper, W. W., Seiford, L. M. & Tone, K. 2000. *Data envelopment analysis,* Dordrecht, Kluwer Academic Publishers.

Daraio, C. & Simar, L. 2007. *Advanced robust and nonparametric methods in efficiency analysis:Methodology and applications*, Springer US.

Das, A. & Ghosh, S. 2006. Financial deregulation and efficiency: An empirical analysis of indian banks during the post reform period. *Review of Financial Economics,* 15**,** 193-221.

Das, A. & Ghosh, S. 2009. Financial deregulation and profit efficiency: A nonparametric analysis of indian banks. *Journal of Economics and Business,* -61**,** 509- 528.

Debreu, G. 1951. The coefficient of resource utilization. *Econometrica,* 19**,** 273-292.

Delis, M. D., Koutsomanoli-Fillipaki, A., Staikouras, C. K. & Katerina, G. 2009. Evaluating cost and profit efficiency: A comparison of parametric and nonparametric methodologies. *Applied Financial Economics,* 19**,** 191-202.

Demirguc-Kunt, A. 1989. Deposit-institution failures: A review of empirical literature. *Economic Review,* 25**,** 1-14.

Deprins, D., Simar, L. & Tulkens, H. 1984. Measuring labor-efficiency in post offices. *In:* CHANDER, P., DRÈZE, J., LOVELL, C. K. & MINTZ, J. (eds.) *Public goods, environmental externalities and fiscal competition.* Springer US.

Deyoung, R. 1997. A diagnostic test for the distribution-free efficiency estimator: An example using u.S. Commercial bank data. *European Journal of Operational Research,* 98**,** 243-249.

Donovan, D. J. 1978. Modelling the demand for liquid assets:An application to canada. *International Monetary Fund staff papers,* 25**,** 676-704.

Drake, L. 2001. Efficiency and productivity change in uk banking. *Applied Financial Economics,* 11**,** 557-571.

Drake, L. & Hall, M. J. B. 2003. Efficiency in japanese banking: An empirical analysis. *Journal of Banking & Finance,* 27**,** 891-917.

Drake, L., Hall, M. J. B. & Simper, R. 2006. The impact of macroeconomic and regulatory factors on bank efficiency: A non-parametric analysis of hong kong's banking system. *Journal of Banking & Finance,* 30**,** 1443-1466.

Drake, L., Hall, M. J. B. & Simper, R. 2009. Bank modelling methodologies: A comparative non-parametric analysis of efficiency in the japanese banking sector. *Journal of International Financial Markets, Institutions and Money,* 19**,** 1-15.

Dyson, R. G., Allen, R., Camanho, A. S., Podinovski, V. V., Sarrico, C. S. & Shale, E. A. 2001. Pitfalls and protocols in dea. *European Journal of Operational Research,* 132**,** 245-259.

Dyson, R. G. & Thanassoulis, E. 1988. Reducing weight flexibility in data envelopment analysis. *The Journal of the Operational Research Society,* 39**,** 563-576.

Economic Survey , P. 2012. *Ministry of finance, government of pakistan* [Online]. Pakistan: Ministry of Finance. [Accessed 7 August 2013 2014].

Elyasiani, E. & Mehdian, S. 1990. Efficiency in the commercial banking industry, a production frontier approach. *Applied Economics,* 22**,** 539-551.

Evanoff, D. D. & Israilevich, P. R. 1991. Productive efficiency in banking. *Economic Perspective,* 15**,** 11-32.

Fama, E. F. 1980. Banking in the theory of finance. *Journal of Monetary Economics,* 6**,** 39-57.

Färe, R. & Grosskopf, S. 2003. Nonparametric productivity analysis with undesirable outputs: Comment. *American Journal of Agricultural Economics,* 85**,** 1070-1074.

Färe, R., Grosskopf, S. & Lovell, C. a. K. 1985. *The measurement of efficiency of production,* Nijhoff, Boston, Kluwer Academic Publishers.

Färe, R. & Lovell, C. a. K. 1978. Measuring the technical efficiency of production. *Journal of Economic Theory,* 19**,** 150-162.

Farrell, M. J. 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society Series a-General,* 120**,** 253-290.

Ferrier, G. D. & Lovell, C. a. K. 1990. Measuring cost efficiency in banking: Econometric and linear programming evidence. *Journal of Econometrics,* 46**,** 229-245.

Fethi, M. D. & Pasiouras, F. 2010. Assessing bank efficiency and performance with operational research and artificial intelligence techniques: A survey. *European Journal of Operational Research,* 204**,** 189-198.

Fethi, M. D., Shaban, M. & Weyman-Jones, T. 2011. Liberalization, privatisation and productivity of egyptian banks: A non- parametric approach. *The Service industries lournal,* 31**,** 1143-1163.

Førsund, F. & Sarafoglou, N. 2002. On the origins of data envelopment analysis. *Journal of Productivity Analysis,* 17**,** 23-40.

Førsund, F. R. & Hjalmarsson, L. 2004. Calculating scale elasticity in dea models. *The Journal of the Operational Research Society,* 55**,** 1023-1038.

Førsund, F. R., Kittelsen, S. a. C. & Krivonozhko, V. E. 2009. Farrell revisited-visualizing properties of dea production frontiers. *Journal of the Operational Research Society,* 60**,** 1535-1545.

Fraser, D. R. & Fraser, L. M. 1990. *Evaluating commercial bank performance : A guide to financial analysis / donald r. Fraser and lyn m. Fraser,* Rolling Meadows, Ill, Bankers Publishing Co.

Frei, F. X. & Harker, P. T. 1999. Measuring aggregate process performance using ahp. *European Journal of Operational Research,* 116**,** 436-442.

Freixas, X. & Rochet, J.-C. 1997. *Microeconomics of banking,* Cambridge, Massachusetts, The MIT Press.

Fried, H., Schmidt, S. & Yaisawarng, S. 1999. Incorporating the operating environment into a nonparametric measure of technical efficiency. *Journal of Productivity Analysis,* 12**,** 249-267.

Fried, H. O., Lovell, C. a. K. & Schmidt, S. S. 2008. *Measurement of productive efficiency and productivity growth,* Oxford, Oxford University Press.

Fukuyama, H. & Matousek, R. 2011. Efficiency of turkish banking: Two-stage network system. Variable returns to scale model. *Journal of International Financial Markets, Institutions and Money,* 21**,** 75-91.

Giannakas, K., Tran, K. C. & Tzouvelekas, V. 2003. Predicting technical effciency in stochastic production frontier models in the presence of misspecification: A monte-carlo analysis. *Applied Economics,* 35**,** 153-161.

Gilbert, R. A. & Wilson, P. W. 1998. Effects of deregulation on the productivity of korean banks. *Journal of Economics and Business,* 50**,** 133-155.

Golany, B. 1988. A note on including ordinal relations among multipliers in data envelopment analysis. *Management Science,* 34**,** 1029-1033.

Golany, B. & Yu, G. 1997. Estimating returns to scale in dea. *European Journal of Operational Research,* 103**,** 28-37.

Gravy, G. 1977. *Money, financial flows and credit in the soviet union,* Cambridge, Mass U.S.A, Ballinger Publishing Company for the National Bureau of Economic Research INC.

Green, R. H., Doyle, J. R. & Cook, W. D. 1996. Efficiency bounds in data envelopment analysis. *European Journal of Operational Research,* 89**,** 482-490.

Greenberg, R. & Nunamaker, T. 1987. A generalized multiple criteria model for control and evaluation of nonprofit organizations. *Financial Accountability & Management,* 3**,** 331-342.

Greene, W. H. 1990. A gamma-distributed stochastic frontier model. *Journal of Econometrics,* 46**,** 141-163.

Guerra-López, I. J. 2008. *Performance evaluation: Proven approaches for improving program and organizational performance*, Hoboken U.S., Jossey-Bass.

Hailu, A. 2003. Nonparametric productivity analysis with undesirable outputs: Reply. *American Journal of Agricultural Economics,* 85**,** 1075-1077.

Hailu, A. & Veeman, T. S. 2001. Non-parametric productivity analysis with undesirable outputs: An application to the canadian pulp and paper industry. *American Journal of Agricultural Economics,* 83**,** 605-616.

Halkos, G. E. & Salamouris, D. S. 2004. Efficiency measurement of the greek commercial banks with the use of financial ratios: A data envelopment analysis approach. *Management Accounting Research,* 15**,** 201-224.

Hancock, D. 1985a. Bank profitability, interest-rates, and monetary-policy. *Journal of Money Credit and Banking,* 17**,** 189-202.

Hancock, D. 1985b. The financial firm: Production with monetary and nonmonetary goods. *Journal of Political Economy,* 93**,** 859-880.

Hao, J., Hunter, W. C. & Yang, W. K. 2001. Deregulation and efficiency: The case of private korean banks. *Journal of Economics and Business,* 53**,** 237-254.

Harada, K. 2005. *Rebuilding the indonesian banking sector : Economic analysis of bank consolidation and efficiency*.

Hauner, D. 2005. Explaining efficiency differences among large german and austrian banks. *Applied Economics,* 37**,** 969-980.

Havrylchyk, O. 2006. Efficiency of the polish banking industry: Foreign versus domestic banks. *Journal of Banking & Finance,* 30**,** 1975-1996.

Hensel, N. D. 2003. Strategic management of cost efficiencies in networks: Cross-country evidence on european branch banking. *European Financial Management,* 9**,** 333-360.

Ho, C. T. & Wu, Y. S. 2006. Benchmarking performance indicators for banks. *Benchmarking: An International Journal,* 13**,** 147-159.

Howcroft, B. & Ataullah, A. 2006. Total factor productivity change: An examination of the commercial banking industry in india and pakistan. *The Service Industries Journal,* 26**,** 189-202.

Huang, T. H. & Wang, M. H. 2002. Comparison of economic efficiency estimation methods: Parametric and non–parametric techniques. *The Manchester School,* 70**,** 682-709.

Hughes, J., Lang, W., Mester, L. & Moon, C.-G. 2000. Recovering risky technologies using the almost ideal demand system: An application to u.S. Banking. *Journal of Financial Services Research,* 18**,** 5-27.

Hughes, J. & Mester, L. 1993. A quality and risk-adjusted cost function for banks: Evidence on the "too-big-to-fail" doctrine. *Journal of Productivity Analysis,* 4**,** 293-315.

Hughes, J. P. 1995. *Recovering technologies that account for generalized managerial preferences: An application to non-risk neutral banks*.

Hughes, J. P., Lang, W., Mester, L. J. & Moon, C.-G. 1996. Efficient banking under interstate branching. *Journal of Money, Credit and Banking,* 28**,** 1045-1071.

Hughes, J. P., Lang, W. W., Mester, L. J., Moon, C.-G. & Pagano, M. S. 2003. Do bankers sacrifice value to build empires? Managerial incentives, industry consolidation, and financial performance. *Journal of Banking & Finance,* 27**,** 417-447.

Hughes, J. P., Mester, L. J. & Moon, C.-G. 2001. Are scale economies in banking elusive or illusive?: Evidence obtained by incorporating capital structure and risk-taking into models of bank production. *Journal of Banking & Finance,* 25**,** 2169-2208.

Hughes, J. P. & Moon, C.-G. 1995. Measuring bank efficiency when managers trade return for reduced risk. *Working Paper.* Department of Economics Rutgers University.

Humphrey, D. 1993. Cost and technical change: Effects from bank deregulation. *Journal of Productivity Analysis,* 4**,** 9-34.

Iannotta, G., Nocera, G. & Sironi, A. 2007. Ownership structure, risk and performance in the european banking industry. *Journal of Banking & Finance,* 31**,** 2127-2149.

Iimi, A. 2004. Banking sector reforms in pakistan: Economies of scale and scope, and cost complementarities. *Journal of Asian Economics,* 15**,** 507-528.

Isik, I. & Hassan, M. K. 2002. Technical, scale and allocative efficiencies of turkish banking industry. *Journal of Banking & Finance,* 26**,** 719-766.

Isik, I. & Hassan, M. K. 2003. Efficiency, ownership and market structure, corporate control and governance in the turkish banking industry. *Journal of Business Finance & Accounting,* 30**,** 1363-1421.

Jaffry, S., Ghulam, Y. & Cox, J. 2013. Trends in efficiency in response to regulatory reforms: The case of indian and pakistani commercial banks. *European Journal of Operational Research,* 226**,** 122-131.

Jaffry, S., Ghulam, Y., Pascoe, S. & Cox, J. 2007. Regulatory changes and productivity of the banking sector in the indian sub-continent. *Journal of Asian Economics,* 18**,** 415-438.

Jeon, D.-S. & Menicucci, D. 2011. When is the optimal lending contract in microfinance state non-contingent? *European Economic Review,* 55**,** 720-731.

Kao, C. & Liu, S.-T. 2004. Predicting bank performance with financial forecasts: A case of taiwan commercial banks. *Journal of Banking & Finance,* 28**,** 2353-2368.

Kim, C.-S. & Davidson, L. F. 2004. The effects of it expenditures on banks' business performance: Using a balanced scorecard approach. *Managerial Finance,* 30**,** 28-45.

Koopmans, T. C. 1951. An analysis of production as an efficient combination of activities. *Activity analysis of production and allocation. Cowles commission for research in economics monograph no. 13.* New York: JohnWiley and Sons.

Kpmg 2012. Banking survey 2012 commercial banks operating in pakistan. *In:* KPMG (ed.) *Banking Survey.* Karachi, Pakistan: KPMG Taseer Hadi & Co.

Kumbhakar, S. C. & Lovell, C. a. K. 2000. *Stochastic frontier analysis,* Cambridge UK, Cambridge University Press.

Kumbhakar, S. C. & Sarkar, S. 2003. Deregulation, ownership, and productivity growth in the banking industry: Evidence from india. *Journal of Money, Credit and Banking,* 35**,** 403-424.

Kwan, S. H. 2003. Operating performance of banks among asian economies: An international and time series comparison. *Journal of Banking & Finance,* 27**,** 471-489.

La Porta, R., Lopez-De-Silanes, F. & Shleifer, A. 2002. Government ownership of banks. *The Journal of Finance,* 57**,** 265-301.

Laeven, L. & Majnoni, G. 2003. Loan loss provisioning and economic slowdowns: Too much, too late? *Journal of Financial Intermediation,* 12**,** 178-197.

Lang, G. & Welzel, P. 1996. Efficiency and technical progress in banking empirical results for a panel of german cooperative banks. *Journal of Banking & Finance,* 20**,** 1003-1023.

Largan, M. C. a. I. O. F. S. C. I. O. B. 2000. *Banking operations,* London, The Chartered Institute of Bankers.

Leightner, J. E. & Lovell, C. a. K. 1998. The impact of financial liberalization on the performance of thai banks. *Journal of Economics and Business,* 50**,** 115-131.

Levine, R. 1998. The legal environment, banks, and long-run economic growth. *Journal of Money , Credit and Banking,* 30.

Li, Y., Liang, L., Chen, Y. & Morita, H. 2008. Models for measuring and benchmarking olympics achievements. *Omega,* 36**,** 933-940.

Liu, J. & Tone, K. 2008. A multistage method to measure efficiency and its application to japanese banking industry. *Socio-Economic Planning Sciences,* 42**,** 75-91.

Lotfi, H. F., Jahanshahloo, G. R., Ebrahimnejad, A., Soltanifar, M. & Mansourzadeh, S. M. 2010. Target setting in the general combined-oriented ccr model using an interactive molp method. *Journal of Computational and Applied Mathematics,* 234**,** 1-9.

Lozano-Vivas, A. 1997. Profit efficiency for spanish savings banks. *European Journal of Operational Research,* 98**,** 381-394.

Lozano-Vivas, A. & Pasiouras, F. 2010. The impact of non-traditional activities on the estimation of bank efficiency: International evidence. *Journal of Banking & Finance,* 34**,** 1436-1449.

Lozano-Vivas, A., Pastor, J. & Pastor, J. 2002. An efficiency comparison of european banking systems operating under different environmental conditions. *Journal of Productivity Analysis,* 18**,** 59-77.

Margono, H., Sharma, S. C. & Melvin Ii, P. D. 2010. Cost efficiency, economies of scale, technological progress and productivity in indonesian banks. *Journal of Asian Economics,* 21**,** 53-65.

Maudos, J. & Pastor, J. M. 2003. Cost and profit efficiency in the spanish banking sector (1985–1996): A non-parametric approach. *Applied Financial Economics,* 13**,** 1-12.

Maudos, J. N., Pastor, J. M., Pérez, F. & Quesada, J. 2002. Cost and profit efficiency in european banks. *Journal of International Financial Markets, Institutions and Money,* 12**,** 33-58.

Mcallister, P. H. & Mcmanus, D. 1993. Resolving the scale efficiency puzzle in banking. *Journal of Banking & Finance,* 17**,** 389-405.

Meenai, S. A. 2010. *Money and banking in pakistan,* Oxford UK, Oxford University Press.

Meeusen, W. & Broeck, J. V. D. 1977. Efficiency estimation from cobb-douglas production functions with composed error. *International Economic Review,* 18**,** 435-444.

Mester, L. J. 1987. A multiproduct cost study of savings and loans. *Journal of Finance,* 42**,** 423-445.

Mester, L. J. 1996. A study of bank efficiency taking into account risk-preferences. *Journal of Banking & Finance,* 20**,** 1025-1045.

Miller, S. M. & Noulas, A. G. 1996. The technical efficiency of large bank production. *Journal of Banking & Finance,* 20**,** 495-509.

Mostafa, M. M. 2009. Modeling the efficiency of top arab banks: A dea–neural network approach. *Expert Systems with Applications,* 36**,** 309-320.

Mukherjee, K., Ray, S. C. & Miller, S. M. 2001. Productivity growth in large us commercial banks: The initial post-deregulation experience. *Journal of Banking & Finance,* 25**,** 913-939.

Noulas, A. G., Ray, S. C. & Miller, S. M. 1990. Returns to scale and input substitution for large u. S. Banks. *Journal of Money, Credit and Banking,* 22**,** 94-108.

Oliveira, C. V. & Tabak, B. M. 2005. An international comparison of banking sectors: A dea approach. *Global Economic Review,* 34**,** 291-307.

Paradi, J., Yang, Z. & Zhu, H. 2011a. Assessing bank and bank branch performance. *In:* COOPER, W. W., SEIFORD, L. M. & ZHU, J. (eds.) *Handbook on data envelopment analysis.* Springer US.

Paradi, J. C., Rouatt, S. & Zhu, H. 2011b. Two-stage evaluation of bank branch efficiency using data envelopment analysis. *Omega,* 39**,** 99-109.

Paradi, J. C. & Zhu, H. 2013. A survey on bank branch efficiency and performance research with data envelopment analysis. *Omega,* 41**,** 61-79.

Pasiouras, F. 2008a. Estimating the technical and scale efficiency of greek commercial banks: The impact of credit risk, off-balance sheet activities, and international operations. *Research in International Business and Finance,* 22**,** 301-318.

Pasiouras, F. 2008b. International evidence on the impact of regulations and supervision on banks' technical efficiency: An application of two-stage data envelopment analysis. *Review of Quantitative Finance and Accounting,* 30**,** 187-223.

Pastor, J., Pérez, F. & Quesada, J. 1997. Efficiency analysis in banking firms: An international comparison. *European Journal of Operational Research,* 98**,** 395-407.

Pastor, J. M. 2002. Credit risk and efficiency in the european banking system: A three-stage analysis. *Applied Financial Economics,* 12**,** 895-911.

Patti, E., Bonaccorsi Di & Hardy, D. C. 2005. Financial sector liberalization, bank privatization, and efficiency: Evidence from pakistan. *Journal of Banking & Finance,* 29**,** 2381-2406.

Podinovski, V. 2002. Weight restrictions and radial measures of efficiency. Coventry: University of Warwick.

Podinovski, V. V. 2004. Production trade-offs and weight restrictions in data envelopment analysis. *Journal of the Operational Research Society,* 55**,** 1311-1322.

Podinovski, V. V. 2005. The explicit role of weight bounds in models of data envelopment analysis. *The Journal of the Operational Research Society,* 56**,** 1408-1418.

Podinovski, V. V. 2007a. Computation of efficient targets in dea models with production trade-offs and weight restrictions. *European Journal of Operational Research,* 181**,** 586-591.

Podinovski, V. V. 2007b. Improving data envelopment analysis by the use of production trade-offs. *Journal of the Operational Research Society,* 58**,** 1261-1270.

Podinovski, V. V. & Thanassoulis, E. 2007. Improving discrimination in data envelopment analysis: Some practical suggestions. *Journal of Productivity Analysis,* 28**,** 117-126.

Ray, S. C. 1991. Resource-use efficiency in public schools: A study of connecticut data. *Management Science,* 37**,** 1620-1628.

Ray, S. C. 2004. *Data envelopment analysis: Theory and techniques for economics and operations research*, Cambridge; New York and Melbourne: Cambridge University Press.

Ray, S. C. & Das, A. 2010. Distribution of cost and profit efficiency: Evidence from indian banking. *European Journal of Operational Research,* 201**,** 297-307.

Read, L. E. 1998. *A comparison of data envelopment analysis and stochastic fronier methods for assessing the effencies of organizational units.* PhD, University of Warwick UK.

Reinhart, C. M. & Rogoff, K. S. 2011. From financial crash to debt crisis. *American Economic Review,* 101**,** 1676-1706.

Resti, A. 1997. Evaluating the cost-efficiency of the italian banking system: What can be learned from the joint application of parametric and non-parametric techniques. *Journal of Banking & Finance,* 21**,** 221-250.

Richards, D. 1996. Elite interviewing: Approaches and pitfalls. *Politics,* 16**,** 199-204.

Rizvi, F. A. 2001. Post-liberalization efficiency and productivity of the banking sector of pakistan. *The Pakistan Development Review,* 40**,** 605-632.

Rogers, K. E. 1998. Nontraditional activities and the efficiency of us commercial banks. *Journal of Banking & Finance,* 22**,** 467-482.

Sahoo, B. K. & Tone, K. 2009a. Decomposing capacity utilization in data envelopment analysis: An application to banks in india. *European Journal of Operational Research,* 195**,** 575-594.

Sahoo, B. K. & Tone, K. 2009b. Radial and non-radial decompositions of profit change: With an application to indian banking. *European Journal of Operational Research,* 196**,** 1130-1146.

Sathye, M. 2003. Efficiency of banks in a developing economy: The case of india. *European Journal of Operational Research,* 148**,** 662-671.

Scheel, H. 2001. Undesirable outputs in efficiency valuations. *European Journal of Operational Research,* 132**,** 400-410.

Sealey, C. W., Jr. & Lindley, J. T. 1977. Inputs, outputs, and a theory of production and cost at depository financial institutions. *The Journal of Finance,* 32**,** 1251-1266.

Seçme, N. Y., Bayrakdaroğlu, A. & Kahraman, C. 2009. Fuzzy performance evaluation in turkish banking sector using analytic hierarchy process and topsis. *Expert Systems with Applications,* 36**,** 11699-11709.

Seiford, L. M. & Thrall, R. M. 1990. Recent developments in dea: The mathematical programming approach to frontier analysis. *Journal of Econometrics,* 46**,** 7-38.

Seiford, L. M. & Zhu, J. 1999a. An investigation of returns to scale in data envelopment analysis. *Omega,* 27**,** 1-11.

Seiford, L. M. & Zhu, J. 1999b. Profitability and marketability of the top 55 u.S. Commercial banks. *Management Science,* 45**,** 1270-1288.

Seiford, L. M. & Zhu, J. 2002. Modeling undesirable factors in efficiency evaluation. *European Journal of Operational Research,* 142**,** 16-20.

Sengupta, K. J. & Sahoo, B. 2006. Efficiency models in data envelopment analysis. Basingstoke: Palgrave Macmillan.

Shephard, R. W. 1953. *Cost and production functions.*, Princeton University Press.

Shephard, R. W. 1972. Theory of cost and production functions. *The Economic Journal,* 82**,** 1059-1061.

Sherman, H. D. & Gold, F. 1985. Bank branch operating efficiency: Evaluation with data envelopment analysis. *Journal of Banking & Finance,* 9**,** 297-315.

Sherman, H. D. & Ladino, G. 1995. Managing bank productivity using data envelopment analysis (dea). *Interfaces,* 25**,** 60-73.

Sherman, H. D. & Rupert, T. J. 2006. Do bank mergers have hidden or foregone value? Realized and unrealized operating synergies in one bank merger. *European Journal of Operational Research,* 168**,** 253-268.

Siddiqi, A. H. 2007. *Practice and law of banking in pakistan,* Karachi, Pakistan, Royal book Company.

Simar, L. & Wilson, P. W. 2008. Estimation and inference in nonparametric frontier models: Recent developments and perspectives. *Foundations and Trends® in Econometrics,* 5**,** 183-337.

Smith, A. 1776. *An inquiry into the nature and causes of the wealth of nations,* Scotland, W.Strahan and T.Cadell London.

Smith, P. 1990. Data envelopment analysis applied to financial statements. *Omega,* 18**,** 131-138.

State Bank of Pakistan 2001-2002. Financial sector assessment. Karachi: State Bank of Pakistan.

State Bank of Pakistan 2003. Financial sector assessment. Karachi: State Bank of Pakistan.

State Bank of Pakistan 2003-2012. Banking statistics of pakistan,. Karachi: State Bank of Pakistan.

State Bank of Pakistan 2006. Banking system review. Karachi: State Bank of Pakistan.

State Bank of Pakistan 2008. Financial stability review. Karachi: State Bank of Pakistan.

State Bank of Pakistan 2009-2010. Financial stability review. Karachi: State Bank of Pakistan.

State Bank of Pakistan 2011a. Financial stability review. Pakistan: State Bank of Pakistan.

State Bank of Pakistan 2011b. Prudential regulations. Karachi, Pakistan: State Bank of Pakistan.

State Bank of Pakistan 2012a. Financial stability review. Pakistan: State Bank of Pakistan.

State Bank of Pakistan 2013. Annual report statistical supplement fy13. Karachi: State Bank of Pakistan.

State Bank of Pakistan 2014. Structure of interest rates-economic data. Karachi: State Bank of Pakistan.

State Bank of Pakistan 2012b. Financial stability review. 2nd Half ed. Pakistan.

Staub, R. B., Da Silva E Souza, G. & Tabak, B. M. 2010. Evolution of bank efficiency in brazil: A dea approach. *European Journal of Operational Research,* 202**,** 204-213.

Stevenson, R. E. 1980. Likelihood functions for generalized stochastic frontier estimation. *Journal of Econometrics,* 13**,** 57-66.

Sturm, J.-E. & Williams, B. 2004. Foreign bank entry, deregulation and bank efficiency: Lessons from the australian experience. *Journal of Banking & Finance,* 28**,** 1775-1799.

Sturm, J.-E. & Williams, B. 2008. Characteristics determining the efficiency of foreign banks in australia. *Journal of Banking & Finance,* 32**,** 2346-2360.

Sturm, J.-E. & Williams, B. 2010. What determines differences in foreign bank efficiency? Australian evidence. *Journal of International Financial Markets, Institutions and Money,* 20**,** 284-309.

Sufian, F. 2009. Determinants of bank efficiency during unstable macroeconomic environment: Empirical evidence from malaysia. *Research in International Business and Finance,* - 23.

Sufian, F. 2011. Banks total factor productivity change in a developing economy: Does ownership and origins matter? *Journal of Asian Economics,* 22**,** 84-98.

Sufian, F. & Habibullah, M. S. 2009. Asian financial crisis and the evolution of korean banks efficiency: A dea approach. *Global Economic Review,* 38**,** 335-369.

Sufian, F. & Habibullah, M. S. 2012. Globalization and bank efficiency nexus: Symbiosis or parasites? *Review of Development Finance,* 2**,** 139-155.

Sufian, F. & Ibrahim, S. 2005. An analysis of the relevance of off-balance sheet items in explaining productivity change in post-merger bank performance: Evidence from malaysia. *Management Research News,* 28**,** 74-92.

Sufian, F. & Majid, M.-Z. A. 2007. Bank mergers performance and the determinants of singaporean banks' efficiency. *Gadjah Mada International Journal of Business,* 9**,** 19-39.

Sun, L. & Chang, T.-P. 2011. A comprehensive analysis of the effects of risk measures on bank efficiency: Evidence from emerging asian countries. *Journal of Banking & Finance,* 35**,** 1727-1735.

Tayebeh, F. & Khansoz, M. 2014. Technology adoption and banking efficiency: A study of iranian banks. *IUP Journal of Banking Management,* 13**,** 29-37.

Thanassoulis, E. 2003. *Introduction to the theory and development of data envelopment analysis*, Kluwer Academic Publishers.

Thanassoulis, E. & Allen, R. 1998. Simulating weights restrictions in data envelopment analysis by means of unobserved dmus. *Management Science,* 44**,** 586-594.

Thanassoulis, E., Boussofiane, A. & Dyson, R. G. 1996. A comparison of data envelopment analysis and ratio analysis as tools for performance assessment. *Omega,* 24**,** 229-244.

Thanassoulis, E., Maria, C. S. P. & Ozrendespić 2008. Data envelopment analysis: The mathematical programming approach to efficiency analysis. *In:* FRIED, H. O., LOVELL, C. A. K. & SCHMIDT, S. S. (eds.) *Measurement of productive efficiency and productivity growth.* 'Oxford University Press'.

Thompson, R. G., Brinkmann, E. J., Dharmapala, P. S., Gonzalez-Lima, M. D. & Thrall, R. M. 1997. Dea/ar profit ratios and sensitivity of 100 large u.S. Banks. *European Journal of Operational Research,* 98**,** 213-229.

Thompson, R. G., Dharmapala, P. S., Humphrey, D. B., Taylor, W. M. & Thrall, R. M. 1996. Computing dea/ar efficiency and profit ratio measures with an illustrative bank application. *Annals of Operations Research,* 68**,** 301-327.

Thompson, R. G., Langemeier, L. N., Lee, C. T., Lee, E. & Thrall, R. M. 1990. The role of multiplier bounds in efficiency analysis with application to kansas farming. *Journal of Econometrics,* 46**,** 93-108.

Thompson, R. G., Singleton, J. F., Thrall, R. M. & Smith, B. A. 1986. Comparative site evaluations for locating a high-energy physics lab in texas. *Interfaces,* 16**,** 35-49.

Thoraneenitiyan, N. & Avkiran, N. K. 2009. Measuring the impact of restructuring and country-specific factors on the efficiency of post-crisis east asian banking systems: Integrating dea with sfa. *Socio-Economic Planning Sciences,* 43**,** 240-252.

Tone, K. 1996. A simple characterization of returns to scale in dea. *Journal of Operations Research Society of Japan* 39**,** 604-613.

Tone, K. 2001. On returns to scale under weight restrictions in data envelopment analysis. *Journal of Productivity Analysis,* 16**,** 31-47.

Tortosa-Ausina, E. 2002a. Bank cost efficiency and output specification. *Journal of Productivity Analysis,* 18**,** 199-222.

Tortosa-Ausina, E. 2002b. Exploring efficiency differences over time in the spanish banking industry. *European Journal of Operational Research,* 139**,** 643-664.

Tortosa-Ausina, E. 2003. Nontraditional activities and bank efficiency revisited: A distributional analysis for spanish financial institutions. *Journal of Economics and Business,* 55**,** 371-395.

Tortosa-Ausina, E., Armero, C., Conesa, D. & Grifell-Tatje, E. 2012. Bootstrapping profit change: An application to spanish banks. *Computers & Operations Research,* 39**,** 1857-1871.

Tsionas, E. G., Lolos, S. E. G. & Christopoulos, D. K. 2003. The performance of the greek banking system in view of the emu: Results from a non-parametric approach. *Economic Modelling,* 20**,** 571-592.

Tulkens, H. 1993. On fdh efficiency analysis: Some methodological issues and applications to retail banking, courts and urban transit. *In:* CHANDER, P., DRÈZE, J., LOVELL, C. K. & MINTZ, J. (eds.) *Public goods, environmental externalities and fiscal competition.* Springer US.

Wahlen, J. M. 1994. The nature of information in commercial bank loan loss disclosures. *The Accounting Review,* 69**,** 455-478.

Wang, K., Huang, W., Wu, J. & Liu, Y.-N. 2014. Efficiency measures of the chinese commercial banking system using an additive two-stage dea. *Omega,* 44**,** 5-20.

Wanke, P. & Barros, C. 2014. Two-stage dea: An application to major brazilian banks. *Expert Systems with Applications,* 41**,** 2337-2344.

Weill, L. 2004. Measuring cost efficiency in european banking: A comparison of frontier techniques. *Journal of Productivity Analysis,* 21**,** 133-152.

Williams, J. & Nguyen, N. 2005. Financial liberalisation, crisis, and restructuring: A comparative study of bank performance and bank governance in south east asia. *Journal of Banking & Finance,* 29**,** 2119-2154.

Wilson, J. O. S., Casu, B., Girardone, C. & Molyneux, P. 2010. Emerging themes in banking: Recent literature and directions for future research. *The British Accounting Review,* - 42**,** - 169.

Wong, Y. H. B. & Beasley, J. E. 1990. Restricting weight flexibility in data envelopment analysis. *The Journal of the Operational Research Society,* 41**,** 829-835.

Wu, H.-Y., Tzeng, G.-H. & Chen, Y.-H. 2009. A fuzzy mcdm approach for evaluating banking performance based on balanced scorecard. *Expert Systems with Applications,* 36**,** 10135-10147.

Yeh, Q.-J. 1996. The application of data envelopment analysis in conjunction with financial ratios for bank performance evaluation. *The Journal of the Operational Research Society,* 47**,** 980-988.

Yildirim, C. 2002. Evolution of banking efficiency within an unstable macroeconomic environment: The case of turkish commercial banks. *Applied Economics,* 34**,** 2289-2301.

Yue, P. 1992. Data envelopment analysis and commercial bank performance: A primer with applications to missouri banks. Federal Reserve Bank of St. Louis Review.

Yuengert, A. M. 1993. The measurement of efficiency in life insurance: Estimates of a mixed normal-gamma error model. *Journal of Banking & Finance,* 17**,** 483-496.

Zaidi, S. A. 2005. *Issues in pakistan economy,* Oxford, UK, Oxford University Press.

Zhu, J. 2009. Envelopment dea models. *Quantitative models for performance evaluation and benchmarking.* New York: Springer.