

2012

An analysis on the efficiency and productivity of the Australian banking sector with a specific emphasis on the global financial crisis (2007-2009)

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Recommended Citation

Forughi, Shima Hassan Zadeh, An analysis on the efficiency and productivity of the Australian banking sector with a specific emphasis on the global financial crisis (2007-2009), Master of Accountancy - Research thesis, School of Accounting and Finance, University of Wollongong, 2012. <http://ro.uow.edu.au/theses/3522>

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**An Analysis on the Efficiency and Productivity of the Australian
Banking Sector with a Specific Emphasis on the Global Financial
Crisis (2007-2009)**

A thesis submitted in the fulfillment of the requirements for the award of the degree

Master of Accountancy-Research

From

University of Wollongong

By

Shima Hassan Zadeh Forughi

School of Accounting and Finance

2012

**TO MY BELOVED PARENTS
MY MAINSTAY AND STRENGTH**

ACKNOWLEDGMENTS

First, I am heartily thankful to my supervisor, Dr. Anura De Zoysa, whose encouragement, supervision and support from the preliminary stages to the concluding level of this thesis enabled me to develop an understanding of the subject. His help has been immense in every respect, whether through valuable and detailed feedback, constant guidance, personal support or good-hearted advice. He has been always there for me, helping me so I feel at home here. His wonderful guidance has been truly valuable in the progress of this research. I owe gratitude to him. I have sincere to his great help as without his help, writing this thesis was impossible.

I would like to convey my gratitude to my co-supervisor Associate Professor Abbas Valadkhani for introducing me to the new horizon in my life that I will never forget.

I would like to deeply thank Dr. Chris O'Donnell for helping me to develop my basic research skills and providing constant assistance in solving problems in relation to software issues and analysis of results. Without his great help I would not have been able to apply the software and analyse the results. I owe a great deal to him.

I also feel indebted to Associate Professor Mary Kaidonis, the Head of School of Accounting and Finance; for giving me advice on the design of my research and the use of statistics. I am also grateful to her kindness and care for her endless academic support. I owe gratitude to her.

I am heartily thankful to Professor Garry Tian, the Head of Postgraduate Studies of School of Accounting and Finance for his kind support before and after the submission of my thesis.

My sincere gratitude goes to Dr. Martin O`Brian, for giving me the opportunity to learn how to conduct research step by step and acquire a solid and rich foundation of

knowledge through which my research came to flourish. His noble devotion has been a great source of inspiration to me for the rest of my academic life.

I also would like to express my profound and sincere gratitude to Mr. Paul Mazzola, for elucidating to me the most important features of the Australian financial system that substantially advanced the course of my research in this field. He has been always there for me to help me with his valuable comments and feedbacks. I owe him deep gratitude.

I would like to express my special sincere regards to Mrs. Fariba Ahmadi Pirshahid for her encouragement, guidance, comments, questions and suggestions. Her eternal support and care have always relieved any difficulty in the progress of my study. I owe her for her kindness.

I am so thankful for our lovely staff of the Faculty of Commerce, the School of Accounting and Finance and School of Economics, for their support, guidance and care. I deeply thank to Mrs. Maree Horne and Mrs. Helen Harman as well as the IT Unit for all their help and guidance.

My sincere gratitude goes to Mr. Bill Morgan and other lovely and kind staff of the Security Department of the University of Wollongong who have been always there for me throughout the days and nights of my study. I owe them a great deal.

I would like to give my special sincere feeling to Dr. Ahmad Nasserli and all my lecturers in the University of Sistan and Baluchestan in Iran.

My special thanks are due to all my lovely friends in Iran and Australia; specially Mrs. Victoria Eftekhari, Dr. Mohsen Sangi, Mr. Serioja Niazi, Mr. Salar Sakhaei, Mr. Mohammadreza Mohagheghian, Mr. Athula Manawaduge, Mr. Michael Hililan, Mr. Ali Najeeb, Mrs. Kardina Kamaruddin, Mr. Mad Ithnin, Mrs. Menik De Zoysa, Mrs. Akiko Philips, Miss Wendy Ruan, Miss Lina Zou and Miss Alina Maydybura, for their endless

emotional support and kindness during my study in Australia; who were always there for me when I needed them.

I heartily thank Ms Sophie J. Williams for her kind support and helping me in the editing of my thesis. I owe gratitude to her.

I would like to express my sincere regards to my best friend Miss Elham Pourazarm for her encouragement, guidance and suggestions. Her eternal support and care has always accompanied me throughout the journey of my study. I owe her deeply for what ease she has brought to my life in all aspects of my life in Australia.

My deep sincere and appreciation goes to my best friend, Miss Shirin-Dokht Nabavi for all her unconditional love, help and emotional support during my study in Australia. I would love to thank her for helping me in the edition of this thesis. I owe a great deal to her.

I would like to be heartily thankful to my brother, Nima who is always there for me in all aspects of my life with his endless support and undying love. His passion and noble devotion has been a great source of inspiration to me for entire my life. I would love to specially thank him for helping me to apply the required computer software and in the structural correction of this thesis. As well, my sincere appreciation goes to his wife, Armita for her love and emotional support. I owe extreme gratitude to her.

I would love to thank my sister, Nazli for her unconditional love, moral support and help. Being in contact with her has always given me a beautiful feeling of warmth and security that I needed so much.

And the last but not least, special, unique and respectful feelings to my understanding and lovely parents Mrs. Shahla and Dr. Ali H. Forughi , who in every aspect of my life, have been always there to support me in every moment of my life and at all steps of my studying in Australia. When it comes to expressing my debt to my parents, words fail me. They have given me everything in my life.

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Glossary

ANZ	Australia and New Zealand Bank
BOQ	Bank of Queensland
CBA	Commonwealth Bank of Australia
CCD	Caves, Christensen and Diewert
CCR	Charnes, Cooper and Rhodes
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DFA	Distribution Free Approach
DMU	Decision Making Unit
FDH	Free Disposal Hull
NAB	National Australia Bank
NIRS	Non-Increasing Returns to Scale
OLS	Ordinary Least Square
Repo	Repurchase agreement
ROA	Return on Assets
ROE	Return on Equity
SFA	Stochastic Frontier Analysis
S & Ls	Savings and Loans Association
TFA	Thick Frontier Analysis
VRS	Variable Returns to Scale

ABSTRACT

The banking industry plays a crucial role in the financial system and economic development of any country. Thus, the evaluation of its efficiency is of great importance. The present thesis analyses the impact of different phases of the recent banking crisis on Australian banks with a view to identifying problem areas in the banking sector and to provide directions for policy improvements.

A multiple-stage approach based on Data Envelopment Analysis (DEA) is utilized in this study to investigate the level of efficiency and productivity of the Australian banks over a 7 year period. This analysis consists of the following five phrases: First, the level of efficiency of banks is measured and compared using three different approaches—intermediation approach, value-added approach, and production approach— with a view to distinguishing how efficiency scores may vary with changes in the corresponding different input-output mixes. Both the constant return to scale (CRS) and variable return to scale (VRS) assumptions have been put into the test. Second, productivity changes of the sample banks are measured analyzing the Malmquist indices. Third, examination of the relationship between the level of efficiency and the institutional size of each bank using a univariate cross-tabulation approach is conducted. Fourth, examination of the impact of the global financial crisis 2007-2009 on the performance of the Australian banks is applied. Fifth, analysis of the effectiveness of recent mergers and acquisitions in Australian banking system in improving the efficiency and performance of the Australian banks is presented.

The findings of the study revealed that during the period investigated in this study, the sample banks exhibited a high pure technical efficiency under all three approaches and high scale efficiency under production and value-added approaches, but lower scale efficiency under the intermediation approach. The banks inefficiency is mainly attributable to the scale

of their operations and under utilization of resources. During the financial crisis, the sample banks produced a high level of technical efficiency under production and value-added approach but the low level of efficiency under intermediation approach may have been caused by the serious decline in amount of investments and loans.

The analysis on Malmquist indices also showed that during the financial crisis 2007-2009, the sample banks experienced productivity growth under the value-added approach and productivity regress under the intermediation approach.

Evaluation of the relationship between the size of banks and their performance revealed that the Big Four banks—ANZ, Commonwealth, NAB and West Pac— operated more efficiently than the other banks under all three approaches during all years of investigation except for 2009 and 2010.

This study makes a significant contribution to the academic literature by providing the first empirical evidence of the impact of the recent global financial crisis (2007-2009) on Australian Banks using the DEA methodology and presenting an analysis of the effectiveness of recent mergers and acquisitions of Australian banks.

Chapter 1 : Introduction

1.1 Background of the Study

Financial crisis is a consequence of financial development and occurs in countries with developed economies more than other countries. The financial crisis 2007 is recognized as a sequence of global crises since the 1970s and started with the subprime mortgage in the United States. This crisis that has been the most important and exceptional one among the other financial crises because of the significant impact it had not only on the US economy but also on other major economies in the world, triggering a global financial crisis in 2008. As a consequence of this crisis, by late 2009, most of the world economies, especially major industrial economies including the Australian economy, were seriously affected (Pomfret 2009).

Throughout the past 2 decades, there has been substantial theoretical and empirical concentration on financial development and the economic growth. The important role of banks in innovation and industrialization progression has been recognized in the literature but there has been no consensus about the impact of the financial sector on economic performance (see for example, Gerschenkron 1962; Patrick 1966; Hicks 1969, Romero-Ávila 2011).

Pagano (1993) argued that financial development might influence economic growth through three major channels which are: (1) the rise of private savings rate; (2) the efficiency improvement of the financial intermediary performance; and (3) the expansion of social capital productivity. A model was developed by Greenwood and Smith (1990) based on which financial markets induce specialization and decrease transaction costs to enhance productivity and growth. In addition, King and Levine (1993b) have stated that because of the

correlation between banking improvement and productivity growth, there is also a fundamental relationship between finance and development.

Generally, it is believed that financial development drives productivity growth as a result of superior resource allocation and hence, leads to economic growth (Waheed and Younus 2010). Therefore, one would expect a financial crisis which disturbs the smooth functioning of the financial system to have a significant negative impact on the efficiency of the banking sector as well as the economic growth of a country. In this background, it is important to examine the impact of the recent global financial crisis, which is now known as GFC, on the banking sector.

There have been many studies examining the consequences of the global financial crisis 2007 on the financial sector of different countries (see for example, Anayiotos et al. 2010; Sufian 2010 and Perlich 2010). The results of these studies show that performance of the financial institutions has been significantly impacted by this crisis. However, as shown in relevant literature presented in Chapter 3, there has not been a study examining the impact of the recent financial crisis on the efficiency and productivity of the Australian banks.

1.2 Significance of the Study

Over the previous decades, banks and other types of financial institutions have experienced a quick technological growth that necessitates advanced evaluation of the efficiency and productivity of these firms. In addition, the recent financial crisis (2007-2009) generated various issues concerning over the Australian financial sector. Three important investment banks namely, Lehman Brothers Australia, Opes Prime and Storm Financial, failed through the financial crisis. Since 2005 to 2008, the cash rate increased from 5.25 percent to 7.25 percent by the Reserve Bank Australia (RBA) (Jones 2009).

The Australian banks appeared to be in a stronger position during the crisis compared to the banking system of other countries. However, several structural problems were created in the Australian banking industry throughout this period among which the most important ones are:

1. the instability of offshore markets affecting the funding capacity of the Australian banking system and the conciliation of the domestic securitization,
2. more concentration in the banking sector, and
3. the avoidance of the Australian economy from unhelpful forces on credit flows like the G20's international regulatory response (Henry 2010).

Also, as a consequence of this crisis, one can observe that there has been a steady decline in the level of investment. Prior to the financial crisis, Australia has noticeably relied on international capital to finance domestic investments. Yet, the common hesitation of financial institutions to lend has greatly reduced the amount of international capital (Kriesler 2009).

The present thesis will assess the effect of the recent global financial crisis (2007-2009) on the performance of the Australian banking system. In order to conduct this analysis, the level of efficiency of the banks included in the sample will be measured by the means of Data Envelopment Analysis (DEA). In addition, the trend of productivity change of these banks will be evaluated throughout the sample period by employing the Malmquist index.

1.3 Research Questions

The main objective of the present thesis is to investigate the impact of the recent financial crisis on the efficiency of the Australian banks. For this purpose, the level of efficiency of the Australian banks before and after the recent financial crisis is measured and evaluated. In addition, the productivity change of these banks will also be evaluated over the

period of 2004-2010 through the analysis of the Malmquist indices. The results obtained from this analysis will address the following five research questions:

1. What is the mean efficiency score of the major Australian banks (Big 4) and the regional banks?
2. What is the total factor productivity change for these banks?
3. How was the efficiency and productivity of the banking system affected by the Global Financial Crisis 2007?
4. Have the mergers and acquisitions occurred in the Australian banking system been successful in improving the efficiency and performance of the banking sector?
5. What is the effect of institutional size on the efficiency of the banks?

1.4 Methodology

Parametric and nonparametric methods are the two most common approaches to assess the performance of the banks. The Stochastic Frontier Analysis (SFA), Dynamic Financial Analysis (DFA), and Thick Frontier Approach (TFA) are parametric methods while Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) are nonparametric techniques. Both approaches yield quite similar results (see Berger and Humphrey 1997 and Pasiouras 2007).

The parametric methods try to detach inefficiency from random error and estimate a functional form to link the inputs and outputs. The major shortcoming of this approach is that the model type should be estimated which may result in the misspecification of the model (Berger and Humphrey 1997). In addition, Thanassoulis (2001) discussed that it is unfeasible to incorporate a variety of inputs and outputs. Considering these problems, nonparametric methods are mostly favorable to analyze the efficiency of the financial institutions.

Among the nonparametric approaches, DEA has been noticeably improved subsequent to the work of Charnes, Cooper, and Rhodes (CCR) (1978). To employ DEA, there is no need to assume any functional form in contrast to the parametric approaches. Technical efficiency scores of institutions could be measured by the means of DEA under both constant and variable returns to scale. In addition, the trend of productivity change can be evaluated through the Malmquist index analysis by the DEA technique. This method contains alternative approaches to assessing performance and is practically oriented and hence, it is a superior methodology for modelling operational practices (Seiford and Thrall 1990).

The present thesis will employ the DEA methodology to evaluate the efficiency of Australian banks during the period 2004 to 2010 to find out the impact of the global financial crisis 2007 on the performance of the Australian banking industry. DEA analyses use various homogenous Decision Making Units (DMUs) and examine the performance of each firm with regards to the efficient frontier; units located on the efficient frontier are the best performing firms, and those scores lying underneath are relatively inefficient and score between 0 and 1.

The Malmquist index will be utilized to measure the productivity change of these banks over the same period. The productivity change will be broken into technical and efficiency changes by the Malmquist index and distance functions will describe the Malmquist total factor productivity. Most of the literature related to the present analysis will be explained through the literature review.

The above analysis will be conducted by the means of the DEA software, DEAP Version 2.1, and will be elucidated in detail through Chapter 4.

The sample of this study include the big 4 banks in Australia—National Australia Bank (NAB), Commonwealth Bank, Australia and New Zealand (ANZ) bank and Westpac—and another six Australian owned banks—Suncorp Group, Adelaide bank, Bendigo bank, St.

George bank, Bank of Queensland (BOQ) and the Macquarie Group. Due to the merger between Adelaide bank and Bendigo bank by the end of 2007, the composition of the sample has changed for the years 2008 to 2010. Similarly, because of the acquirement of St. George Bank by the Westpac, St. George Bank is not included in the efficiency analysis of 2009.

The research question one is answered by analyzing the mean efficiency score of the sample banks using DEA method. The second research question will be answered by investigating the nature of productivity movements through the Malmquist indices. This analysis will explore three major issues:

1. the evaluation of the changes in productivity during the period 2004-2010;
2. the decomposition of these productivity changes into the catching-up and frontier-shift effects; and
3. determining the main cause of gain/loss due to improvement/failure of technical efficiency or of the scale efficiency through further decomposition of the catching-up effect.

The analysis on the efficiency and productivity movements of the Australian banks in the sample over the period of 2007 to 2009 will provide the answer to the third research question. By measuring the nature of returns to each bank through their scale efficiency, the fourth research question on whether mergers had any impact on the efficiency and productivity of the banking system will be answered. Finally, through a univariate approach, the fifth research question on whether the size of the financial institution could be influential in the efficiency of the banks will be answered.

1.5 Limitations

There are some limitations in accomplishing the current study which are as follows:

1. there might be bad debts raised through financial activities which are not reported by the banks. Hence, this issue will arrive at higher efficiency scores;
2. the DEA method does not measure the firm's efficiency with statistical averages. It rather examines inefficiency of a particular firm corresponding to comparable firms. Therefore, the potential outliers of this technique will affect the empirical results specifically in case of small sample size studies; and
3. in order to find the relationship between the size of institution and its efficiency, the value of the total assets presented in the balance sheet is considered as the institutional size in this study. This identification is based on the choice of the author and any other valuation would be relevant to define the size.

1.6 Thesis Structure

This thesis consists of six chapters. After the present introductory chapter, the rest of the study is structured as follows:

Chapter 2- The Australian banking system is presented, starting with a brief history of the Australia's banking industry since the nineteenth century continued by the creation of the central banking, regulatory system and the deregulation era. An overview of the global financial crisis 2007-2009 is presented in the following section pointing out the major events occurred throughout the crisis. At the end, the effect of these events on the Australian financial system is reviewed together with the structural challenges that were revealed after the crisis.

Chapter 3- The literature Review describes a summary of the relevant studies on the efficiency of financial institutions (mainly banks). This summary of literature contributes to

understanding the current study. The utilization of the DEA method is appraised through the relevant literature on the efficiency measurement of the financial institutions worldwide and in Australia throughout two sections. This is followed by a discussion on the studies on the productivity changes using the Malmquist indices. A brief review of the studies on the various aspects of the financial crises is conducted in the last part.

Chapter 4- Methodology provides a discussion of the applied technique to analyse the data. This chapter illustrates a framework to measure the efficiency of firms using a DEA model. Efficiency analysis by the DEA method has been elucidated based on both constant returns to scale (CRS) and variable returns to scale (VRS) models. As well, the analysis and measurement of the Malmquist indices is explored through this chapter. The rationale behind the specification of inputs and outputs in the process of efficiency and productivity assessment is discussed. The assortment of the sample and the source of data will be also clarified.

Chapter 5- Empirical results and analysis reports the results obtained through the analysis of the data based on the described methodology in Chapter 4. The results of the study are classified into three core groups which are as follows: (1) The overall efficiency scores of the studied banks over the sample period under the three approaches to the DEA model; (2) Changes in productivity during the investigation period from 2004 to 2010; and (3) Disclosure of the relationship between the size (total asset) of each bank and its efficiency score employing the univariate cross tabulation. Chapter 6 provides the conclusions of the study.

Chapter 2 : Australian Banking System

2.1 Introduction

Previous chapter has provided an introduction to the study and an overview on the current study as a whole. This chapter provides an overview of the Australian banking industry from 19th century to the end of the global financial crisis 2007-2009. An examination of the historical developments in the banking industry in Australia reveals that the banks and other type of financial institutions in Australia have gone through swift technological developments throughout the previous decades. Furthermore, during the period from 1980s to early 1990s, the Australian banking sector has transited from a highly regulated sector to a deregulated sector. These changes in the banking sector have necessitated the need for studies to examine the changes in efficiency and productivity of these organizations. In addition to the above mentioned changes in the banking industry, it has also been subjected to a number of financial crises. The Financial crisis of 2007 began with the subprime mortgage in the United States of America and became global in 2008. It is argued that this crisis is a sequence of global crises since the 1970s. The global financial crises have frequent bases but due to the rigorousness of the US downturn, the financial crisis 2007-2009 is considered as the most exclusive amongst the post-1945 crises (Pomfret 2009). The effect of the crisis on different aspects of the Australian economy has been studied by different authors (see for instance Duffie 2010, Perlich 2009, Karunaratne 2010, Kriesler 2009). This study attempts examine the impact of 2007 crisis on the Australian banking industry. Therefore, this chapter will also provide an overview of the consequences of the recent crisis on the banking industry of Australia. The rest of the chapter is structured as follows: Section 2.2 reviews the history of banking in Australia under three parts—birth of Central banking, a full regulatory system and

deregulation eras. Section 2.3 discusses the impact of the financial crisis of 2007-2009 on the Australian banking sector. A summary of this chapter is provided in Section 2.4.

2.2 History

In the nineteenth century, the Australian financial system consisted of trading and savings banks, pastoral companies, life offices, trustee companies, building societies and finance companies. Among these, trading banks were the most significant ones and they raised funds nationally as well as internationally. Their operations were based on conventional banking practices and were prosperous until bank crash of 1893 (Thomson and Abbott 2001).

In 1840, the British Treasury placed regulations to be pursued by colonial banks and revised these conditions in 1846. These restrictions included:

- Advances on land were illegal;
- Banks were not allowed to hold its own shares or make advances on them;
- Note issue should be equal to the value of paid up capital;
- The amount of liabilities was to be at the most three times of paid up capitals and twice of the issued capital;
- The initial period for a bank to be a body corporate should not be more than 30 years; and
- Banks were required to provide the statistical returns of assets and liabilities (Pope 1989, p.5).

According to Thomson and Abbott, “the regulations of 1840 and 1846 can be viewed as the synthesis resulting from conditions that had arisen in Great Britain, and in the Australian context were imported as a regulatory thesis” (Thomson and Abbott 2001, p.71). However, to take advantage of the speedy growing economy of mid-nineteenth century,

Australian banks avoided these regulations and hence, every bank in Australia needed a parliamentary license till 1860s. For banks to be incorporated without any specific legislation Australian colonial governments set down general company Acts and based on their regulatory standards, the banks were obliged to present statistical information as the only consistent requisite (Butlin 1986). Australian banks experienced a largely unregulated environment in the second half of the nineteenth century with not many barriers to entry and reacted in different ways. Many businesses were settler colonies and hence, had limited collateral on which to borrow excepting illiquid securities. Therefore, banks had to accept illiquid assets such as landed property and livestock as collateral for loans to expand their profitability and growth prospects (Hawke 1973 and Jones and Mueller 1992).

Banks had to cut margins between lending and deposit rates and to take superior lending risks as a result of severe competition between new entrants for market share in the mostly free banking atmosphere of the 1870s and 1880s (Pope 1989). Banks lowered the ratio of cash and gold to deposits as well as ratio of capital and reserves to loans and hence, prudential standards declined (Merrett 1989, 1997; Pope 1989; Schedvin 1989). The decline in the prudential standards to be applied by banks on one hand and the reluctance of the governments to impose prudential standards on the other hand, represent the strong economic growth of the time that caused the increased competition persuading banks to accept higher risks on loans to sustain market share. The weak investment decisions by government and private organizations in the 1880s, the general failure of the widened financial institutions in the 1890s, and lack of prudential standards, caused a rigorous depression and banking crisis of 1893 (Merrett 1989, 1997). The colonial governments did not attempt to impose regulations in response to this crisis but instead, along with federation, the state and commonwealth governments, founded and developed government owned savings banks and commenced agricultural and housing loan plans. It is worth pointing out that the Australian

government of the nineteenth century did not interfere in the private sector activity by the formal regulations; the major type of intervention was in the form of national services (Butlin, Barnard and Pincus 1982).

Therefore, the Australian government strengthened the saving banks in response to the 1980s crisis. The most important concern of legislators during and after the crisis was to ensure that the consumers' savings be secure. In addition, there were concerns about the supply of cheap finance for government loans and availability of the long term finance for farmers and homebuilders. Direct demands of the banking system and general public along with the government interventions in other parts of the Australian economy influenced the regulatory response of the government.

In fact, the status of the savings banks changed considerably from small organizations managed by government trustees or post offices of the colonial governments before the financial crisis to more secure organizations after that and started a constant growth rate. The state savings banks developed at a steady rate after the collapse of the trading banks and building societies following the 1890s financial crisis. Simultaneously, the governments attempted to create organizations that could provide a safe place for depositors. In addition, the Labor Party preferred to use government-owned banks and hence, "they advocated the establishment of a national trading and savings bank that would compete with the private trading banks" (Thomson and Abbott 2001, p74). Finally, the Commonwealth Bank was established in 1911 to compete with the private banks and be a secure haven for depositors (Gollan 1968).

2.2.1 Birth of Central Banking

Although the subject of central banking emerged at the beginning of new century, till 1930s and before the Second World War, the central banking authorities were very delicate

and the government intervention was preferably into the general banking business rather than into central banking (Thomson and Abbott 2001, p75).

Before the First World War, the rate of Australian currency was stable to gold and sterling and the banks desired to manage their own operations by themselves. Also, the states and the government could choose any desirable private bank for their banking activities. Therefore, there was no reason to establish a central bank in Australia. The establishment of Commonwealth Bank in 1911 was a major development in the banking sector in Australia. It was established to operate as a common trading and savings bank rather than as a central bank. The sense of nationalism raised by the First World War encouraged British dominions to set up their own central bank. The International Financial Conferences in Brussels in 1920 and Genoa in 1922 is also played a considerable role in establishing central banks for British dominations (DeKock 1974, p.9). Consequently, Central Banks were established in “the British dominions of South Africa (1921), Australia (1924), New Zealand (1933), Canada (1935), Ireland (1942), and in a number of European and South American countries” (Thomson and Abbott 2001, p75). At this time, the Commonwealth Bank also began to act as a central bank. At the beginning, the new central banks had limited responsibilities/tasks. They were authorized to notes issuance along with acting as bankers to other banks and government. Later on, they acquired the authority to conduct monetary policy. According to the Commonwealth Bank Act of 1920, the authority of note issue transferred from the treasury to the note issue department of the Commonwealth Bank and after 1924. This department was directly managed by the bank’s directors. As stated, the purpose of the 1924 Act was “the complete transformation of the Commonwealth Bank and the Notes Board into a central bank” (Giblin 1951, p.32). This change occurred as a result of the strict practices of the notes board and was a response to the currency deficiency of the early 1920s (Giblin 1951).

In the 1920s, the main objective of the Commonwealth Bank was to control the general and savings banks activities, support the government to finance the debts and provide a feasible payment system. However, the trading banks did not like to bank with the Commonwealth Bank and avoided any mandatory regulation. In response to the economic volatility of the early 1920s along with the global trend, the Commonwealth Bank moved into central banking in the early 1920s. Though, at this time, the central banking powers of the Commonwealth Bank were fairly weak due to the fact that there were not severe political forces to launch central banking authorities. In addition, the trading banks “responded in an antithetical fashion by refusing to bank significant amounts of funds with it and so weakened its monetary powers” (Thomson and Abbott 2001, p76). On the other hand, the government intervened mainly into the government banks operation rather than the central banking authorities or the regulatory standards throughout the war. However, this regulatory intervention was not adequate to face the Great Depression of 1930s and consequently, after reassessing the monetary powers of the Commonwealth Bank, a new broad regulatory system was founded through the Second World War (Thomson and Abbott 2001).

2.2.2 A Full Regulatory System

To accomplish the financial system over the Great Depression, the Australian government established a Royal Commission on Monetary and Banking which largely recommended the definition and reinforcement of the central bank functions of the Commonwealth Bank (Royal Commission on Money and Banking 1937). According to the commission, “private banks should be licensed, supply statistical data to the Commonwealth Bank, keep a minimum variable deposit with the bank, maintain a proportion of their assets in the form of government securities and make agreements with the government on the mobilization of gold and sterling reserves” (Thomson and Abbott 2001, p77). However, due

to the delays in the government's response, the central bank powers did not enhance till the occurrence of the Second World War. After the war occurred, The National Security (Banking Regulations) Acts were commenced in 1939-1941 that expanded the control of the Commonwealth Bank "over bank liquidity, bank interest rates, advance policy, foreign exchange, and the establishment of new banks" (Thomson and Abbott 2001, p77). The Commonwealth Bank Act of 1945 as well as the Banking Act of 1945 expanded these authorities. The monetary policy was conducted using the regulations over bank liquidity. The restricted nature of the Australian bond market of that time necessitated this type of monetary policy instead of the conventional use of open market operations. To create a regulatory regime concerning demand management was an indication of the recessed conditions of the 1930s. In fact, the regulatory regime emerged in response to the concerns about the Great Depression; however, the influence of the time on the nature of the regulatory structure is considerable. The other aspect of the 1945 regulatory regime is that its major aim was to conduct anti deflationary monetary policy.

The Australian financial sector became very strong through the decades after the 1945 Banking Act. Earlier, it consisted of a group of conventional and strict institutions controlled by trading banks but after the 1945 Banking Act, the financial sector modified into a modern and complicated system and till 1980, consisted of extremely developed institutions. Throughout the modernization period of the financial sector, the regulatory structure of the 1945 Banking Act was kept unchanged; "the only major regulatory organizational change that occurred was the separation of the central bank powers of the Commonwealth Bank in 1959 and the creation of the Reserve Bank of Australia (RBA)" (Thomson and Abbott 2001, p78).

Other types of financial institutions such as credit unions, finance companies and merchant banks emerged over the years of 1950s, 1960s and 1970s and grew faster than

banks as a result of less regulation in the period after the Second World War. At that time, regulations for building societies and credit unions was compelled by each state government that were more flexible than those set up by the RBA on the banks. As a result, the nonbanks presented a stronger growth than the banks and hence, the importance of the banks reduced as well as their asset share of the financial sector.

During the 1960s and 1970s, due to increase in the number of competitors, the regulatory burden became more intense. To overcome the impact of regulation, the banking sector constructed their finance institutions. In order to reach this objective, banks entailed lending constraints on their borrowers, limiting house mortgages to 80% of the purchase price of property, effectively providing a means of credit allocation at the arbitrary low interest rate ceiling. The banks arranged finance for those borrowers who did not have the remaining 20% of funds through their subsidiary finance companies. Therefore, the regulated banks were able to substitute unregulated (or less regulated) ways of serving their customers. At this stage, banks introduced new products like bank bills, credit lines, floating rate notes, hedging methods and other practices to decrease the tax equivalent cost of regulation (Kane 1981).

The development of these nonbank financial institutions weakened the monetary policy instruments of the RBA during 1960s and 1970s and as a result, the RBA began to depend on the open-market operations more and more. As the secondary market for government securities developed, the open-market activities became more effective by the 1970s. The rising efficiency of open-market operations persuaded policy makers that a more market-based approach was required. By reducing the size of the banking industry's aggregate market share, bank regulators were forced to lighten up or abandon the onerous regulations. To respond to these political pressures, deregulation of the banking system was formed during 1980s. In Australia, bank deregulation commenced in 1981 following the Campbell Report (Thomson and Abbott 2001).

2.2.3 Deregulation

The recommendations of financial system inquiries in the 1980s (the Campbell Report) and early 1990s (the Wallis inquiry) resulted in a transformation of the Australian financial system by deregulation. The current form of the regulatory regime and structure of the present financial system is essentially based on the results and recommendations of these inquiries that have been mostly toward increasing the competitive capacity of financial institutions.

As a result of the interaction between the banks and nonbank financial institutions, the current rules were modified which is known as the deregulation of the Australian banking system. Deregulation has been considered as a special form of regulation through which a limit is assigned without stiffening another limit (Kane 1991). In 1981, the Campbell Inquiry into the Australian banking sector found that the operation and improvement of the financial markets were being deformed and restrained due to the direct controls on banks and therefore, recommended to deregulate the Australian banking system (Australian Financial System Inquiry 1981). The process of deregulation completed by 1986 that floated the currency, eliminated the controls on the capital and interest rates and permitted the foreign banks to enter the Australian banking system. There were still some prudential requisites such as reserve and liquidity requirements that were limited to the assets (expressed in Australian dollar) and balance sheet activities and were commenced for just prudential reasons and were not monetary policy instruments. As suggested by the Campbell Committee, these measures were applicable to banks only and not to other financial institutions. The establishment of this new regulatory system was a response to changing circumstances of the Australian financial markets and was as well influenced by the international environment that was tended to deregulation (Thomson and Abbott 2001).

The recommendations of the financial system inquiries in the 1980s and early 1990s as well as the Wallis Inquiry (the Report of the financial system inquiry) released in March 1997, resulted in a deregulation in the Australian financial system. The structure of the financial sector was established mostly based on the results and recommendations of these inquiries that were mostly in a direction to improve the competitive viability of banks. In such situation, the efficiency of all institutions should be examined and inefficiency must be reduced. Although, many problems associated with competition were eliminated, banking continues to be a highly regulated industry. Deregulation has taken place many years ago. However, the entry and exit of banks, liquidity requisites, capital adequacy and mergers and acquisitions are still regulated. Financial institutions are exposed to the Banking Act (1959), Corporations Act (2001), Trade Practices Act (1974) and the Consumer Credit Code which is somehow contrasting with the objectives of Wallis Inquiry (Pelosi 2008). Better allocation of resources will result in a more efficient banking system that leads to greater profitability, larger amount of funds intermediated, improvement in the price and quality of services and at last, forming a more secure banking system (Pelosi 2008).

2.3 Global Financial Crisis 2007-2009

One of the consequences of financial development is the rising number of the financial crises that if be placed in a longer-term perspective of financial restructuring may bring superior prosperity. More developed economies will financially develop faster and hence, are exposed to volatility and instability sources which are never seen in less developed economies. The financial intermediation that granted the opportunity of divergence of desired saving from desired investment, created the business cycles of the preceding two centuries. Modern macroeconomics was the response to this reform.

Financial crisis of 2007 began with the subprime mortgage in the United States of America and became global in 2008. Rather than inadequately appraised mortgage lending, this crisis was also motivated by poor loans for construction and housing in other countries. This financial crisis is recognized as a sequence of global crises since the 1970s and was the most important one due to the size of the US economy. Although the global financial crises have common roots, because of the severity of the allied US recession, the post-2007 crisis is considered as the exceptional one among the post-1945 crises (Pomfret 2009).

In 2009, the global economy was seriously influenced by this crisis as most of the major industrial economies have been involved and the expected growth rate of emerging markets discontinued by more than half. The current downturn in the global economy is said to be a result of decline in business cycle as well as the effect of the banking and financial crisis in all the major economies of the world (Karunaratne 2010).

2.3.1 The Crisis Outline

Melvin and Taylor (2009) have analyzed the crisis 2007 focusing on the foreign exchange market and divided the crisis into distinctive phases. A significant volatility in the equity markets occurred in July 2007 and afterwards, in the mid August 2007 the currency markets experienced a major slow down in the carry trade (a strategy of purchasing/taking a long position in high interest rate currencies funded by selling/taking a short position in low interest rate currencies) and hence, most of the investors in the currency markets faced enormous losses. To expand this concept, consider short Japanese Yen (JPY) and long Australian and New Zealand dollars (AUD and NZD). Based on the interest rate parity (IRP), a change in the exchange rates will compensate the difference between the interest rates of two currencies. Therefore, JPY (with a low interest rate) should be appreciated compared with NZD. Though, in reality, the low interest rate currency mostly depreciates against the

high interest rate currency rather than appreciates. This type of movement in the exchange rate will cause bigger carry trade profits. The unwinding in the carry trades occur when market is under pressure and usually happened once or twice a year as been observed in the past. The carry trade unwind of August 16, 2007 has been as destructive as the most significant one that occurred in October 1998 subsequent to a Russian bond failure (Melvin and Taylor 2009). The volatility in the equity market started to increase in August 2007 and reached 28% by the middle of the month. The volatility declined during the months of September and October and ended in the November 2007.

In early November 2007, the currency market entered to the second phase of the crisis when the volatility dropped subsequent to the August crisis. However, the volatility rose drastically in the second week of November 2007 (Melvin and Taylor 2009). By the beginning of March, some rumours were spread regarding a vital failure of Bear Stearns and in spite of the efforts of its executives, “clients began to move their business away from Bear Stearns” (Melvin and Taylor 2009, p1321). Both prime brokerage clients and banks providing repo¹ finance to this huge investment bank did so due to their concern about the firm`s bankruptcy and losing their cash. Therefore, the Federal Reserve Bank of New York had to support the Bear Stearns and grant it a short-term loan since Bear Stearns was losing its usual interbank repo sources to supply the short-term funds and might not be able to meet its obligations. By the mid- March, JP Morgan Chase purchased Bear Stearns for \$10 per share. The credit risk highly dropped and the returns to the carry trade were significantly descending before the Bear was disconnected from interbank funding but when the Federal Reserve began to assist the firm and following its takeover by JP Morgan Chase, market concerns

¹ Repo is a repurchase agreement accomplished to raise short-term capital. Through this practice, a bank/financial institution buys securities with the condition that the seller must repurchase the same securities at an agreed price on a certain date.

were relaxed and the returns to the carry trade became positive and credit risk again declined (Melvin and Taylor 2009). Following the above events, people were expecting the financial markets to return to the normal situation and were not aware of “the storm that was lying just ahead” (Melvin and Taylor 2009, p1321).

The most dramatic incident during the crisis was the collapse of Lehman Brothers. The subprime mortgage brought in huge losses for Lehman and consequently, there has been no chance to sell the whole company. Therefore, Lehman bankruptcy was announced by the mid September and resulted in losses on other firms and turmoil never been witnessed. The disruptive failure of this major bank had several facets— the returns to the carry trade notably dropped and an extraordinary risk aversion and deleveraging turned out. In addition, volatility heightened to astonishing levels that were not comparable to the previous peaks through the crisis. In fact, the Lehman bankruptcy put in an exclusively new insight of risk and fear was formed throughout the market about who would be the next to fail.

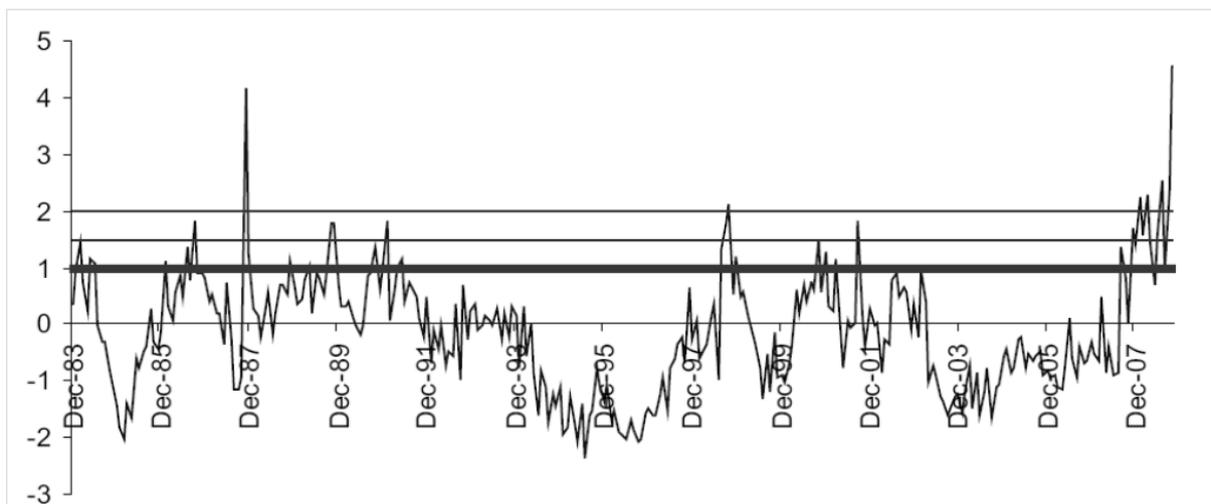
Melvin and Taylor (2009) accomplished a general financial stress index (FSI) to examine “to what extent a global measure of financial stress would have captured or confirmed these effects” (Melvin and Taylor 2009, p1326). In other words, the consequential scored FSI illustrates that “how many standard deviations the FSI is away from its time-varying mean” (Melvin and Taylor 2009, p1327).

To compile the FSI variable, the market-based indicators were utilized to restrain the fundamental features of a financial crisis. Among the crisis features one can mention huge movements in asset prices, an quick increase in risk and uncertainty, rapid shifts in liquidity and a considerable decline in banking system health indicators as well as three banking indicators (the beta of banking sector shocks, the spread between interbank rates and the yield on Treasury Bills and the slope of the yield curve), three of the securities market (corporate bond spreads, stock market returns and time-varying stock return volatility) and an indicator

of the foreign exchange market (a time-varying measure of real exchange volatility for each country) (Melvin and Taylor 2009).

Based on the study conducted by the International Monetary Fund (IMF), seventeen developed countries have been investigated through the FSI analysis for the period starts from December 1983 to October 2008. These countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, the U.K. and the USA Figure 2.1 presents the scored global FSI achieved through the study of Melvin and Taylor (2009).

Figure 2.1: The Scored Global FSI



Source: Melvin and Taylor (2009), p1328

The above graph shows that during the foremost crises of the past twenty years, the global FSI passes through the threshold of the two-standard deviation beyond the mean. Over the financial crisis 2007, the global FSI breaks the standard deviation thresholds in January and later in March 2008 corresponding to the failure of Bear Stearns. The global FSI experiences a drop (to about 0.7 standard deviations above the mean) in May 2008 but remains more than one standard deviation beyond the mean during the investigated period. Following the collapse of Lehman Brothers in September, the global FSI rose to more than four standard deviations from the mean. High leveraging and excessive risk-taking have been

the common characteristics of numerous financial crises since the 1970s. However, the financial crisis of 2007 influenced major organizations in the US as the world's largest economy while it had independent roots in other economies (Melvin and Taylor 2009). Australia confronted disputes as it is an open economy influenced by the worldwide depression. In addition, there was a bubble asset in the Australian economy that had burst (Pomfert 2009).

2.3.2 Australia and the Crisis

Among Organization for Economic Cooperation and Development (OECD) countries, Australia has experienced the largest number of deregulations since 1983. The main remarkable result of these reforms was the continuous economic growth over the decade and a half proceeding to 2008. Pomfert (2009) has acknowledged that "On a material level (wealth, incomes and the range of goods and services on which to spend this wealth), the majority of Australians benefited from the reforms" (Pomfert 2009, p256).

It is noteworthy that the majority of banks all over the world were not insolvent during the middle of the crash of financial institutions and the well-managed banks have escaped from the effect of the US investment banks or Northern Rock. In fact, some banks purchased assets at fire-sale prices from troubled banks and flourished as a result. It is argued that to predict the good and bad banks is not easy because of the complexity of some traded assets, however, so far the Australian financial sector has avoided foremost casualties (Pomfert 2009).

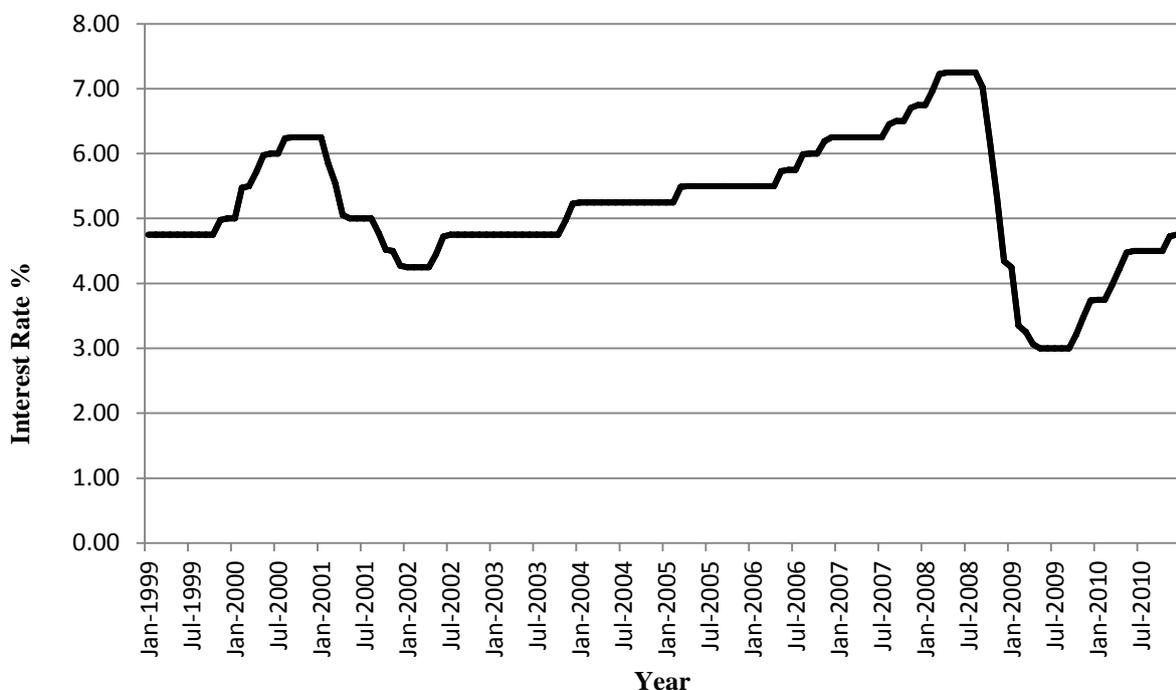
Since 1970s, there have been numerous financial crises. Deregulation and innovations that facilitated risk-taking in financial systems including deposit insurance strengthened the easy credit. Interest rate has been used by policy makers as a device to sustain interior

balance between inflation and unemployment. However, the role of interest rate as the price of capital and a support whilst the existence of asset bubbles has been ignored.

Figure 2.2 presents the trend of interest rate in Australian financial market since 1999 to the end of 2010:

The figure presents a considerable growth in the interest rate of money market in Australia during the financial crisis 2007. There is a sharp drop in the rate of interest by the second half of July, 2008 from above 7% to around 3%. The interest rate remained at this low level till the end of 2009 and starts to rise again. Interest rate reached to roughly 5%.

Figure 2.2: The Trend of Interest Rate in the Australian Money Market (%)



Source: Reserve Bank of Australia, accessed 12/5/2011

Excess of domestic investment to domestic savings is a fundamental feature of the Australian economy. The international borrowings by the Australian banks have considerably influenced the account deficit which implies the crucial role of banks in financing the country's excess of investment over savings (Henry 2010).

Accurate supervision of the Australian banking sector resulted in a stronger position of the Australian banks after the financial crisis 2007 in comparison with the banking systems of other countries (Pomfret 2009). However, as Henry (2010) pointed out after the crisis, the Australian banking system is facing serious structural challenges. These are as follows:

- The capacity of the banking system to raise fund on cost competitive conditions in a situation that the instability of offshore markets (especially in Europe) are continuously increasing. In addition, the improvement of the domestic securitization market is pacified following a rigorous interference throughout the crisis.
- As a result of the crisis, the banking industry has become more concentrated. As a result, competitive banking environment for the customers should be encouraged specifically at the retail level; and
- The G20's international regulatory response to the crisis must be applied while the Australian economy avoids unhelpful forces on credit flows (Henry 2010).

On the other hand, Kriesler (2009) argued that in spite of low rates of interest, investments declined during the crisis. He believes that the nature of the crisis resulted in “the fail of confidence within the financial sector. The reason was that the financial institutions were seriously hesitated to lend since they could not distinguish the secure and reliable borrowers anymore. To finance domestic investments, Australia has relied importantly on international capital which was also minimized due the common hesitation of financial institutions to lend (Kriesler 2009). In Australia, three important investment banks which were Lehman Brothers Australia, Opes Prime and Storm Financial, failed through the financial crisis.

Lehman Brothers purchased a local funds manager, Grange Securities in early 2007 and rebranded it as Lehman Brothers Australia. Grange Securities started to trade toxic assets that reinforced the failure of the parent company in 2008. More than 40 municipal councils

invested almost \$625 million in Collateralized Debt Obligation packages which were sold easily at satisfying rates. This type of instruments was connected to “Credit Default Swaps, whose returns were dependent on the health of American corporate and mortgage markets” (Jones 2009, p95). In fact, all these complicated actions have been arranged by the administrators of Lehman Brothers Australia; they had falsified the company’s legal documents in May 2009 and the foremost creditors and the Australian operations personnel pulled out almost 100 percent of their claims. However, the dependent creditors who were the councils just received around 2 to 13 percent of their investments and were stopped operating (Jones 2009).

The ANZ has lent hundreds of huge loans to stock broking firms since 2003. Opes Prime was the most important one who borrowed \$650 million from the ANZ. Opes was aimed at raise of stock market which was its intrinsic fault because many of the listed stocks in the share portfolios did not make revenue. In 2008, the ANZ advanced Opes since it was failing and offered considerable discounts to its clients’ shares. The collapse of share prices that caused the margin calls wounded the Opes Prime.

Storm Financial has been a financial advisory institution used to sell “a one product package- the use of debt to speculate on the permanent upward movement of share prices” (Jones 2009, p97). The package was a home mortgage loan accompanied by a margin loan to be invested in an indexed fund. Storm has assigned this indexed fund which included “the loan quantum to be further enhanced if the nominal share value increased or if any slack appeared in the loan to valuation ratio” (Jones 2009, p97). Retirees, low income unemployed or disability pensioners constituted the customers of Storms; they were not properly informed about their investment. In January 2009, Storm Financial broke down due to two main reasons. Many independent advisory institutions came under the control of Storm between 2003 and 2007 and hence, the organization has been operating under an extremely centralized

management. The second reason was the close relationship between Storm and the Commonwealth Bank since 1994. This expansion offered loans to Storm clients and assigned a distinctive office outlet to serve this organization. In addition, the annual sales targets of Storm were increased by the Commonwealth. However, the share market started to fall by the end of September 2008 that resulted in various unexpected events lead to the Storm failure.

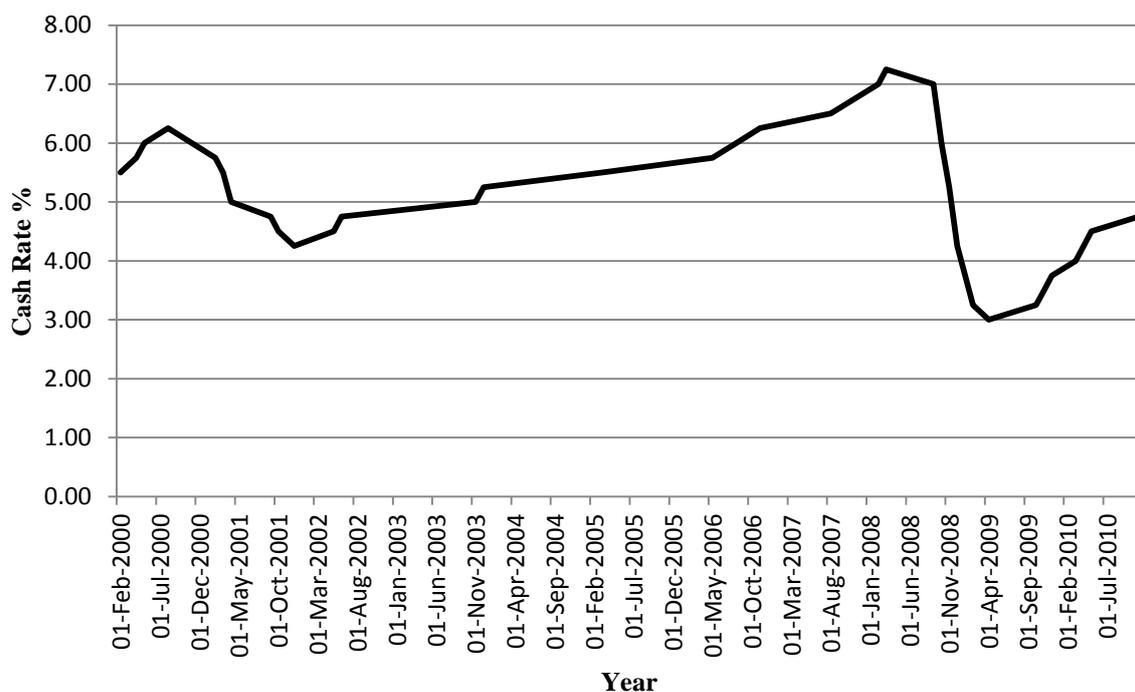
Besides the above events, several other large and important financial and investment organizations have been also crashed during the crisis in Australia. The most important collapses have been occurred in Timbercorp, Great Southern, City Pacific Limited, the Gold Coast-based large scale MFS, Chartwell Enterprise, ABC Learning, Babcock and Brown and Allco Finance. It is worth mentioning that as indicated through the above examples, some major and regional banks have been involved with the collapse of these organizations such as Commonwealth Bank Australia, Bendigo and Adelaide bank and Macquarie bank as the funds suppliers or investors. In addition, two most significant takeovers have been occurred in the Australian banking sector; the takeover of St. George by West Pac as well as the takeover of Bank West by Commonwealth bank which were approved by ACCC by the end of 2008.

Ultimately, the concentration of authority in the Australian banking sector has been the most terrible consequence of the crisis. Jones (2009) stated that “the dominance of the big four banks in Australia is without precedent” (Jones 2009, p104). These banks came into existence as trading banks and now they are called allfinanz institutions involving in investment banking, insurance, wealth management, stock broking who have monopolized the issue of recent mortgage issuance since 2009. It is said that these banks have got the price power because of the structural changes. While, small and medium sized firms have hardly had access to credit and credit pricing, the big four have been exploiting controlled pricing process that determines the desired rate of profit or growth as well as the price of products.

The price is paid by the rest of the economy which relied highly on the four major banks (Jones 2009).

Throughout the crisis, some of the Australian regulatory agencies found diverse challenges. As a significant instance, Jones (2009) argues that “the Reserve Bank (RBA) has been reduced to a single policy instrument- the overnight cash rate” (Jones 2009, p107). Between May 2002 and March 2008, the Reserve Bank has increased the cash rate by 0.25 percent. The most persistent enhancements occurred during a period of three years from March 2005 from the rate of 5.25 percent to 7.25 percent. This trend has been clearly illustrated via the following graph:

Figure 2.3: The Cash Rate Trend Determined by the RBA (%)



Source: Reserve Bank of Australia, accessed 12/5/2011

Although, these increases have been fairly moderate comparing to the trend of cash rate in 1980s, the cash rate was not desirable and asset price inflation has existed in Australia.

In addition, variation of the cash rate may make asset bubbles worse posing negative effects on them.

The other failure has taken place in the Australian Prudential and Regulatory Authority (APRA) which manages Bank of International Settlements standards on prudential capital holdings. The inefficiency of APRA throughout the crisis has been due to a great deal of the substantial capital developed by the four major banks. The intervention of APRA in bank practices declined and it was only officially supervising bank bad debts. In fact, APRA failed basically relating to wholesale debt and equity/ debt hybrid capital² of the banks (Jones 2009). At June 2009, only 60 percent of the liabilities of Australian-based banks were related to the national operations including 15.2 percent liabilities attributable to the operations of non-residents. This debt raised on the customer deposits has been recognized as the expected outcome of the alteration of the four major banks from trading banks to allfinanz organizations.

2.4 Summary

The rapid economic growth of mid-nineteenth century in Australia resulted in the disapproval of the rigid regulations posed by the Great Britain on banks. Hence, Australian banks were operating in an extensive unregulated environment through the second half of the nineteenth century and were free to act in different ways until 1911 when the Central Bank came into existence.

Later, the regulatory regime established by the emergence of the 1930s recession and it was strengthened over the decades preceding to the Banking Act of 1945. Following the recommendations of the Campbell Report during the 1980s and the Wallis inquiry over

² Hybrid Capital is a type of debt containing the characteristics of both debt and equity and could be applied as a substitution for equity. Preference shares are the example of these instruments.

1990s, the Australian financial system turned into a deregulated system. It has been argued that the present constitution of today's financial system is on the basis of the results and recommendations of these inquiries. However, there are still some regulations on the banks entry and exit, liquidity requisites, capital adequacy and mergers and acquisitions.

Following the US subprime mortgage, the global financial crisis 2007-2009 occurred. Different stages of the crisis including the collapses of Bear Stearns and Lehman Brothers have been reviewed through the chapter. The APR (Australian Prudential Authority) has affirmed that facing the financial crisis, the Australian banks have appeared to be stronger comparing to the banking sectors of other countries because of its powerful management. However, there are some challenges existing in the Australian banking sector which are mentioned as the rising capacity of the banking industry, the increased concentration of the banking system and the application of the G20's international regulatory response to the crisis (Henry 2010). In addition, some important takeovers have been taken place between the Australian banks.

The major failures have been occurred in the Australian financial system some of which are reviewed through the present chapter such as Lehman Brothers Australia, Opes Prime and Storm Financial, the RBA and the APRA.

The following chapter will provide an overview of the relevant literature on the efficiency of the financial institutions using Data Envelopment Analysis (DEA) and the productivity changes measured by the Malmquist indices. The studies examined will be classified into the international and national (Australian) DEA studies. The chapter will also appraise the relevant studies on the effect of global financial crises.

Chapter 3 : Literature Review

3.1 Introduction

The previous chapter provides an overview on the Australian banking industry since the 1840s. The situation of Australian banks has been investigated during the era of full regulation and the deregulation period. The financial crisis 2007 has been explicated from different aspects since the beginning. Different phases throughout the crisis have been reviewed and the impact of the two peaks of the crisis- the collapse of Bear Stearns and Lehman Brothers- are analyzed. The trend of the interest rate in Australia over a period of 10 years has also been presented to clarify the effect of the global downturn on the Australian financial market.

The purpose of the present chapter is to investigate the national and international literature on the efficiency and productivity of the financial institutions applying the Data Envelopment Analysis (DEA). A literature on the productivity change employing the Malmquist index will be also provided along with citing the empirical results that would be valuable to comprehend the study.

The relevant literature is reviewed under five sections. Section 3.2 reviews the outline of efficiency studies on the financial institutions. Section 3.3 provides an overview of the international DEA studies to evaluate the efficiency and productivity of financial institutions. The DEA studies conducted to analyze the efficiency of the Australian banks and financial institutions have been summarized in Section 3.4. Section 3.5 reviews the studies accomplished to assess the productivity change of the financial institutions by employing the Malmquist indices followed by a brief literature on the global financial crisis through Section 3.6. Lastly, Section 3.7 summarizes the chapter.

3.2 Review of Efficiency Studies

Berger and Humphrey (1997) reviewed 130 studies about the financial institutions of 21 countries applying parametric (TFA, DFA and SFA) and nonparametric efficiency techniques (DEA and FDH) and provided a broad international literature review on the efficiency of financial institutions. Based on this survey, 75 percent of the efficiency studies examined the US financial institutions, 20 percent studied financial institutions of other developed countries (not including Australia) and only 5 percent investigated the efficiency of financial institutions in a few developing countries. Berger and Humphrey (1997) found that through these studies, depository financial institutions (banks, S & Ls³, credit unions) experience an average efficiency of about 77 percent. They divided the main results of these studies into three extensive categories based on the principal contribution of each study:

1. governmental policy implications,
2. dealing with the general research issues relating to financial institutions, and
3. to improve their managerial performance.

They concluded that the nonparametric approaches usually yield a bit lower mean efficiency estimates and seem to have larger dispersion than the parametric methods outcomes (Berger and Humphrey 1997).

DEA has been increasingly applied to analyze the efficiency of financial institutions over the past few decades. Emrouznejad et al. (2008) point out more than 4000 studies published as journal articles or book chapters by 2500 different authors. Sherman and Gold (1985) were the first to apply DEA to examine the efficiency of 14 branches of a US savings bank. DEA is a method of efficiency measurement by analysis of homogenous Decision Making Units (DMUs) in a particular sample. The best practice in the sample will be

³ Savings and loans associations (S & Ls) are a sort of financial institutions initially created to accept savings from private investors and to offer home mortgage services to the public.

recognized and every DMU will be compared with that to enlighten the efficient and inefficient firms (Sathye, 2001). DMUs on the efficient frontier are the best practice organizations and score 1 DMUs and DMUs under the efficient frontier are relatively inefficient and between 0 and 1.

Malmquist indices are applied to measure the productivity of organizations and evaluate the effect of technological change on their efficiency. The Malmquist total factor productivity index will be identified by the means of distance functions. The total factor productivity indexes will be decomposed into efficiency change and technical change factors.

The present study will summarize the relevant literature considering the international and national (Australian) studies, the studies on the efficiency determinants of financial institutions and a brief literature on different aspects of the Global Financial Crisis 2007.

3.3 International DEA Studies

As mentioned above, Sherman and Gold (1985) applied the DEA methodology to measure the efficiency of 14 branches of a US savings bank. To identify outputs, they classified 17 most common bank transactions into 4 categories and set the number of transactions as the outputs. The specified inputs were labor, office space and supply costs. Based on the results, 6 branches out of 14 were inefficient. The average efficiency score of this study has been found to be 96 percent.

Rangan et al. (1988) proceeded the unit of assessment from branches to consolidated financial institutions and examined the efficiency of 215 US banks using DEA. They employed the intermediation approach and labor, capital and purchased funds were the selected inputs against 5 outputs which were real estate loans, commercial and industrial loans, consumer loans, demand deposits and time and saving deposits. They concluded that by applying only 70 percent (mean efficiency score = 70%) of the actually employed inputs,

banks could generate the same level of outputs. Pure technical inefficiency and scale inefficiency have been also examined through this study and the results indicated that the sources of inefficiency in banks were pure technical and scale inefficiencies of the banks were comparatively small.

Favero and Papi (1995) investigated the technical and scale efficiency of a cross sectional sample of 174 Italian banks in 1991 by using input-oriented DEA model. They applied intermediation and asset approach to select inputs and outputs. Labor (the number of full-time employees), capital, loanable funds (including current accounts and saving deposits) and a measure of financial capital available for investment are the inputs under the asset approach and loans, investment in securities and bonds, and non-interest income are the outputs. The average efficiency scores obtained under this approach were 79 percent (CRS) and 84 percent (VRS). Under intermediation approach they changed the mixture of inputs and outputs by transferring current accounts and saving deposits from inputs to outputs and obtained average efficiency scores of 88 percent (CRS) and 91 percent (VRS). The authors examined the determinants of bank efficiency by applying regression analysis on the bank specific measure inefficiency. The empirical results presented that the productivity specialization, bank size and to a smaller extent, location can provide the best explanation for the efficiency.

Taylor et al. (1997) employed DEA to measure the efficiency of 13 Mexican commercial banks over the period from 1989 to 1991 (a panel data). Total deposits and total non-interest expense have been specified as inputs and total income was the single output of the study. They found an efficiency score of 0.72 for an average bank and that the efficiency of the banks could be raised corresponding to the competitors` efficiencies by altering their input mix over time. Comparing the two different methods of measuring efficiency, the ROA (Return on Assets) and ROE (Return on Equity) ratios were found weakly correlated with

technical efficiency but this weak positive relationship does not indicate that DEA efficient banks were essentially the most profitable ones.

Drake (2001) estimated the relative efficiencies of the major UK banks using a panel data sample between 1984 and 1995 by the DEA methodology. He as well, employed the Malmquist productivity indices to analyze the productivity change in the UK banking industry over this period. To investigate the banks efficiencies, the intermediation approach applied by specifying fixed assets, number of employees and deposits as inputs and loans, liquid assets along with investments and other income as outputs; fixed assets and number of employees are inputs under production approach and outputs are loans, liquid assets along with investments, other income and deposits. The author estimated four models to assess the relationship between the institutional size and its efficiency (Model 1), the effect of bad debt as an additional input (Model 1a), a modified model to production approach (Model 2) and considering bad debts as an additional input in Model 2 (Model 2a). The efficiency scores obtained through their analysis are 87 percent for Model 1, 88 percent for Model 1a, 56 percent for Model 2 and 57 percent for Model 2a. The empirical results of presented an obvious increasing return to scale for the smaller banks in compare with larger banks. However, larger banks were found more efficient than smaller banks. The UK banks included in the sample exhibited a positive productivity growth as signified by the Malmquist indices.

Das and Ghosh (2006) assessed the efficiency of the Indian commercial banks during the post reform period from 1992 to 2002 applying an input-oriented DEA model. They used three approaches to combine the banks` inputs and outputs which are intermediation approach (inputs: demand deposits, saving deposits, fixed deposit, capital related operating expense and labor; outputs: advances and investments), value-added approach (inputs: labor, capital related operating expense and interest expenses; outputs: advances, investments, demand deposits, saving deposits and fixed deposit) and production approach (inputs: interest

expenses, employee expenses and capital related operating expense; outputs: interest income, non-interest income). The average efficiency scores obtained in this study are 78 percent under intermediation approach, 91 percent under value-added approach and 74 percent under operating approach. They recognized reasonably well performance for the medium-sized public banks with higher levels of technical efficiency. However, some Indian banks were highly inefficient over the liberalization period which may have been caused by the underutilization of valuable resources as well as the scale of operations. The banks have been found to be more efficient under value-added approach than the production and intermediation approaches over the post reform era. They concluded that the trend of efficiency and technological change could be the response of the industry to the deregulation forces.

Sufian and Habibullah (2010) used input-oriented DEA methodology to assess the efficiency of Thai banks during the post-Asian financial crisis period, 1999-2008, through which important reforms occurred in the banking sector of Thailand. They argued that interpreting random errors as inefficiency by DEA is a disadvantage of this method and hence, applied an ordinary least square (OLS) regression to achieve reliable estimators of the regression coefficients. The specified inputs in the study are total deposits, fixed assets and labor and the outputs are total loans, investment and non-interest income and found the average efficiency score of 87 percent. The results presented a rise in the efficiency of Thai banks over the period of the study; small banks were found to be the most efficient and medium-sized banks were the least efficient among the sector. The authors attributed the higher efficiency of domestic banks in compare with the foreign banks to the higher level of pure technical efficiency and found that the source of inefficiency has been essentially from scale inefficiency rather than pure technical inefficiency. They finally concluded that the Asian financial crisis had negatively affected the efficiency of Thai banking industry.

The DEA methodology and the way of inputs and outputs specification through the above literature are of a great value in the present thesis. As it is observed, the methodology of most of these studies is input-oriented DEA that will be utilized in this study. Table 3.1 in pages 37-40 presents a summary of international literature on DEA methodology.

3.4 Australian DEA Studies

Avkiran (1999b) examined the efficiency of a sample of 16-19 Australian trading banks throughout the deregulated period over 1986-1995. The impact of mergers on the banking efficiency was also evaluated by comparing the efficiency scores before and after a merger. The author assumed constant returns to scale and input minimization modelling and two combinations of inputs and outputs addressed as Model A (inputs: interest expense and non-interest expense; outputs: net interest income and non-interest income) and Model B (inputs: deposits and staff numbers; outputs: net loans and non-interest income). The average efficiency scores of these models are:

- Model A: min of 78.99% to the max. of 91.48%
- Model B: min. Of 37.23% to the max. of 79.43%

The empirical results presented an improvement in the overall operating efficiency of the banking industry during the post-deregulation period. Based on the outcomes of the studies of the merger cases, the author concluded that acquiring banks are more efficient than the target banks.

Table 3.1: International DEA Studies

Author	Country	Data	Method	Mix of Inputs and Outputs	Input/output Orientation	Average Efficiency Estimates	Main Results
Sherman and Gold (1985)	USA	14 branches of a savings bank; Year 1982	DEA	Inputs: labor, office space and supply costs; Outputs: the number of transactions		96%	<ul style="list-style-type: none"> • Poor management were presented in 4 inefficient branches • A highly profitable branch has been inefficient • 2 of the inefficient branches found to have the lowest number of transactions
Rangan et al. (1988)	USA	215 banks; Year 1986	Intermediation approach to DEA	Inputs: labor, capital and purchased funds; Outputs: real estate loans, commercial and industrial loans, consumer loans, demand deposits and time and saving deposits		70%	<ul style="list-style-type: none"> • The banks were operating at a constant returns to scale • The major part of the inefficiency is caused by pure technical efficiency (wasting resources) • Bank size presented positive effect on the technical efficiency and product diversity had negative effect

Favero and Papi (1995)	Italy	174 banks; Year 1991	1. Asset and 2. Intermediation approaches to DEA	1. Inputs: labor and a measure of financial capital available for investment capital, loanable funds Outputs: loans, investment in securities and bonds, and non-interest income 2. Inputs: Labor and a measure of financial capital available for investment capital Outputs: loanable funds , loans, investment in securities and bonds, and non-interest income	Input oriented	Asset approach: 79% (CRS), 84% (VRS); Intermediation approach: 88% (CRS), 91% (VRS)	<ul style="list-style-type: none"> • Both technical and allocative inefficiency were existed • The productive specialisation , size and location have been found as the determinants of inefficiency
Taylor et al. (1997)	Mexico	13 commercial banks; Period of 1989-1991	DEA	Inputs: total deposits and total non-interest expense Output: total income		72%	<ul style="list-style-type: none"> • 6 to 8 banks were found to be efficient each year • Banks were more efficient with ARs • “Banks with high minimum profit ratios have relatively less downside risk” (Taylor et al. 1997, p360)
Drake (2001)	UK	Major banks; Period of 1984-1995	1. Intermediation and 2. production approach to DEA	1. Inputs: fixed assets, number of employees and deposits Outputs: loans, liquid assets, investments and other income; 2. Inputs: fixed assets and number of employees Outputs: loans, liquid assets along with investments, other income and deposits		Model1: 87% Model 1a: 88% Model2: 56% Model 2a: 57%	<ul style="list-style-type: none"> • Pure technical efficiency found to be larger under production approach rather than the intermediation approach • Small banks presented lower X-efficiency than larger banks • Technical inefficiencies were more significant than scale inefficiencies

Das and Ghosh (2006)	India	Banks; Period of 1992-2002	1. Intermediation, 2. Value-added and 3. Production approaches to DEA	1. Inputs: demand deposits, saving deposits, fixed deposit, capital related operating expense and labor Outputs: advances and investments 2. Inputs: labor, capital related operating expense and interest expenses Outputs: advances, investments, demand deposits, saving deposits and fixed deposit 3. Inputs: interest expenses, employee expenses and capital related operating expense Outputs: interest income, non-interest income	Input oriented	Intermediation approach: 78%, Value-added approach: 91%, Operating approach: 74%	<ul style="list-style-type: none"> • Technical efficiency of banks were higher under value-added approach than the intermediation approach • Different ownership status, level of non-performing loans, size, asset quality, management and other determinants resulted in differences in the efficiency performance of banks • Regulatory changes might cause rough effects on different- sized banks
Sufian and Habibullah (2010)	Thailand	30 Banks; Period of 1999-2008	DEA and OLS	Inputs: total deposits, fixed assets and labor Outputs: total loans, investment and non-interest income	Input oriented	87%	<ul style="list-style-type: none"> • Domestic banks exhibited higher level of efficiency than the foreign banks • Small banks have been found to be more scale efficient than larger banks • Thai banks have been working at a non-optimal operations` scale

Sathye (2001) applied input-oriented DEA to assess the overall, technical and allocative efficiency of Australian banks, ANOVA to compare it with the foreign banks operating in Australia and the least square regression to find out the factors influencing efficiency. The sample consisted of 29 banks out of 32 (domestic and foreign) banks over the year of 1996. To specify the inputs and outputs, the author selected intermediation approach based on which the inputs were opted as labor, capital and loanable funds against loans and demand deposits as outputs and found the average efficiency score of 58 percent. The empirical results presented that the efficiency of Australian banks is lower than the world mean efficiency and determined the influential factors on efficiency. Based on these results, the author attributed the inefficiency of Australian banks to the technical inefficiency (waste of inputs) rather than allocative inefficiency (to choose an incorrect inputs mix). Finally, the study found that the Australian banks were more efficient than foreign-owned banks. Through the study, Sathye (2001) emphasized that the indication of the sources of inefficiency by the DEA method helps banks with strategic planning.

Following a similar scope to the study of Drake (2001) on the UK banking sector, Neal (2004) extended the two earlier studies on the efficiency of the Australian banks accomplished by Avkiran (1999) and Sathye (2001). Neal (2004) applied DEA methodology to assess the x-efficiency (technical and allocative efficiency) and Malmquist productivity indices to analyze the productivity change of the Australian banks over the period of 1995 and 1999. Both input- and output-oriented approaches are applied. Two inputs (number of bank branches and loanable funds) and three outputs (loans and advances, demand deposits and other operating income) are specified for each bank based on intermediation approach and the average efficiency of the analysis was found to be 77 percent. The empirical results illustrated a higher level of allocative efficiency for the banks rather than technical efficiency. In addition, the regional banks were found to be technically and allocatively inefficient while

the four large national banks were located on the best practice frontier for most years of the sample. The Malmquist indices confirmed an important growth in the productivity of the Australian banking sector over the studied era and again the regional banks are recognized as the worst performers. The author concluded that low efficiency and low productive growth of the regional banks led them to merge with the large or other regional banks.

Sturm and Williams (2004) investigated the impact of foreign bank entry and deregulation on the efficiency of Australian banks employing the DEA methodology and compared the efficiency of foreign banks with the Australian banks using input-oriented Malmquist indices over the period of 1988 to 2001. Labor, capital and deposits have been applied as inputs to create loans and off-balance sheet items as outputs. In the study, four alternative models specified the inputs and outputs and since the results of efficiency estimations are sensitive to the design of inputs and outputs (Berger, Hunter and Timme 1993), the obtained results of each model are presented below:

In model 1, inputs are employee numbers, deposits and borrowed funds and equity capital and outputs are loans advances and other receivables and “off-balance sheet activity measured as commitments and contingent liabilities” (Sturm and Williams 2004, p1783). This model examines 15 banks over six years which is the largest sample in the study and found the average efficiency score of 81 percent. Model 1a applied the same input and output specification as the model 1 except that the loans are divided into two groups which are loans advances and other receivables excluding housing loans and the housing loans. The average efficiency score of the banks studied under this model was found to be 86 percent. The focus of this model is on the retail activities of banks. Concerning about the impact of wholesale activities, model 1b employs an additional output which is investments and the obtained average efficiency was 87 percent. Model 2 is a revenue focused model that specifies inputs as interest expenses and non-interest expenses and outputs are net interest income and non-

interest income. The average efficiency under this model was 88 percent. With regards to the important role of the variety of bank types in the efficiency improvements, the DEA empirical results presented an increase in the efficiency of the Australian banks during the post-deregulation era. The authors concluded that the early 1990s recession brought in a discrete shift in the course of efficiency changes.

Kirkwood and Nahm (2006) employed input-oriented DEA methodology to assess the cost efficiency of the 10 Australian banks (listed on the Australian Stock Exchange) from 1995 to 2002. They introduced two DEA models specifying different mix of inputs and outputs. Under Model A, number of full-time equivalent employees (banking service efficiency), property, plant and equipment (net of accumulated depreciation) and interest-bearing liabilities are the inputs and interest bearing assets and non-interest income are the outputs specified to find the efficiency of banking services. Model B consists of the same inputs mix as Model A and profit before tax and abnormal items are the outputs specified to analyze the profit efficiency of banks. Results obtained from Model A indicated that the banks performance improved due to higher level of allocative efficiency rather than technical efficiency and the average efficiency score has been found to be 97 percent. On the other hand, under Model B, allocative efficiency has been decreased and banks have been less efficient comparing to the efficiency results of Model A. The average efficiency score obtained under this model was 80 percent. The overall outcomes of this study presented that the efficiency of banking services and profit efficiency of the major banks improved whereas, the regional banks exhibited a slight change in the banking services efficiency and a decline in the profit production efficiency. The authors concluded that the changes in the efficiency of the banks in the sample are reflected in stock returns.

Paul and Kourouche (2008) used an input-oriented DEA method to evaluate the technical efficiency of the 10 Australian banks over the period of 1997 to 2005, the post-

Wallis period. Following intermediation approach, interest expense and non-interest expense are defined as the inputs and net interest income and non-interest income as the outputs of the study. Based on the empirical results, the level of technical efficiency varied across the banks and over the years. The average efficiency score obtained from this analysis was found to be 97 percent. Paul and Kourouche (2008) concluded that “the National Australia Bank, Commonwealth Bank and Macquarie Bank are found to be technically efficient, whereas Adelaide Bank, the Bank of Queensland and Westpac Bank are found to be prominently inefficient” (Paul and Kourouche 2008, p.260). The results indicated that technical efficiency of the small banks is the lowest and also has decreased over time caused by the decline in scale efficiency. The efficiency of the medium-sized banks considerably improved more than that of small and large banks.

Applying the input-oriented DEA methodology, Wu (2008) evaluated the efficiency consequences of seventeen mergers and acquisitions in the Australian banking industry referring to the four pillars policy (that prevents mergers among the four major banks). He employed intermediation approach and specified labor, physical capital and loanable funds as inputs and net loans, investment and number of branches as outputs. In addition, a second-stage regression was utilized to analyze the efficiency performance of the banks after merger. The author found that “the acquiring banks are larger, more aggressive and less efficient than the target banks. The major source of inefficiency is scale inefficiency” (Wu 2008, p154). The acquiring banks were found to be 79 percent efficient on average and the average efficiency score of the target banks was found to be 91 percent. The four major banks were found to function beyond the range of diseconomies of scale and if they merge together, the efficiency of consolidated banks and whole banking sector will be inevitably declined. The empirical results presented that the four major banks operate over a sequence of diseconomies of scale and hence, mergers among them will certainly reduce efficiency in the

consolidated banks as well as whole banking system. The regression results also confirmed the negative effects of mergers on the banks efficiency implying that “post-merger efficiency is positively related to the merging entities’ efficiencies prior to merger” (Wu 2008, p154).

The DEA method of efficiency measurement and the way of specification of inputs and outputs applied through the international and Australian studies on banking sectors will provide a basis for the methodology of the present study to answer the research questions 1, 4 and 5. A summary of the above literature is presented in pages 46-48 in Table 3.2.

3.5 Productivity and Efficiency Studies

Another indicator of the performance of the financial institutions is the change of productivity over time. Various studies have applied the Malmquist index to examine the productivity change of these types of organizations. For the first time, the study of Caves et al (1982) commenced the use of the Malmquist index. Subsequently, Fare et al. (1989, 1994), applied the Malmquist index to decompose the productivity change into efficiency and technical changes. The Malmquist index was employed to evaluate the productivity change of the banking industry for the first time through the study of Berg et al. (1992). Some relevant literature of this issue is explicated through this section.

Table 3.2: Australian DEA Studies

Author	Data	Method	Mix of Inputs and Outputs	Input/ Output Orientation	Average Efficiency Estimates	Main Results
Avkiran (1999)	Trading banks; Period of 1986-1995	Two models of DEA	1.Inputs: interest expense and non-interest expense Outputs: net interest income and non-interest income 2.Inputs: deposits and staff numbers Outputs: net loans and non-interest income	Input- oriented	Model A: min of 78.99% to the max. of 91.48%; Model B: min. Of 37.23% to the max. of 79.43%	<ul style="list-style-type: none"> • Australian banks exhibited more efficiency during the post-deregulation period • Investigation of merger cases presented that acquiring banks have been more efficient than target banks • Half of the studied cases revealed a positive correlation between the change in market share and change in overall efficiency
Sathye (2001)	29 banks; Year 1996	Intermediation approach to DEA	Inputs: labour, capital and loanable funds Outputs: loans and demand deposits	Input- oriented	58%	<ul style="list-style-type: none"> • Australian banks were found to be less efficient than the world mean efficiency • The removal of four-pillar policy would lead in a lower level of efficiency in banks
Neal (2004)	12 banks; Period of 1995-1999	Intermediation approach to DEA	Inputs: number of bank branches and loanable funds Outputs: loans and advances, demand deposits and other operating income	Input- and Output-oriented	77%	<ul style="list-style-type: none"> • Banks found to be more allocative efficient than technically efficient • The four major banks have been the best-practiced for most years of the study

Author	Data	Method	Mix of Inputs and Outputs	Input/ Output Orientation	Average Efficiency Estimates	Main Results
Sturm and Williams (2004)	20 domestic banks and 19 foreign banks; Period of 1988-2001	Four models of DEA	1.Inputs: employee numbers, deposits and borrowed funds and equity capital Outputs: loans advances and other receivables, commitments and contingent liabilities 2.Inputs:the same as Model 1 Outputs: loans advances and other receivables minus housing loans, commitments and contingent liabilities and housing loans 3.Inputs:the same as Model 1 Outputs: loans advances and other receivables minus housing loans, commitments and contingent liabilities, housing loans and investments 4.Inputs: interest expenses and non-interest expenses Outputs: net interest income and non-interest income	Input- oriented	Model 1: 81%; Model 1a:86%; Model 1b: 87%; Model 2: 88%	<ul style="list-style-type: none"> • Scale inefficiency were found to be the main cause of technical inefficiency • The four major banks exhibited higher pure technical inefficiency and lower scale inefficiency • Foreign banks presented higher technical efficiency (as a result of higher scale efficiency) than the domestic banks
Kirkwood and Nahm (2006)	10 banks listed on the Australian Stock Exchange; Period of 1995-2002	Two models of DEA	1.Inputs: interest-bearing liabilities, property, plant and equipment, number of full-time equivalent employees Outputs: interest bearing assets and non-interest income 2.Inputs:the same as the first model Outputs: profit before tax	Input- oriented	Model A: 97% Model B: 80%	<ul style="list-style-type: none"> • Improvements have been presented in banking services and profit efficiencies of the major banks • Banking service efficiency remained unchanged for the regional banks • Revenue efficiency raised for the major banks and declined for the regional banks

Author	Data	Method	Mix of Inputs and Outputs	Input/ Output Orientation	Average Efficiency Estimates	Main Results
Paul and Kourouche (2008)	10 Australian banks; Period of 1997-2005	Intermediation approach to DEA	Inputs: Interest expense and non-interest expense Outputs: net interest income and non-interest income	Input- oriented	97%	<ul style="list-style-type: none"> • Technical efficiency have been found to be the lowest for the small banks caused by the decline in scale efficiency • The medium and large banks have exhibited less pure technical efficiency than the small banks • Efficiency improvement in the medium banks have been superior to both the small and large banks
Wu (2008)	Commercial banks; period of 1983-2001	Intermediation approach to DEA	Inputs: labour, physical capital and loanable funds Outputs: net loans, investment and number of branches	Input- oriented	79% for acquiring banks, 91% for target banks	<ul style="list-style-type: none"> • “The acquiring banks were found to be larger, more aggressive and less efficient than the target banks” (Wu 2008, p154) • Scale inefficiency have been the main source of inefficiency • Mergers were recognized to have negative effect on banks efficiency

The productivity change of four major trading banks and six regional banks in Australia have been analyzed through the study of Avkiran (2000) applying output-oriented DEA method and Malmquist indices. The author used intermediation approach to specify inputs (which are staff numbers, deposits, interest expense and non-interest expense) and outputs (which are net loans, net interest income and non-interest income). Total productivity presented an overall rise of 3.2 percent per year over the studied period. The major trading banks presented higher technological development than the regional banks but a similar technical efficiency. The total productivity increased in overall due to the improvement of the technological progress rather than the technical efficiency.

Worthington (2000) decomposed the productivity growth of fifteen Australian Building societies into technical efficiency change and technological change. The Malmquist input-oriented index has been applied using production approach of DEA method. Selected inputs are members' funds, physical capital, labour and the number of full-branch equivalent operations and outputs involve call deposits, term deposits, personal loans, residential loans, commercial loans and other financial investments. The author found that technological progress contributed to the productivity improvement more than the efficiency change. The mean annual growth of the total factor productivity over the investigation period from 1993/4 to 1996/7 has been 4.9 per cent.

Mukherjee et al. (2001) employed DEA to examine the efficiency of 201 US commercial banks over the post-deregulation period, 1984-1990 employing input-oriented DEA model. Malmquist productivity indices were applied to measure the productivity growth. They evaluated the involvement of technical change, technical efficiency change and scale change to productivity growth. Five inputs and five outputs are defined in the study. Inputs are transaction deposits, non-transaction deposits, equity, labor and capital and outputs are commercial and industrial loans, consumer loans, real estate loans, investments and total

non-interest income. The empirical results presented 4.5 percent annual productivity growth on average. The results obtained from the second-stage panel regressions implied that higher productivity growth has been caused by larger asset size and product mix specialization while lower productivity growth was related to higher equity.

Investigating the major UK banks over the period 1984-1995, Drake (2001) applied the Malmquist index to analyse the trend of change in the banks efficiency and productivity. Based on the empirical results, scale inefficiencies found to be more imperative than the X-inefficiencies. The author found a maximum productivity growth of 4.9 per cent throughout the sample of banks during the investigated period. As a whole, UK banks experienced a positive productivity movement over the period of study.

To evaluate the effects of deregulation on the productivity of the Australian banks, Sathye (2002) carried out a study to measure the productivity change of 17 Australian banks during 1995 to 1999 by the means of the Malmquist index analysis. Following the intermediation approach, interest expenses and non-interest expenses are specified as inputs and net interest income and non-interest income are the outputs of the study. The results indicated a 3.5 percent decline in the trend of productivity movement in the Australian banking industry over the period studied. As well, the technical efficiency of these banks has reduced by 3.1 percent since 1995 to 1999. The author concluded that deregulation has posed negative effect on the productivity growth of the Australian banks though it positively affected the banks during the initial years.

As mentioned in Section 3.3, Neal (2004) applied the Malmquist indices to evaluate the productivity change of Australian banks and found a considerable growth in efficiency of the banking sector. During the investigated period of 1995-1999, total factor productivity has been raised by an average of 7.6 percent annually. The author found an annual rise of 11.5 per cent in the productivity of banks due to the movement in technological change.

Sturm and Williams (2004) applied DEA, Malmquist indices and stochastic frontier analysis to evaluate the effect of foreign bank entry on the efficiency of Australian banks after deregulation from 1988 to 2001. DEA models and results explained earlier in Section 3.4. According to the results of Malmquist index, banks have experienced an average productive growth after the deregulation and the technological change recognized as the major source of this improvement. The measurement of the productivity change resulted in 10 percent productivity growth under models 1 and 1b and 8 percent growth under Model 1a. Model 2 found 3 percent decline in the banks productivity level. The authors finally concluded that “the foreign banks provided an important source of technological efficiency changes immediately after deregulation, and after the shock of the recession of the early 1990s the domestic banks somewhat improved their scale of operations” (Sturm and Williams 2004, p1796).

Lyrودي and Angelidis (2006) used DEA to investigate the efficiency of 994 firms from the ten latest members of the European Union through the era before their entry in the EU, 1996-2002. Then, the Malmquist index was applied to analyse the technological change and technical efficiency change to find the sources of inefficiency. They applied the value-added approach to select the inputs which are labor, other operating expenses and total fixed assets and outputs which are total deposits, total customer loans and investments. In addition, the authors analyzed the relationship between the sizes of financial institutions and their productivity. According to the empirical results, financial institutions in half of the countries presented an average growth of 4.5 percent in their productivity level over the six years. The decomposition of the Malmquist index exposed that the productivity growth was lower for the best practice firms than the remaining institutions. The relationship between the size of banking institutions and productivity growth was found to be statistically insignificant, except Latvia, where this relationship was positive and significant.

The empirical methodologies applied by the above studies are of a great value in the analysis of the productivity of the Australian banks by the means of DEA and Malmquist indices and answer the second research question of the current thesis. The literature on the productivity change employing the Malmquist index is summarized in Table 3.3 in pages 53-54.

3.6 Studies on Global Financial Crisis

There are a quite large number of studies investigating different aspects of the recent global financial crisis, 2007-2009 mostly on its US bases and sources. There have been some attempts to evaluate the impact of the crisis on the Australian economy and its various sectors. Valentine (2009) has surveyed four possible policies to find the most appropriate package for the Australian government to deal with the downturn. He concluded that reduction of the interest rate, some adjustments to decrease labor costs for employers, to diminish the value of Australian dollar and to accomplish advantageous infrastructure projects would be valuable policies for Australia to face the crisis. Arguing that the falling CPI, reducing output growth rate and the growing unemployment rate are indicators of a significant drop in aggregate demand, Kriesler (2009) investigated impact of crisis on the Australian economy. He examined four major sources of the aggregate demand i.e. consumption demand, investment demand, net exports and government demand. The outcomes of the study could be summarized as follows:

Table 3.3: Studies on Productivity and Efficiency

Author	Country	Data	Approach	Productivity Change	Main Result
Avkiran (2000)	Australia	24 banks; Period of 1986-1995	Malmquist index	3.2% TFP growth	<ul style="list-style-type: none"> • Total productivity raised on the whole caused mainly by technological progress rather than technical efficiency
Worthington (2000)	Australia	Building societies; Period of 1993/4-1996/7	Malmquist index	4.9% TFP growth	<ul style="list-style-type: none"> • The role of technological progress in productivity growth have been more important than the efficiency change • The total factor productivity growth rate were annually 4.9% over the sample study
Mukherjee et al. (2001)	USA	201 commercial banks; period of 1984-1990	DEA-Malmquist index	4.5% TFP growth	<ul style="list-style-type: none"> • Banks with large assets experienced higher productivity growth • Productivity growth rate have been 4.5%
Drake (2001)	UK	9 major banks; Period of 1984-1995	Malmquist index	4.9% TFP growth	<ul style="list-style-type: none"> • Productivity growth rate were found to be 4.9% • UK banks experienced positive productivity growth
Sathye (2002)	Australia	17 banks; Period of 1995-1999	DEA-Malmquist index	3.5% TFP decline	<ul style="list-style-type: none"> • 3.1% decline in the technical efficiency • 3.5% decline of the total factor productivity • Deregulation posed negative impact on the productivity of the Australian banks
Neal (2004)	Australia	12 banks; Period of 1995-1999	Malmquist index	7.6% TFP growth	<ul style="list-style-type: none"> • The total factor productivity exhibited an average growth of 7.6% each year • Technological change have been 11.5% annually

Author	Country	Data	Approach	Productivity Change	Main Result
Sturm and Williams (2004)	Australia	20 domestic banks and 19 foreign banks; Period of 1988-2001	DEA-Malmquist index-SFA	Model 1: 10% TFP growth; Model 1a: 8% TFP growth; Model 1b: 10% TFP growth; Model 2: 3% TFP decline	<ul style="list-style-type: none"> • Productivity of banks improved during the era after deregulation • Technological change has been recognised as the main source of the productivity growth rather than technical efficiency
Lyroudi and Angelidis (2006)	EU	994 institutions; Period of 1996-2002 (before their entry)	DEA-Malmquist index	4.5% TFP growth	<ul style="list-style-type: none"> • The best-practice firms experienced the lowest productivity growth than the rest • The highest average productivity growth was found to be 17.6% and the largest decline in efficiency was 1.8%

1. a considerable fall of demand has been the foremost effect of the crisis on the Australian economy;
2. the author recommends the government expenditure to adopt the slack to prevent slow growth in output and rise of unemployment;
3. the fundamental idea of the study is to reveal the important role of public investment and expenses in the improvement of employment and output growth.

For further literature on the recent global financial crisis see Melvin and Taylor (2009), Davies (2009), Jones (2009), Edey (2009), Eslake (2009) and Karunaratne (2010).

Pomfert (2009) evaluated the global financial crisis of 2007 and the challenges Australia is facing with. He stated that deregulations and innovations in the financial sectors played an important role in the economic growth of the USA, UK and Australia; however, the turnover of this high growth has been the risk-taking institutions generating bad loans. The author concluded that appropriate regulations for the financial sector are required to be made by policy makers to prevent the expected future banking collapses. In addition, Australia experienced a burst asset bubble and as an open economy, it is affected by the global trade recession. However, Australia has been successful to avoid a serious domestic financial crisis.

Employing the DEA methodology, Sufian (2009) evaluated the efficiency of Malaysian banks over the period of 1995-1999, concerning the Asian financial crisis 1997. He specified the inputs and outputs under the three major approaches which are intermediation approach (inputs: deposits, labor and capital; outputs: loans and investments), value-added approach (inputs: labor, capital and interest expenses; outputs: deposits, loans and investments) and operating approach (inputs: interest expenses, labor and other operating expenses; outputs: interest income and non-interest income). The author applied the Tobit model to handle the distribution features of efficiency measures that could be valuable to

improve the performance. The findings of the study presented high level of inefficiency in the Malaysian banks. According to the results of the multivariate regression analysis, technical efficiency has been positively related to the loans intensity. Foreign banks have been found to be more efficient than the domestic banks.

Sufian and Habibullah (2009) applied DEA to evaluate the impact of financial crisis 1997 on the Korean banks using three approaches which are intermediation approach (inputs: deposits, labor and capital; outputs: loans and investments), value-added approach (inputs: labor, capital and interest expenses; outputs: deposits, loans and investments) and production approach (inputs: interest expenses and labor; outputs: interest income and non-interest income). Based on the empirical results, the Korean banks exhibited high level of inefficiency over the Asian financial crisis period and specially a year after the crisis. The major source of inefficiency had been recognized as the under utilization of inputs. The panel fixed effects regression analysis outcomes indicated that the majority of the determinant variables had statistically significant impact on the banks efficiency but the impact was not found similar through the three approaches.

Later, Sufian (2010) accomplished the same study (applying the same methodology and mix of inputs and outputs) to analyze the impact of the Asian financial crisis on the banking system of Malaysia and Thailand and found high inefficiency in banking sectors of both countries during the crisis era. The empirical results obtained from intermediation and value-added approaches presented a higher TE level in the Malaysian banking sector over the post crisis period while operating approach results indicated a lower TE level. The Thai banks exhibited a lower TE level during this period under the three approaches.

Considering Australian economy as a dual economy, Perlich (2009) analyzed the impact of the global financial crisis on the economy of NSW, Victoria, Queensland and Western Australia as four most important states. He believed that a dual-economy analysis

would better reveal the grounds of high growth of the Australian economy before the crisis and the excessive effect of the crisis on the states under study. The study found that although the astonishing growth of China protected the Australian economy from the most terrible impacts of the crisis, there is still a fear of returning to the social and economic imbalances which appeared before the crisis.

Anayiotos et al. (2010) evaluated the efficiency of 125 commercial banks in fourteen emerging European countries over the periods before and after the financial crisis 2007 employing the DEA methodology. Following the asset approach, total capital, interest expense and operating expense were specified as inputs and total loans, pre-tax profit and securities portfolio were specified as outputs. According to the results, the banks efficiency was highly related to the development degree of the host country before the crisis. The efficiency of banks is found to be increased during the period before the crisis and dropped over the crisis. The authors concluded that “foreign-owned banks in emerging Europe seem to be less efficient than their parent banks, suggesting that although they may bring some efficiency benefits to their host country, they are highly affected by the local business and operational environment” (Anayiotos et al. 2010, p247).

The above literature about the effect of financial crises on the banking systems in different countries will be helpful to examine the effect of the Global Financial Crisis 2007-2009 on the performance of Australian banks and answer the third research question of the present study. Table 3.4 provides a summary of the literature on the financial crises in pages 59-60.

3.7 Summary

The above literature on the financial crises with a specific look at the global financial crisis 2007-2009 indicate that there is no study to analyze the effect of the financial crisis on the Australian banking industry. In addition, there is a huge number of studies applying the DEA methodology to examine the efficiency and productivity of financial institutions, particularly banks, accomplished in developed countries especially in the USA while the performance of Australian banks using the DEA method have been almost limited and in a similar direction. The majority of DEA studies on the Australian banking sector have evaluated the efficiency and productivity of banks before and after deregulation era.

To the best of the author`s knowledge, present thesis will be the first study employing the DEA methodology to find the efficiency of the Australian banks before the crisis 2007 and all through it and assess the banks productivity change using Malmquist indices.

Three major approaches of DEA have been mostly applied through the literature on the efficiency of financial institutions which are intermediation approach, value-added approach and production approach. Therefore, the inputs and outputs have been specified in almost an identical basis in the studies. The most commonly applied inputs are labor, expenses (interest and non-interest) and capital under production and value-added approaches and deposits have been added to these inputs under intermediation approach; outputs mainly consisted of income (interest and non-interest) under production approach and loans, investments and deposits under intermediation and value-added approaches with various types of classification.

Table 3.4: Studies on the Global Financial Crisis

Author	Country	Data	Methodology	Main Results
Pomfert (2009)	Australia	Financial intermediaries	Aggregate demand management	<ul style="list-style-type: none"> • In the USA, UK and Australia, financial deregulation and innovation played important role in the economic growth of 1990s and 2000s • Although Australia did not experience a severe financial downturn, bank collapses are expected in the future
Sufian (2009)	Malaysia	Banks; Period of 1995-1999	DEA- Tobit model	<ul style="list-style-type: none"> • Malaysian banks have been highly inefficient over the period of study • technical efficiency has been positively related to the loans intensity • Foreign banks have been found to be more efficient than the domestic banks.
Sufian and Habibullah (2009)	Korea	Commercial banks; Period of 1992-2003	DEA	<ul style="list-style-type: none"> • Korean banks have experienced high level of inefficiency over the crisis and a year after • Under utilization of inputs has been recognized as the main source of inefficiency • majority of the determinant variables had statistically significant impact on the banks efficiency but the impact was not found similar through the three approaches

Author	Country	Data	Methodology	Main Results
Sufian (2010)	Malaysia and Thailand	Commercial banks; Period of 1992-2003	DEA	<ul style="list-style-type: none"> • the Malaysian and Thai banks exhibited high level of inefficiency over the crisis and a year after • Intermediation and value-added approaches presented a higher TE level in the Malaysian banking sector over the post crisis period while operating approach results indicated a lower TE level • The Thai banks exhibited a lower TE level during this period under the three approaches.
Perlich (2010)	Australia	Economy of the Australian “Resource states” (Queensland and WA) and “Manufacturing states” (NSW and Victoria)	Dual economy analysis	<ul style="list-style-type: none"> • Although the astonishing growth of China protected the Australian economy from the most terrible impacts of the crisis, there is still a fear of returning the social and economic imbalances appeared before the crisis.
Anayiotos et al. (2010)	14 emerging European countries	125 commercial banks; Period of 2004-2009	DEA	<ul style="list-style-type: none"> • Foreign banks presented higher level of efficiency than the domestic banks • The most influential efficiency determinant have been found to be the credit expansion before the crisis • Determinants of bank efficiency have been found as: “size, EU membership, being in a financial group with a presence in more than one country, credit market regulation, interest rate spreads, state ownership, asset quality and stock market size” (Anayiotos et al. 2010, p257)

All of the studies investigating the impact of global financial crisis 2007 on the Australian economy declared that the Australian financial sector has not been affected as severe as other economies; however, there are some important issues that may cause serious problems in the future such as increased concentration of the banking system and the improvement pacification of domestic securitization market which are discussed in chapter 2.

As discussed above, the DEA literature of the financial crises presented that all of the financial units have experienced high levels of inefficiency after the financial crisis in compare with the banks performance before the crisis. The efficiency and productivity of Australian banks have never been evaluated through the global financial crisis 2007 by means of DEA methodology and Malmquist indices. Next chapter will explain in detail the procedure of obtaining the efficiency scores by DEA and measuring the productivity movement in the Australian banking sector applying Malmquist index.

Chapter 4 : Methodology

4.1 Introduction

The previous chapter reviewed the relevant studies on the efficiency and productivity of financial institutions applying Data Envelopment Analysis (DEA) and Malmquist index. The review of literature revealed that three approaches (production, intermediation and value-added approaches) to the DEA methodology have been mostly applied through these studies to specify the inputs and outputs. The DEA method and Malmquist index will be explicated in the present chapter.

DEA is a non-parametric linear programming initiated by Charnes et al. (1978) based on the work of Farrell (1957). They expanded the engineering ratio approach to the efficiency measurements of single-input, single-output to multi-input, multi-output firms (Seiford and Thrall 1990). In other words, they have defined the efficiency to simplify the concept of single output ratio in economics, engineering and even further natural sciences (Charnes et al. 1978). DEA swiftly developed practically and theoretically after the study of Charnes et al. (1978) and 4000 studies were published till 2007 applying DEA methodology that is an indication to its strengths (Emrouznejad et al. 2008). DEA is able to identify feasible peers or role models in addition to simple efficiency scores and does not require any functional form assumption contrary to the parametric approaches (Sathye 2001). Because of its practical orientation, DEA is recognized as a superb technique for modelling operational processes and includes alternative approaches to assess performance (Seiford and Thrall, 1990). The original CCR study has been expanded to reach to a more profound analysis of both sides of the mathematical duality structure: the multiplier and the envelopment sides (Seiford and Thrall, 1990). Further advantages of this method are mentioned through the chapter.

This chapter is structured as follows: DEA methodology and its application in efficiency measurement are described in section 4.2. Section 4.3 provides a comparison between DEA method as a nonparametric approach and parametric approaches. Constant returns to scale and variable returns to scale are explained through sections 4.4 and 4.5 respectively. The input- and output-oriented DEA models are defined and compared in section 4.6. Sections 4.7 and 4.8 respectively explain the cost efficiency and scale efficiency measurements. Inputs and outputs to be analyzed are specified through section 4.9. Section 4.10 focuses on the Malmquist indices and the measurement of the productivity change between investigated periods. The chapter will be summarized in section 4.11.

4.2 DEA Methodology

Different but homogenous DMUs in a particular sample can be analyzed using DEA. DEA identifies the best practice in the sample and compares every single DMU with that to notify the efficient and inefficient DMUs with the constraint that all DMUs rest on or under the efficient frontier (Sathye, 2001). DMUs on the efficient frontier are the best practice organizations and score 1 DMUs and DMUs enveloped by the efficient frontier and lie underneath are relatively inefficient and between 0 and 1.

In microeconomic theory, the production function concept is a basis to describe the input-output relationship in an organization. The production function illustrates the maximum quantity of outputs that can be generated using a given amount of inputs. On the other hand, the input-oriented DEA model describes the minimum amount of inputs to obtain a given level of outputs (Seiford and Thrall, 1990).

Charnes et al. (1978) proposed an input orientation model assuming constant returns to scale (CRS) and afterwards, Fare, Grosskopf and Logan (1983) and Banker, Charnes and Cooper (1984) proposed models with variable returns to scale (VRS). The input-oriented

CRS model was the first model being broadly applied and is appropriate in a condition that all firms operate in an optimal scale. However, firms may not be able to work at optimal scale because of imperfect competition, government rules and regulations, economic/financial restrictions and so forth. In such circumstances applying CRS DEA models will yield imprecise technical efficiency scores. Thus, VRS models were suggested as an alternative to CRS models that enable calculation of technical efficiency without any scale-efficiency distortion effects (Coelli 2005).

4.3 DEA against Parametric Approaches

In the banking literature, there are two approaches to evaluate the performance and measure the efficiency:

- parametric methods such as the Stochastic Frontier Analysis (SFA), Dynamic Financial Analysis (DFA), and Thick Frontier Approach (TFA);
- non-parametric methods such as DEA and Free Disposal Hull (FDH).

According to Pasiouras (2007), both methods yield quite similar efficiency scores. As well, Berger and Humphrey (1997) investigated 61 parametric and 69 nonparametric studies and achieved the same conclusion.

The parametric approach tries to separate inefficiency from random error and estimates a functional form to connect inputs and outputs. However, the parametric methods suffer from their own paucities. The major problem with them is that the type of the model (linear, non-linear, logarithmic, etc.) must be estimated which may yield into a misspecified model (Berger and Humphrey 1997).

The other shortcoming of this approach argued by Thanassoulis (2001) is that it is not possible to deal with a variety of inputs and outputs. To overcome these deficits, the nonparametric methods are applied to measure the efficiency of financial institutions.

By adopting DEA methodology, there is no need to identify “a priori the general shape of the boundary and run the risk of misspecifying” (Thanassoulis 2001, p11).

Instead of estimating a functional form to link inputs and outputs, DEA attempts to construct a production possibility set from the units’ input-output correspondences which is enveloped by a piece-wise linear frontier. As stated by Seiford and Thrall (1990) it is easier to estimate the efficient frontier using DEA and the obtained efficient frontier is stronger. Moreover, DEA is a technique aimed at achieving frontiers rather than central tendencies. Under this approach, a piecewise linear surface will be floated to lie on top of the observations instead of fitting a regression plane within the centre of the data. This unique feature enables DEA to proficiently uncover relationships that stay unknown for other method (Seiford and Thrall 1990). In addition, Sathye (2001) believes that “The ability to identify possible peers or role models as well as simple efficiency scores gives it an edge over other methods” (Sathye 2001, p665). As well as the strength to measure the efficient frontier and find the role models for inefficient DMUs, DEA is useful to provide practical information regarding performance management of the operating units like measuring optimal scale size, evaluating productivity over time and decomposing efficiency into different layers of management engaged to function of the units. DEA is recognized by Sathye (2001) as a preferred approach to be applies in examining small sample sizes comparing to parametric ones.

The other advantage of applying DEA is that different measurement units can be utilized for inputs and outputs; for instance, asset size as an input can be expressed in dollar while, number of staff can be applied as another input without a need to priori exchange between them (Coelli et al. 2005). Taking into account all of these advantages, the DEA methodology is a widely accepted technique to evaluate the performance of organizations and to measure their scores of efficiency.

Furthermore, DEA is able to treat properties such as isotonicity, nonconcavity, economics of scale, piecewise linearity, Cobb-Douglas forms, discretionary and nondiscretionary inputs, categorical variables, and ordinal relationships. In addition, DEA allows to constructively develop of an empirical production function with its fractional derivatives (Seiford and Thrall, 1990).

4.4 Constant Returns to Scale DEA Model

We begin the discussion of the DEA model by the input-oriented CRS model. To identify the notations, assume N inputs and M outputs for each of I firms. For the i -th firm, N inputs are shown on the column vectors x_i and M outputs on q_i . The data for all I DMUs (firms) are represented by the $N \times 1$ input matrix, X , and the $M \times 1$ output matrix, Q .

The ratio form, intuitively introduces DEA. To obtain the maximum efficiency measure of every DMU, the ratio of all outputs over all inputs should be computed for each firm, such as $u'q_i / v'x_i$, where u is an $M \times 1$ vector of output weights and v is a $N \times 1$ vector of input weights. The following mathematical programming problem will be solved to achieve the optimal weights:

$$\begin{aligned}
 & \max_{u,v} (u'q_i / v'x_i) \\
 & st \quad u'q_i / v'x_i \leq 1, \quad i = 1, 2, \dots, i, \\
 & u, v \geq 0
 \end{aligned} \tag{1}$$

Finding values for u and v will maximize the efficiency measure of the i -th firm subject to the constraint that all efficiency measures must be less than or equal to 1. A problem inherent in the above ratio formulation is the existence of numerous solutions (Coelli et al. 2005).

The constraint $v'x_i = 1$ could be imposed to avoid this problem:

$$\begin{aligned}
 & \max_{\mu, v} (\mu'q_j), \\
 & st \quad v'x_j = 1, \\
 & \quad \mu'q_j - v'x_j \leq 0, \quad j = 1, 2, \dots, j, \\
 & \quad \mu, v \geq 0,
 \end{aligned} \tag{2}$$

The change of notation from u and v to μ and v presents a different linear programming (LP) problem which is known as the *multiplier* form of DEA.

An equivalent envelopment form of this LP problem contains fewer constraints than the multiplier form ($N + M < I + 1$) and hence, is a preferred form to solve. This form of LP problem can be derived applying the duality in linear programming as follows:

$$\begin{aligned}
 & \min_{\theta, \lambda} \theta, \\
 & st \quad -q_i + Q\lambda \geq 0 \\
 & \quad \theta x_i - X\lambda \geq 0 \\
 & \quad \lambda \geq 0
 \end{aligned} \tag{3}$$

Where λ presents a $I \times 1$ vector of constants and θ is a scalar and the technical efficiency score of the i -th firm is presented by the value of θ . To estimate the value of θ for each DMU, the LP problem must be solved I times (once for every firm in the sample). According to Farrell (1957), this problem convinces $\theta \leq 1$; when $\theta = 1$, the firm is technically efficient since the production point rests on the efficient frontier.

Under CRS, the efficiency change component can be decomposed into scale efficiency (finds changes in variation between VRS and CRS) and pure technical efficiency change (computed relative to VRS). To achieve the scale efficiency, the pure technical

efficiency is first calculated by re-calculating the efficiency change score under VRS; the ratio of CRS technical efficiency to VRS technical efficiency will be estimated consequently (Coelli et al. 2005).

4.5 Variable Returns to Scale DEA Model

As pointed out earlier, in the existence of imperfect competition, government regulations, financial restrictions and so on, applying CRS models is not appropriate since the firms do not operate at their optimal scale. Employing CRS models in such situations will result in measures of technical efficiency that are confused by scale efficiencies. The reason is the TE scores obtained from the CRS DEA is composed of two constituents which are the results of scale inefficiency and pure technical inefficiency (Coelli et al. 2005).

To avoid this problem, the VRS specification is formed simply by adding the convexity constraint $I'\lambda = 1$ to the envelopment form of DEA and the following equation will be achieved:

$$\begin{aligned}
 & \min_{\theta, \lambda} \theta, \\
 & st \quad -q_i + Q\lambda \geq \theta \\
 & \quad \theta x_i - X\lambda \geq \theta \\
 & \quad I'\lambda = 1 \\
 & \quad \lambda \geq 0,
 \end{aligned} \tag{4}$$

Where I is a $I \times 1$ vector of unity. The VRS DEA model (which is input-oriented) forms a convex hull of intersecting planes (in the three-dimensional case)/ facets (in cases with more than three dimensions) that “envelop the data points more tensed than the CRS

conical hull” (Coelli et al. 2006, p172). This will result in greater technical efficiency scores than or equal to the efficiency scores obtained from the CRS model (Coelli et al. 2006).

4.6 Input and Output Orientations

As discussed in sections 4.1 and 4.2 based on Farrell’s input-oriented model, technical inefficiency is obtained as a relative reduction in input usage with constant levels of output. Another way to measure the technical inefficiency is to proportionally increase the output production and keep fixed levels of input. When CRS is assumed, both measures yield equal values but under VRS, different efficiency scores will be achieved.

When DMUs are firms with particular obligations to accomplish, like electricity generation, the level of inputs will be the main decision variables and hence, the input-oriented models are required. Alternatively, when DMUs are firms with fixed resource capacities and are asked to produce as much outputs as possible, it would be more appropriate to employ an output-oriented model. Basically, the orientation should be selected considering the level of control that managers have on the quantities of either inputs or outputs. Moreover, the choice of orientation does not have important effect on the efficiency scores and is largely arbitrary (Wheelock and Wilson 1999).

An output-oriented DEA model is very similar to an input-oriented DEA model. For instance, the output-oriented VRS model can be identified as follows:

$$\begin{aligned}
 & \left[D_o^{t+1}(x^{t+1}, y^{t+1}) \right]^{-1} \max_{\phi, \lambda} \phi, \\
 st \quad & -\phi y_{i,t+1} + Y_{t+1} \lambda \geq 0, \\
 & x_{i,t+1} - X_{t+1} \lambda \geq 0, \\
 & N1' \lambda = 1 \\
 & \lambda \geq 0,
 \end{aligned} \tag{5}$$

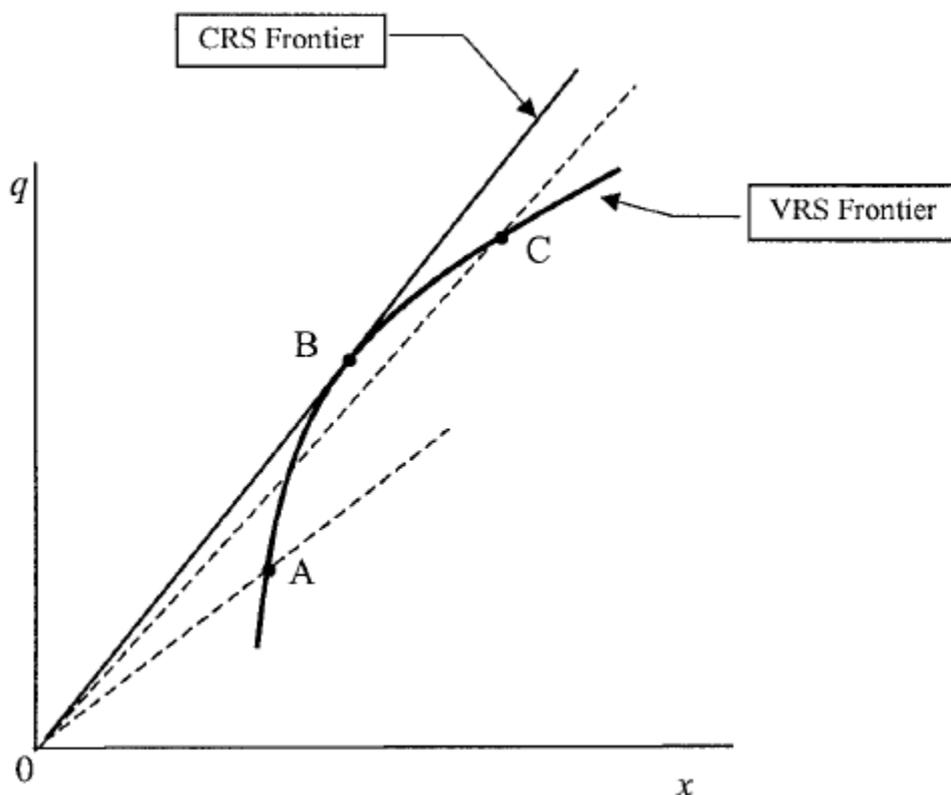
Where $\phi - 1$ indicates the proportional raise in outputs when the input level is held constant, and $1 \leq \phi \leq \infty$. Thus, $1/\phi$ defines the TE score, which is between 0 and 1 (Coelli et al. 2005).

As argued by Coelli et al. (2005), an input-oriented model “sought to identify technical inefficiency as a proportional reduction in input usage, with output levels held constant” (Coelli et al. 2006, p180). Considering this issue that the financial institutions tend to decrease costs, most of the related studies have employed the input-oriented approach to measure the efficiency of DMUs. Therefore, present thesis will apply an input-oriented model to explore the efficiency of banks.

4.7 Scale Efficiency

Figure 4.1 illustrates a one-input, one-output VRS production technology.

Figure 4.1: The Effect of Scale on Productivity



Source: Coelli et al. 2006, p59

Area S is a production set between the VRS production frontier, q , and the x-axis, inclusive of these bounds. “The firms operating at the points A, B and C are all technically efficient, because the productivity of each of these firms is equal to the ratio of their observed output and input quantity (y/x) and this expression indicates that even though these three firms are all technically efficient, they are not equally productive. This apparent inconsistency is due to the effects of scale” (Coelli et al. 2006, p58).

Firm A, operating in the rising returns to scale part of the production frontier, could become more productive by enhancing its scale of operation towards point B.

Point C, operating in the decreasing returns to scale portion of the production frontier, could become more productive by reducing its scale of operation towards point B.

The firm operating at point B is not capable to become more productive by adjusting its scale of operation. It is said that the firm at point B functions at the most productive scale size (MPSS) or evenly at the technically optimal productive scale (TOPS). As it can be seen, a ray from the origin is tangential to the production frontier at this point which is called the CRS technology. This TOPS point can be described mathematically as $TOPS = \max\{y/x \mid (x, y) \in S\}$ which is equivalent to discovering the possible production point that maximizes productivity (Coelli et al. 2006).

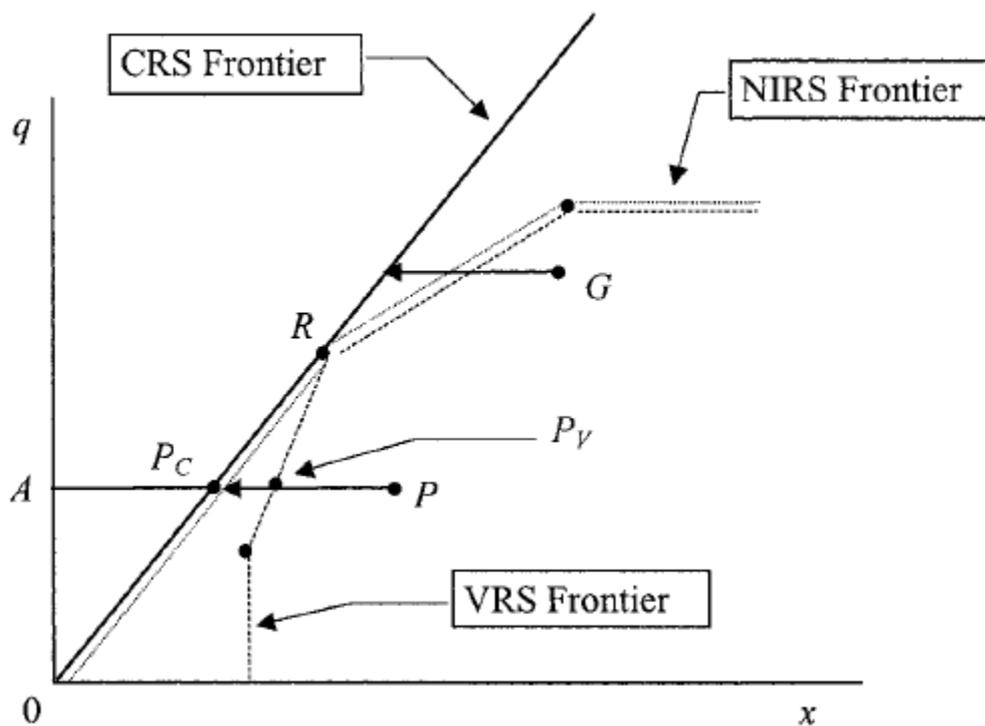
4.7.1 The Nature of Returns to Scale

A problem with the above measure of scale efficiency is that the value does not specify whether the firm is operating in an area of increasing or decreasing returns to scale. This matter can be determined by running a further DEA problem with non-increasing returns to scale (NIRS) imposed. This is done by altering the DEA model in LP 4 by substituting the $I'\lambda = 1$ constraint with $I'\lambda \leq 1$, to present:

$$\begin{aligned}
& \min_{\theta, \lambda} \theta, \\
& \text{st} \quad -q_i + Q\lambda \geq \theta \\
& \quad \theta x_i - X\lambda \geq \theta \\
& \quad I'\lambda \leq 1 \\
& \quad \lambda \geq 0,
\end{aligned}
\tag{23}$$

Figure 4.2 illustrates the NIRS DEA frontier:

Figure 4.2: Scale Efficiency Measurement in DEA



Source: Coelli et al. 2006, p174

By seeing whether the NIRS TE score is equal to the VRS TE score, one can determine the nature of the scale inefficiencies, due to increasing or decreasing returns to scale, for a particular firm (Coelli et al. 2006).

Increasing returns to scale exist for a firm when they are not equal like the case at point P in Figure 4.2 and there is decreasing returns to scale if they are equal as is the case for point G in the above figure. The study of Fare, Grosskopf and Logan (1983) on the electricity industry presents an example of this approach.

It should be noted that the restriction, $\sum \lambda \leq 1$, ensures that the i -th firm is not “benchmarked” against considerably larger firms, but may be compared with smaller firms (Coelli et al. 2006).

4.7.2 Calculation of Scale Efficiencies

As Coelli et al. (2006) explained, “scale efficiency measures can be obtained for each firm by conducting both a CRS and a VRS DEA, and then decomposing the TE scores obtained from the CRS DEA into two components, one due to residual scale inefficiency and one due to pure technical inefficiency (i.e. VRS TE). If there is a difference in the CRS and VRS TE scores for a particular firm, then this indicates that the firm has scale inefficiency” (Coelli et al. 2006, p172).

Scale inefficiency measures are illustrated in Figure 4.1 using a one-input, one-output case. The CRS and VRS DEA frontiers are specified in the figure. The input-oriented technical inefficiency of the point P is the distance PP_C under CRS and the technical inefficiency under VRS would only be PP_V . Scale inefficiency is resulted into the difference between these two TE measures, $P_C P_V$ (Coelli et al. 2006).

These concepts can be explained in ratio efficiency measures as follows:

$$TE_{CRS} = AP_C/AP \quad (18)$$

$$TE_{VRS} = AP_V/AP \quad (19)$$

$$SE = AP_C/AP_V \quad (20)$$

All of these evaluations are bounded by zero and one. We also note that

$$TE_{CRS} = TE_{VRS} \times SE \quad (21)$$

because

$$AP_C/AP = (AP_V/AP) \times (AP_C/AP_V). \quad (22)$$

Therefore, the CRS technical efficiency measure is decomposed into two components: pure technical efficiency and scale efficiency. This scale efficiency measure can be approximately interpreted as the ratio of the average product of a firm operating at the point P_V to the average product of the firm operating at point R which is the technical optimal scale (Coelli et al. 2006).

4.8 Malmquist Index

DEA calculates measures of efficiency of the firms and higher levels of efficiency from one year to another do not indicate attainment of higher productivity by a firm. Because the technology may have changed, it is important to find the productivity changes between two time periods as well.

Three different indices are frequently used to evaluate technological changes: The Fischer (1992), Tornqvist (1936) and Malmquist (1953) indexes.

Through the present study, to identify the improvement or decline in the efficiency of the firms over time, the Malmquist index is employed to measure the productivity change and also, to decompose it into technical and efficiency changes. Distance functions are used to define the Malmquist total factor productivity index. A multi-input, multi-output production technology can be described by distance functions without initiating behavioural objectives like profit maximisation or cost minimisation (Rao and Coelli 1998).

Caves, Christensen and Diewert (CCD) (1982) introduced Malmquist productivity indices. They explained that the geometric mean of two Malmquist output productivity indices is equal to the Tornqvist index which is accurate for a translog technology. They have

applied translog production function referring to the work of Christensen et al. (1973) in which they argued that a translog production frontier (or the production possibility frontier) is “a transcendental function of logarithms of its arguments, the quantities of net outputs” (Christensen et al. 1973, p29).

Caves et al. (1982) assumed that:

- the underlying technology is translog;
- conditions consist of technical efficiency and allocative efficiency; and
- all the second-order terms should be identical over time (Caves, Christensen and Diewert 1982).

On the other side, Tornqvist index assumes a continuous efficient production and hence, it does not allow decomposing productivity growth into efficiency and technology changes (Färe et al. 1994). Consequently, Färe et al. (1994) initiated a non-parametric approach to calculate the Malmquist index of productivity growth; they presented that the component distance functions can be computed by using their relationship with the technical efficiency measures developed by Farrell (1957) applying a DEA/ non-parametric linear programming technique.

According to Farrell (1957), the consequential total factor productivity indexes could be decomposed into efficiency change and technical change constituents. Moreover, contrasting to the Tornqvist TFP indices, there is neither a need to have input and output prices which are applicable neither in allocative efficiency measurement, to measure the Malmquist indices nor to an assumption on the functional form of the original production technology. To simplify, Färe et al. (1994) analyzed a single-input, single-output case under the output-oriented approach (the analysis under the input-oriented approach could be defined in the same way) (Grasskopf 1993; Färe et al. 1994).

We begin the analysis with the Malmquist productivity index (MI) relative to a single technology, t , as defined by CCD and used by Färe et al. (1994):

$$MI_{CCD}^t = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \quad (24)$$

Where 0 shows that the output-oriented approach is applied, (x^t, y^t) is a production point at which output y^t is generated by input x^t within period t ; (x^{t+1}, y^{t+1}) indicates that y^{t+1} amount of output is achievable in period $t+1$ by employing x^{t+1} quantity of inputs. $D_o^t(x^t, y^t)$ is a distance function determining the maximum proportional change in output and essential to make (x^t, y^t) practical for the t technology. In other words, $D_o^t(x^t, y^t)$ is equivalent to the relative technical efficiency of production point (x^t, y^t) compared to the frontier of period t (Farrell technical efficiency in period t). Likewise, $D_o^t(x^{t+1}, y^{t+1})$ calculates the maximum proportional change in output and essential to make (x^{t+1}, y^{t+1}) practical for the $t+1$ technology. Therefore, for the $t+1$ technology:

$$MI_{CCD}^{t+1} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \quad (25)$$

Färe et al. (1994) specify the output-based Malmquist productivity change index as the geometric mean of two CCD-type Malmquist productivity indexes to avoid choosing a subjective benchmark:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \sqrt[2]{\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right)} \quad (26)$$

If $M > 1$, the total factor productivity has changed positively between periods 1 and 2. According to Färe et al. (1992), this total factor productivity change can be decomposed into two components:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \times \sqrt[2]{\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)} \quad (27)$$

The phrase outside the square root sign measures the Farrell technical efficiency change between period t and $t+1$; the phrase under the square root is the geometric mean of the shift in technology between years t and $t+1$ evaluated at x^{t+1} and at x^t , and so signifies a shift in technology or in the frontier. Thus:

$$\text{Efficiency change} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \quad (28)$$

$$\text{Technical change} = \sqrt[2]{\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)} \quad (29)$$

Four distance functions solving four linear programming problems must be computed to calculate the above measures (Coelli 1996). Based on the work of Coelli (1996), CRS output-oriented LP is applied to calculate the distance functions; the convexity constraint is

eliminated and time subscripts are included. Therefore, the distance functions will be achieved by solving the following DEA-type LP problems:

$$\begin{aligned}
 & \left[D_o^t(x_t, y_t) \right]^{-1} = \max_{\phi, \lambda} \phi, \\
 \text{st} \quad & -\phi y_{it} + Y_t \lambda \geq 0, \\
 & x_{it} - X_t \lambda \geq 0, \\
 & \lambda \geq 0,
 \end{aligned} \tag{30}$$

$$\begin{aligned}
 & \left[D_o^{t+1}(x_{t+1}, y_{t+1}) \right]^{-1} = \max_{\phi, \lambda} \phi, \\
 \text{st} \quad & -\phi y_{i,t+1} + Y_{t+1} \lambda \geq 0, \\
 & x_{i,t+1} - X_{t+1} \lambda \geq 0, \\
 & \lambda \geq 0,
 \end{aligned} \tag{31}$$

$$\begin{aligned}
 & \left[D_o^t(x_{t+1}, y_{t+1}) \right]^{-1} = \max_{\phi, \lambda} \phi, \\
 \text{st} \quad & -\phi y_{i,t+1} + Y_t \lambda \geq 0, \\
 & x_{i,t+1} - X_t \lambda \geq 0, \\
 & \lambda \geq 0,
 \end{aligned} \tag{32}$$

$$\begin{aligned}
 & \left[D_o^{t+1}(x_t, y_t) \right]^{-1} = \max_{\phi, \lambda} \phi, \\
 \text{st} \quad & -\phi y_{it} + Y_{t+1} \lambda \geq 0, \\
 & x_{it} - X_{t+1} \lambda \geq 0, \\
 & \lambda \geq 0,
 \end{aligned} \tag{33}$$

The above LP problems must be solved for every single firm within each period and add up to the number of LP problems (Coelli 1996). Therefore, in the present study, they were solved using the DEAP, V. 2.1 for all the sample banks.

4.9 Specification of Inputs and Outputs

Though the choice of variables in efficiency studies considerably impacts the results, there is no consensus about the specification of outputs and inputs (see Das and Ghosh 2006, Sathye 2001, Drake 2001). But it is significant to properly specify inputs and outputs to avoid biased performance assessment (Berger and Mester 1997; Thanassoulis 2001).

Under DEA approach, DMUs must be homogenous that is they use the same resources and generate the same products although in variable quantities. In other words, DMUs transform inputs to outputs (Charnes et al. 1978).

The three widely used approaches, utilising different mixes of inputs and outputs, will be applied through the present study which are:

- *Production approach*: is introduced by Benston (1965) and considers banks as providers of services to customers. Because physical inputs are required to carry out transactions and provide financial and advisory services, the input set consists of physical variables such as labor, information system, material and etc. or their related costs (Das and Ghosh 2006).
- *Intermediation approach*: views financial institutions as funds intermediaries between savers and investors. “Banks produce intermediation services through the collection of deposits and other liabilities and their application in interest-earning assets, such as loans, securities and other investments” (Das and Ghosh 2006, p201). Under this approach, both operating and interest expenses are incorporated as inputs and loans and other major assets as outputs (Das and Ghosh 2006).

- *Value-added approach*: is regarded as a variant of the intermediation approach. The asset approach and the user cost approach are the other variants of the intermediation approach. The intermediary role of banks is of the focus of these three approaches that mainly use financial data. The output set under the value-added approach are those balance sheet categories that contribute to bank value added ; these categories are usually deposits and loans as they are responsible for the major part of value-added. The labor, capital and interest expenses can be specified as inputs (Das and Ghosh 2006).

It is noteworthy that the traditional microeconomic theory of the firm is applied to banking by the first two approaches while the third approach modifies the classical theory by including some particular activities of banking (Das and Ghosh 2006). Based on the above description of different approaches to be applied through the present study, the specified inputs and outputs under every approach are summarized in Table 4.1.

Table 4.1: Specification of Inputs and Outputs

Approaches	Inputs	Outputs
<i>Production approach</i>	Interest expenses	Interest income
	Operating expenses	Non-interest income
	Labor	
<i>Intermediation approach</i>	Deposits	Loans
	Operating expenses	Investments
	Labor	
<i>Value-added approach</i>	Interest expenses	Deposits
	Operating expenses	Loans
	Labor	Investments

In addition, taking into account that some other factors rather than the applied inputs and outputs might be influential in the efficiency of an organization, the present study will investigate the effect of the institutional size on its efficiency applying the univariate approach. Based on the economies of scale in microeconomic theory, there is a negative relationship between the size of a financial institution and its efficiency. Larger firms may experience diseconomies of scale because of the difficulties and complexities involved in the management of a large company.

4.9.1 Data

The present study will investigate the efficiency measures of the Australian banks over the period 2004-2010 for the sample of the four major banks and six other Australian owned banks; however, the size of sample will be altered for different years of the studied period due to some mergers happened in the banking sector during this era. The reasons to choose these banks to analyze are:

1. ANZ, Commonwealth, NAB and West Pac are the most important Australian banks (known as the Big Four);
2. other banks in the sample are the main national and regional banks some of which have experienced mergers or have been acquired by another bank (as mentioned in chapter 2); and
3. the purpose of the study is to evaluate the performance of the major banks during the global financial crisis 2007-2010.

The required variables to be applied as specified inputs and outputs are obtained through the annual financial reports of these banks. In order to conduct DEA models of the study (both CRS and VRS DEA models) as well as Malmquist DEA methods to find indices of total factor productivity (TFP) change, technological change, technical efficiency change

and scale efficiency change, the DEAP Version 2.1 computer program will be applied (Coelli 1996).

4.10 Summary

The present research aims at finding the efficiency scores of 10 Australian banks over a 7-years period (2004-2010) applying DEA methodology. The VRS DEA method is applied to examine the efficiency and productivity of the Australian banking sector over the recent global financial crisis using an input-oriented model.

DEA measures the efficiency scores of the homogenous DMUs in a sample to find the best practice DMU and state which DMUs are efficient and which are not. DEA floats a piecewise linear surface to lie on top of the observations instead of fitting a regression plane within the centre of the data. This unique feature of this method discloses hidden relationships to other approaches (Seiford and Thrall 1990). Considering the easiness of estimating the efficient frontier, the ability to find the role models, the capacity to provide practical information regarding performance management of the operating units, applicability to analyze small sample sizes along with other benefits discussed above through the chapter, DEA is recognized as the most acceptable and suitable method to measure the efficiency of the DMUs.

The CRS and VRS DEA models explained in the chapter will be estimated to examine the performance of banks at optimal level as well as under inadequate condition (like when imperfect competition, government regulations, financial restrictions are existed) (Sathye 2001). The calculations of the cost and scale efficiency scores are described and their decomposition processes are presented. As discussed, cost efficiency is decomposed into technical and allocative efficiencies and scale efficiency is resulted from the decomposition of the technical efficiency.

Three approaches are utilized to select different mixtures of inputs and outputs to avoid possible errors in the measurement. The specified inputs and outputs under production approach, intermediation approach and value-added approach are revealed.

The Malmquist index is employed to measure the productivity change from one period to the other and to identify the growth or decline in the efficiency of the DMUs. The Malmquist total factor productivity index is defined using the distance functions.

The specified inputs and outputs will be analyzed through the following chapter to find the efficiency scores of the Australian banks included in the sample. As well, the Malmquist index will be analyzed to measure the productivity trend of the Australian banks included in the sample. Further analysis will be made to find the effect of the institutional size on the technical efficiency of financial institutions.

Chapter 5 : Empirical Results and Analysis

5.1 Introduction

The empirical findings of the present study will be presented in this chapter. The application of the DEA technique to measure the efficiency of financial institutions has been illustrated in Chapter 4. Based on this methodology, three main issues will be addressed in the present analysis which are:

- the technical efficiency of the Australian banks included in the sample will be measured before and after the recent global financial crisis (2007-2009);
- the components of technical efficiency namely, pure technical efficiency and scale efficiency, will be analyzed through the sample period; and
- the productivity change of the studied bank will be measured using the Malmquist index to examine its catching-up effect and frontier shift effect.

The current thesis will evaluate the sensitivity and strength of the obtained efficiency scores under three alternative approaches to the DEA model which are production approach, intermediation approach and value-added approach.

Under production approach, inputs consist of interest expenses, labor and operating expenses and specified outputs are interest income and non-interest income. The same approach has been employed through the work of Das and Ghosh (2006).

The selected inputs under intermediation approach are deposits, labor and operating expenses and outputs contain loans and investment. This approach has been utilized by the study of Rangan et al. (1988), Favero and Papi (1995), Drake (2001), Das and Ghosh (2006), Sathye (2001), Neal (2004), Paul and Kourouche (2008) and Wu (2008) as discussed in Chapter 3.

Labor, operating expenses and interest expenses are the inputs specified under the value-added approach and loans, investment and deposits are treated as the outputs. Das and Ghosh (2006) have followed the same approach in addition to the production and intermediation approaches.

To address the research questions stated in Chapter 1, the results of the study are sorted in three major groups:

1. the efficiency scores of the banks over the sample period under the three approaches;
2. the productivity movements of the studied banks during the period 2004/2005-2009/2010; and
3. to find the relationship between the size of each bank and its performance.

The present chapter is structured as follows. The correlation coefficient of applied inputs and outputs will be examined through Section 5.2. Technical efficiency of the Australian banks will be analyzed in Section 5.3. To measure the technical efficiency and its components, pure technical efficiency and scale efficiency, the DEA method will be applied in this section. The productivity changes of the studied banks will be measured through Section 5.4 employing the Malmquist index. In Section 5.5, the relationship between the institutional size and the efficiency of the firms will be investigated. The major outcomes of this study will be summarized through Section 5.6.

5.2 Input-Output Correlation Analysis

Prior to the DEA analysis, the relationship between the applied inputs and outputs is examined by means of correlation analysis. Correlation presents a direct or indirect⁴ relationship between two sets of data. Considering the existence of indirect correlation, one cannot precisely decide about the reason behind the changes of the dependent variable

⁴ Indirect correlation means the dependent variable is affected by a third variable.

through only correlation coefficient. In fact, the correlation coefficient is only applied to find any possible relationship between variables and the accurate relationship will be discussed by the analysis of the DEA results under the following sections.

The results of correlation analysis are presented through Table 5.1. To accomplish this analysis, the correlation of the inputs of every single bank (the horizontal row of the Table) was measured against the banks outputs (the vertical column).

Table 5.1: Correlations between Inputs and Outputs

		Deposits	Labor	Operating Expenses	Interest Expenses
ANZ	Loans	99	98	98	85
	Investments	30	15	15	61
	Operating Income	97	99	98	79
	Interest Income	93	89	87	97
NAB	Loans	95	98	-3	81
	Investments	45	23	81	-24
	Operating Income	86	78	32	46
	Interest Income	83	86	-23	97
CBA	Loans	98	95	88	96
	Investments	96	88	88	78
	Operating Income	91	93	82	89
	Interest Income	96	93	87	98
Westpac	Loans	99	99	96	86
	Investments	81	82	85	58
	Operating Income	99	99	97	86
	Interest Income	91	92	85	98

		Deposits	Labor	Operating Expenses	Interest Expenses
BOQ	Loans	98	94	95	98
	Investments	87	63	65	80
	Operating Income	95	95	97	95
	Interest Income	96	95	95	99
Suncorp	Loans	90	21	84	98
	Investments	77	10	82	92
	Operating Income	61	-30	92	82
	Interest Income	90	11	88	99
Macquarie	Loans	-73	-77	-75	-60
	Investments	44	29	33	22
	Operating Income	2	3	2	12
	Interest Income	96	96	97	100
St. George	Loans	75	94	92	85
	Investments	54	86	93	67
	Operating Income	70	99	96	81
	Interest Income	96	90	75	99

		Deposits	Labor	Operating Expenses	Interest Expenses
Bendigo & Adelaide	Loans	100	87	93	99
	Investments	-100	-86	-93	-99
	Operating Income	85	99	97	99
	Interest Income	99	94	98	94
Adelaide	Loans	93	85	92	98
	Investments	-65	-74	-65	-78
	Operating Income	100	66	74	96
	Interest Income	97	80	87	99
Bendigo	Loans	100	100	99	99
	Investments	-81	-81	-75	-81
	Operating Income	99	99	100	99
	Interest Income	100	100	99	100

The above results present that the inputs of the ANZ bank have high correlation coefficient with the outputs except deposits, labor and operating expenses that have small correlation with investments. For the NAB, there is a negative correlation between operating expenses and loans, interest expenses and investments and operating expenses and interest income. The rest of inputs are in a high correlation with outputs except deposits and labor

with investments as well as operating expenses with operating income that show a correlation coefficient of less than 50 percent. As has been explained above, negative or small correlations could be a result of the effect of a third variable and can be observed in Suncorp bank, Macquarie bank, Bendigo and Adelaide bank, Bendigo bank and Adelaide bank.

In Suncorp bank, labor has small correlation with loans, investments and interest income and has negative correlation with operating income. All of the inputs of Macquarie bank are in a negative correlation with loans of this bank and small correlation with investments and operating income. The rest of inputs and outputs of these two banks are highly correlated. All of the inputs of both Bendigo bank and Adelaide bank present high negative correlation coefficient with investments amount of these banks before they merged that cause the same correlation between the inputs and investments of Bendigo and Adelaide bank. There are high correlation coefficients between the inputs and outputs of CBA, Westpac, BOQ and St. George.

It is worth mentioning again that the above correlation analysis has been accomplished to preliminarily find any possible relationship among the studied data and because of the indirect relationships and effect of third variables, we cannot decide about the relationship of the variables. Therefore, the following sections present the DEA and Malmquist analysis to find out the efficiency and productivity of the studied banks by means of the specific inputs and outputs.

5.3 Efficiency of the Australian Banks

This section presents a discussion on the technical efficiency of the Australian banks over the period of 2004-2010 applying input-oriented CRS DEA model. Pure technical efficiency and scale efficiency are also analyzed as the two components of technical efficiency.

The required data for this analysis have been collected from the financial statements of the sample banks included in their annual reports published from 2004 to 2010. The sample for the first four years from 2004 to 2007 includes ten banks which are the Big Four (National Australia Bank, Commonwealth Bank, the Westpac and Australia and New Zealand Banking Group) and six regional banks (Bank of Queensland, Adelaide Bank, Bendigo Bank, St. George Bank, the Reserve Bank of Australia and the Macquarie Banking Group). Since the Bendigo bank and the Adelaide bank were merged in November 2007 to create Bendigo and Adelaide Bank, the sample for the period from 2008 to 2009 nine banks. Furthermore, the sample for 2010 reduced to eight banks due to the takeover of St. George Bank by the Westpac Banking Corporation on 1st, December 2008. As for 2009, St. George has published its own annual report separately from Westpac. However, in 2010, the St. George`s annual report was published as a part of Westpac annual reports.

Tables 5.2, 5.4 and 5.5 will exhibit the results of technical efficiency, pure technical efficiency and scale efficiency based on the three relevant approaches, production approach, intermediation approach and value- added approach. The results are obtained via solving equations (3.4) and (4.4) illustrated in Chapter Four and as can be observed, are different under different approaches.

Table 5.2: Average Technical Efficiency of Australian Banks, 2004-2010

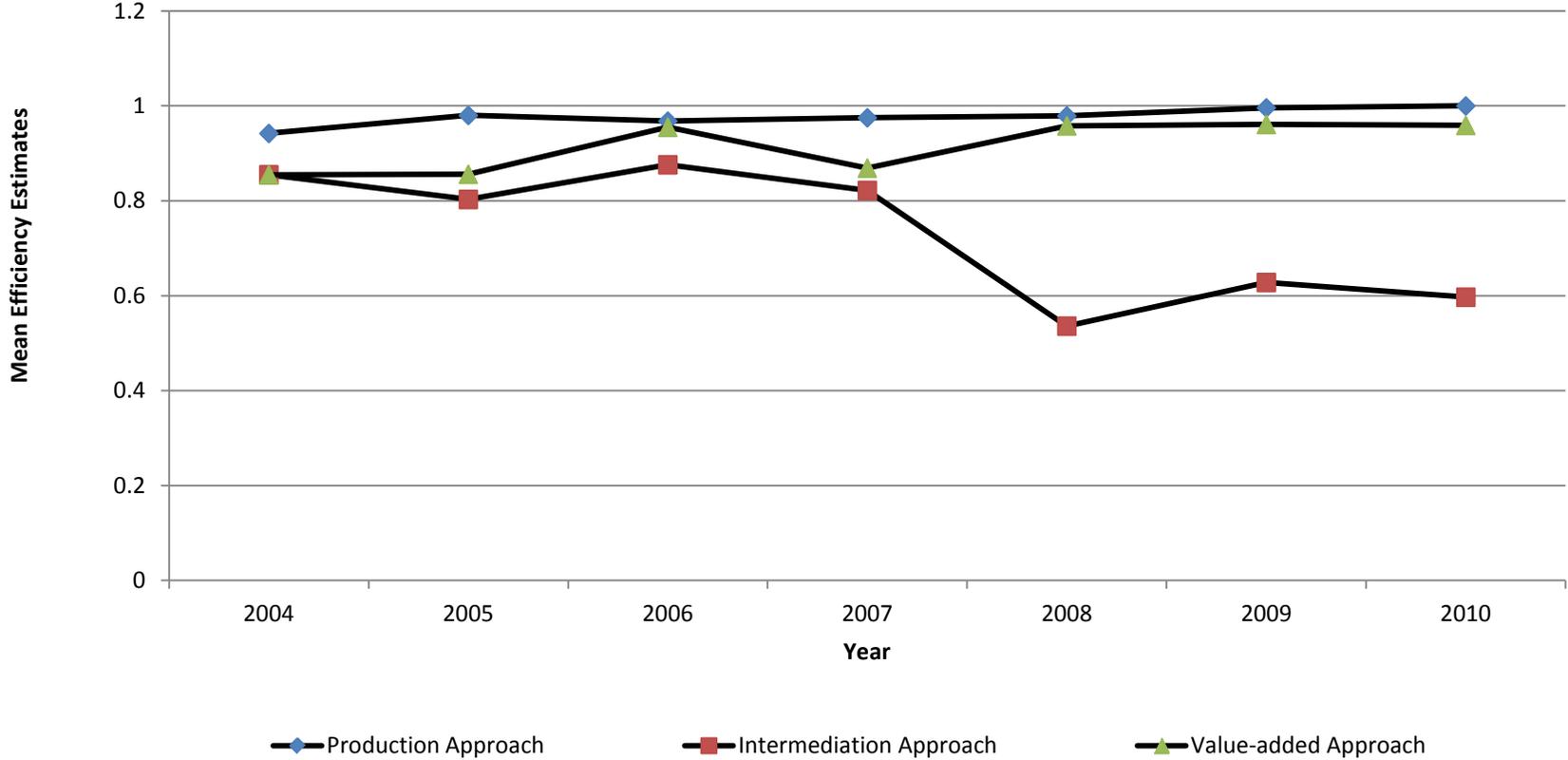
Year	Number of Institutions	Number of Efficient Institutions	Average Efficiency (E)	Average Inefficiency [(1-E)/E]
Production Approach				
2004	10	4	0.942	0.061
2005	10	5	0.98	0.02
2006	10	6	0.968	0.033
2007	10	6	0.975	0.026
2008	9	4	0.979	0.021
2009	9	6	0.996	0.004
2010	8	8	1	0
Average			0.977	0.023
Intermediation Approach				
2004	10	3	0.855	0.17
2005	10	2	0.803	0.245
2006	10	4	0.876	0.141
2007	10	5	0.822	0.216
2008	9	2	0.536	0.866
2009	9	2	0.628	0.592
2010	8	3	0.597	0.675
Average			0.731	0.415
Value-Added Approach				
2004	10	3	0.855	0.17
2005	10	3	0.856	0.168
2006	10	7	0.955	0.047
2007	10	4	0.869	0.151
2008	9	6	0.958	0.044
2009	9	6	0.961	0.041
2010	8	6	0.959	0.043
Average			0.916	0.095

Analysis of diverse sets of inputs and outputs under each approach will produce different results indicating the flexibility of DEA methodology. Based on the above results, banks are found to be more technically efficient under production approach (0.977) than the

average efficiency estimates under value-added approach (0.916) and intermediation approach (0.731), respectively. Under production approach, the mean efficiency (E) is about 98 percent entailing that the Australian banks have been performed fairly well over the studied period. This result could be due to the high rates of interest over this period since interest income has been considered as an output under production approach. The intermediation approach, on the other hand shows the lowest efficiency score for all banks. The mean value of E is almost 73 percent and the decrease of the resource consumption by the banks is 26 percent. Under this approach, the banks have exhibited considerably low average efficiency during the financial crisis. The reason is the considerable decline in the investments level (which is a specified output under intermediation approach) over the crisis. The results of the value-added approach show the mean efficiency of banks is 92 percent, indicating banks need to lessen the input usage for 8 percent through their output production. In fact, as observed in value-added approach, employing a larger number of inputs and outputs, will usually result in higher efficiency score. Through the literature, this issue is known as the ‘curse of dimensionality’ which means that some firms have many dimensions (i.e. inputs and outputs) (Das and Ghosh 2006).

Based on the data in Table 5.2, the trend of the mean technical efficiency of the Australian banks is illustrated in Figure 5.1 as follows.

Figure 5.1: Technical Efficiency of Australian Banks, 2004-2010



As shown in figure 5.1 above, the mean technical efficiency over the sample period shows the lowest trend under the intermediation approach. Based on the results of this approach, technical efficiency presented a smooth trend before the financial crisis. However, it dramatically dropped by the beginning of the Global Financial Crisis in 2007 through to the mid 2008. Since then the technical efficiency rose very slightly till 2009 but started to drop again to the year 2010. Under production approach, the Australian banks have experienced a very even trend since 2004 till 2010 considering a very small growth during the crisis from 2008 to 2010. Under value-added approach, there have been swings in the efficiency trend of the Australian banks from 2004 to 2008 and after that, this trend became constant till 2010.

Table 5.3 presents bank specific results for technical efficiency estimates under the production, intermediation and value-added approaches for the studied period. A best-practice firm shows an efficiency score of 1 and less efficient banks present efficiency score of less than 1. The lower the efficiency score is the less efficient the firm compared to other firms in the sample.

Table 5.3: Performance Trend of Australian Banks, 2004-2010

Approach/Year	2004	2005	2006	2007	2008	2009	2010	Average Efficiency (E)
Production Approach								
Suncorp Group	1	1	1	1	1	1	1	1
Bendigo	1	1	1	1				1
Adelaide	1	1	1	1				1
St. George Bank	1	1	1	1	1	0.978		0.996
Bendigo & Adelaide					0.977	1	1	0.992
West Pac	0.968	0.964	1	1	0.988	1	1	0.988
Australia & New Zealand Bank	0.977	0.956	1	1	0.963	0.988	1	0.983
Commonwealth Bank	0.982	0.993	0.989	0.979	0.944	0.994	1	0.983
National Australia Bank	0.89	0.959	0.973	0.99	1	1	1	0.973
Bank of Queensland	0.932	0.933	0.951	0.917	0.94	1	1	0.953
Macquarie Bank	0.671	1	0.765	0.865	1	1	1	0.899
Average	0.942	0.98	0.968	0.975	0.98	0.995	1	0.977
Intermediation Approach								
Suncorp Group	1	1	1	1	1	1	1	1
Adelaide	1	1	1	1				1
Commonwealth Bank	0.807	0.925	1	0.986	0.663	1	1	0.912
St. George Bank	0.936	0.847	0.723	0.723	0.704	0.828		0.786
Bendigo	1	0.66	0.628	0.661				0.737
Australia & New Zealand Bank	1	0.981	1	0.919	0.454	0.399	0.272	0.712
West Pac	0.99	0.936	0.919	0.997	0.243	0.34	0.447	0.696
Bank of Queensland	0.842	0.681	0.647	0.96	0.424	0.477	0.529	0.651
Macquarie Bank	0.173	0.122	1	0.127	1	1	1	0.632
National Australia Bank	0.807	0.877	0.84	0.892	0.197	0.301	0.315	0.604
Bendigo & Adelaide					0.138	0.308	0.214	0.220
Average	0.855	0.803	0.876	0.822	0.536	0.628	0.597	0.731

Approach/Year	2004	2005	2006	2007	2008	2009	2010	Average Efficiency (E)
Value-added Approach								
Suncorp Group	1	1	1	1	1	1	1	1
Bendigo	1	1	1	1				1
Adelaide	1	1	1	1				1
Bendigo & Adelaide					1	1	1	1
Commonwealth Bank	0.886	0.991	1	0.945	1	1	1	0.974
West Pac	0.973	0.878	1	1	0.953	0.989	1	0.970
Bank of Queensland	0.939	0.92	0.902	0.908	1	1	1	0.953
St. George Bank	0.939	0.914	0.876	0.988	1	1		0.953
Australia & New Zealand Bank	0.978	0.967	1	0.872	0.880	0.856	0.833	0.912
National Australia Bank	0.71	0.745	0.774	0.785	0.789	0.804	0.842	0.778
Macquarie Bank	0.129	0.142	1	0.188	1	1	1	0.637
Average	0.855	0.856	0.955	0.869	0.958	0.961	0.959	0.916

Note: Some cells are blank in the above table because the particular banks were not operating in the Australian financial sector during the respective year. Bendigo Bank and Adelaide Bank were merged by the end of 2007 and hence, there is no efficiency score for these banks since 2008 to 2010; the merger between Bendigo Bank and Adelaide Bank created the Bendigo and Adelaide Bank which started its operation since 2008. The St. George Bank was acquired by the Westpac and was not operating as an independent bank during 2010.

All the banks in Table 5.3 are sorted in a descending order based on the level of average efficiency score presented in the last column. Therefore, the most efficient banks are appeared at the top row under all three approaches.

The total average mean technical efficiency of the above Australian banks has been at the highest level (98 percent) under production approach whereas the average mean efficiency calculated under the value-added approach produced the second highest level of efficiency, amounting to 92 percent. On the contrary, the average efficiency score of the

banks studied calculated under the intermediation approach has amounted to 73 percent, showing the lowest level of efficiency among the three approaches used in this study.

As per the results shown in Table 5.3, under intermediation approach, Australian banks have exhibited a large disparity in their efficiency score ranging from only 12 percent to 100 percent. This immense diversity has not been presented under the other two approaches except for Macquarie Bank under value-added approach that reveals efficiency score of 1 in four years (2006, 2008, 2009 and 2010) and less than 20 percent in the rest (13 percent in 2004, 14 percent in 2005 and 19 percent in 2007). This divergence in the efficiency scores of Macquarie Bank might be as a result of very low price level of the labour, operating and interest expenses (which are the specified inputs under value-added approach) incurred by this bank.

The highest efficiency score of the Commonwealth Bank is around 98 percent which is obtained under the production approach. Under the intermediation approach the second highest mean efficiency score after the Suncorp Group and the Adelaide Bank belongs to the Commonwealth Bank which is 91 percent having efficiency level of 1 over the years 2006, 2009 and 2010. Its efficiency score under value-added approach has been 97 exhibited efficiency score of 1 in 2006, 2008, 2009 and 2010.

The mean efficiency score of the National Australia Bank (NAB) has been at its highest level under production approach (97 percent) compare to its level under intermediation approach (60 percent) and value-added approach (77 percent). Under production approach, the efficiency score of this bank presented an upward trend since 2004 to 2007 and then rose to 1 in 2008 to 2010 (during the financial crisis). However, under production approach, this bank exhibited efficiency score of around 80 to 90 percent from 2004 to 2007 but its efficiency dramatically fell to about 20 to 30 percent during the years

2008 to 2010. Under value-added approach, NAB has exhibited a rising trend of efficiency level throughout whole period studied.

The highest mean efficiency score of the Westpac has been obtained under production approach as at 99 percent and 97 percent value-added approach. This bank has presented large efficient scores under both production and value-added approaches during the whole studied period as well as the financial crisis. However, under intermediation approach, its efficiency level dropped dramatically from the efficiency score of approximately 1 in 2007 to 24 percent in 2008 and it has been low over the financial crisis until 2010. This bank scored the lowest efficiency level (70 percent) under intermediation approach rather than the other two approaches.

The highest efficiency score of Australia and New Zealand Bank (ANZ) has been achieved under production approach at 93 percent and its lowest level of efficiency has been achieved under intermediation approach which is 71 percent. Under intermediation approach, the ANZ exhibited very high level of efficiency since 2004 to 2007 (scores of 1 and 98 percent) but it dramatically fell to 45 percent in 2008 and experienced a descending trend during the financial crisis (efficiency score of 40 percent in 2009 and 27 percent in 2010). Under value-added approach, the efficiency level of the ANZ has exhibited a downward trend over the financial crisis; its efficiency score has been 1 in 2006 and then dropped to 87 percent in 2007, 88 percent in 2008, 86 percent in 2009 and 83 percent in 2010. Under production approach, the ANZ has experienced efficiency score of 1 in 2007 and 2010.

The Suncorp Group has been found to be the best-practice bank having mean technical efficiency score of 1 under all three approaches through the whole period studied.

The Bendigo Bank presented the mean efficiency score of 1 under both production and value-added approaches. Under intermediation approach, its mean efficiency score is 74

percent having efficiency score of 1 in 2004 which fell dramatically to 66 percent in 2005 and remained around the same level till 2007.

Before its merger with the Bendigo Bank, the Adelaide Bank is found to be the most efficient bank relative to other institutions under all three approaches. Like the Bendigo Bank, its efficiency score over the years from 2005 to 2007 has been 1.

Since the emergence of the Bendigo and Adelaide Bank in 2008, its efficiency score has been 1 until 2010 under value-added approach. After value-added approach the highest efficiency level of this bank has been exhibited under production approach which is 99 percent. The lowest mean efficiency score of the Bendigo and Adelaide Bank has been 22 percent under intermediation approach through which its efficiency scores have been very low (13, 31 and 21 percent) during its three years of operation.

Under all three approaches, the Macquarie Bank has presented the efficiency score of 1 during the financial crisis through the years of 2008, 2009 and 2010. The Macquarie Bank is found to be the least efficient bank among other banks in the sample under production approach and value-added approach with the mean efficiency score of 90 percent and 64 percent respectively. Throughout the studied period the efficiency scores of this bank have been very low under intermediation approach and value-added approach (less than 20 percent) over 2004, 2005 and 2006.

St. George is found to be more than 99 percent efficient in average under production approach which is its highest mean efficiency score compared to this level under value-added approach (95 percent) and intermediation approach (79 percent) over the six investigated years of its operation (2004-2009) before becoming a subsidiary of the Westpac. Under production approach, its efficiency score has been 1 for whole the studied period except in 2008 in which the efficiency level has been declined slightly to 98 percent. However, this bank has exhibited the efficiency score of 1 in 2008 and 2009 under value-added approach.

Under intermediation approach, St. George exhibited a descending movement since 2004 to 2008 but its efficiency score has been increased noticeably to 83 percent in 2009.

As shown in Table 5.3, the efficiency levels of the banks studied have been considerably high throughout the financial crisis under both production and value-added approaches. However, under intermediation approach, the banks efficiency has been dramatically declined over the financial crisis. As it has been explained earlier in the Chapter 4, the outputs under intermediation approach are loans and investments of the banks during the investigation period which are considered as the result of consumption of the deposits, labor and operating expenses as inputs. According to the data obtained from the financial statements of the studied banks, the amount of loans and investments has been considerably decreased over the sample period.

To better explicate the performance of the Australian banks included in the sample, Table 5.4 has presented the average technical efficiency of each bank during the sample period under all three approaches. The columns by the title of Rank show the efficiency position of each bank in the sample period under each approach.

Table 5.4: Ranking of the Australian Banks Based on the Average Technical Efficiency, 2004-2010

Financial Institution	Average Efficiency					
	Production Approach	Rank	Intermediation Approach	Rank	Value-added Approach	Rank
Suncorp Group	1	1	1	1	1	1
Bendigo	1	1	0.737	4	1	1
Adelaide	1	1	1	1	1	1
St. George Bank	0.996	2	0.786	3	0.953	4
Bendigo & Adelaide	0.992	3	0.220	10	1	1
West Pac	0.988	4	0.696	6	0.970	3
Australia & New Zealand Bank	0.983	5	0.712	5	0.912	5
Commonwealth Bank	0.983	6	0.912	2	0.974	2
National Australia Bank	0.973	7	0.604	9	0.778	6
Bank of Queensland	0.953	8	0.651	7	0.953	4
Macquarie Bank	0.899	9	0.632	8	0.637	7
Average	0.978		0.723		0.925	

As can be observed in Table 5.4, the Suncorp Group and the Adelaide Bank has been ranked as the most efficient banks under all three approaches. The St. George Bank has achieved the second rank under production approach, the third rank under intermediation approach and the fourth rank under value-added approach. The Bendigo and Adelaide Bank has obtained the first rank under value-added approach but the last under intermediation approach. This bank is found to be the third efficient bank under production approach. The

efficiency of the Westpac is at its highest level under value-added approach and obtained the third rank among other banks. Westpac is appeared to be the fourth efficient bank under production approach and the sixth under intermediation approach. The ANZ Bank has achieved the fifth rank under all three approaches which is almost in the middle point among the other banks in the sample. The Commonwealth Bank is found to be the second most efficient bank under intermediation and value-added approaches but the sixth efficient bank under production approach. Other banks namely the NAB, the BOQ and the Macquarie Bank are ranked between the sixth and ninth place under all approaches except the BOQ which has been appeared to be the fourth efficient bank under value-added approach.

One can immediately figure out that the level of investments by the studied Australian banks has been considerably declined during the financial crisis to the extent that the Macquarie Bank has not have any investment (investment = 0) during 2008, 2009 and 2010.

By applying the VRS DEA model (equation 4 in chapter 4), pure technical efficiency has been estimated and the obtained results of this model is presented through the Table 5.5 as follows.

Table 5.5: Average Pure Technical Efficiency of Australian Banks, 2004-2010

Year	Number of Institutions	Number of Efficient Institutions	Average Efficiency (E)	Average Inefficiency [(1-E)/E]
Production Approach				
2004	10	10	1	0
2005	10	10	1	0
2006	10	10	1	0
2007	10	10	1	0
2008	9	7	0.991	0.0091
2009	9	7	0.997	0.003
2010	8	8	1	0
Average			0.998	0.002
Intermediation Approach				
2004	10	8	0.978	0.022
2005	10	7	0.961	0.041
2006	10	7	0.964	0.037
2007	10	7	0.941	0.063
2008	9	5	0.904	0.106
2009	9	6	0.949	0.054
2010	8	5	0.891	0.122
Average			0.941	0.063
Value-Added Approach				
2004	10	8	0.93	0.075
2005	10	8	0.918	0.089
2006	10	9	0.985	0.015
2007	10	8	0.921	0.086
2008	9	8	0.999	0.001
2009	9	8	0.996	0.004
2010	8	7	0.998	0.002
Average			0.964	0.039

It is observed in the above table that banks have presented the highest average of pure technical efficiency (almost 100 percent) under production approach relative to the other two approaches. Under this approach, the average efficiency score of the banks examined has been 1 for all sample years except for 2008 and 2009 where it has varied slightly lower than 1. This level of pure technical efficiency has not been obtained under intermediation approach (with mean pure technical efficiency of 94 percent) and value-added approach (with mean pure technical efficiency of 96 percent). During the financial crisis, banks have had a downward trend of average pure technical efficiency under intermediation approach while their average pure technical efficiency has been high under production and value-added approaches over this period.

It is noteworthy that the number of efficient institutions is considerably varied under CRS DEA model (technical efficiency) and VRS DEA model (pure technical efficiency). This variation could be due to the existence of scale inefficiencies through the financial institutions.

Scale efficiency is obtained as a result of dividing technical efficiency (CRS DEA scores) by pure technical efficiency (VRS DEA scores). Table 5.6, presents the scale efficiency estimates of the investigated Australian banks over the studied period.

Table 5.6: Average Scale Efficiency of Australian Banks, 2004-2010

Year	Number of Institutions	Number of Efficient Institutions	Average Efficiency (E)	Average Inefficiency [(1-E)/E]
Production Approach				
2004	10	4	0.942	0.062
2005	10	5	0.98	0.02
2006	10	6	0.968	0.033
2007	10	6	0.975	0.026
2008	9	5	0.988	0.012
2009	9	6	0.999	0.001
2010	8	10	1	0
Average			0.979	0.022
Intermediation Approach				
2004	10	4	0.876	0.141
2005	10	2	0.837	0.195
2006	10	5	0.908	0.101
2007	10	2	0.878	0.139
2008	9	2	0.566	0.767
2009	9	3	0.648	0.543
2010	8	3	0.638	0.567
Average			0.764	0.35
Value-Added Approach				
2004	10	3	0.885	0.13
2005	10	3	0.899	0.112
2006	10	7	0.969	0.032
2007	10	4	0.933	0.072
2008	9	6	0.959	0.043
2009	9	6	0.965	0.036
2010	8	6	0.961	0.041
Average			0.939	0.067

Among the three approaches to the DEA technique, the Australian banks under investigation have exhibited the highest level of scale efficiency under production approach which is 98 percent and the lowest scale efficiency of 76 percent under intermediation approach. The average scale efficiency of the studied banks under intermediation approach has been considerably lower over the financial crisis than the other years (57 percent in 2008, 65 percent in 2009 and 64 percent in 2010). In 2008, banks have presented the least scale efficiency of 57 percent under intermediation approach.

5.4 Productivity Analysis

Malmquist indices of productivity change have been demonstrated in Chapter 4. The productivity changes of the Australian banks have been measured for 7 Australian banks over the period 2004/2005-2009/2010. Because of the mergers and acquisitions occurred in the Australian banking system over the studied period, some banks have not been existed in whole the period of investigation. Bendigo Bank and Adelaide Bank have been operating till 2007 and St. George till 2009 and on the other hand, the Bendigo and Adelaide Bank were created in 2008. Therefore, a different sample consisted of 7 banks (the NAB, ANZ, Westpac, Commonwealth Bank, BOQ, Macquarie Bank and the Suncorp Group) has been applied to measure the productivity changes of the Australian banks.

The other issue regarding this study is the suitable approaches to conduct the productivity measurement. Under production approach, the specified outputs are interest income and non-interest income. A non-interest loss (a negative figure for non-interest income) is appeared on the income statement of the Macquarie Bank in 2009. This negative figure is considered as a bad output and hence, could not be used by the software (DEAP, V. 2.1) to measure the productivity change of the Australian banks. For this reason, the production approach has been eliminated from our analysis at this stage and the productivity

change of the investigated banks has been evaluated under intermediation and value-added approaches.

Productivity movements over time arise as a result of enhancement in technical efficiency or scale efficiency known as catch-up effect, as well as technological changes which is frontier-shift. The changes in efficiency, technology and finally productivity of the examined Australian banks throughout the period 2004-2010 will be analyzed in this section. The results of the Malmquist indices under the three approaches, productivity, intermediation and value-added, have been summarized in Table 5.7.

The efficiency change, technical change, pure technical efficiency, scale efficiency and total factor productivity change are presented in Table 5.7. The investigated banks are sorted in the table based on the level of total factor productivity from the highest to the lowest shown in the last column to simplify the comparison of results.

Table 5.7: Malmquist Index Summary of the Australian Banks Means, 2004/2005-2009/2010

Bank/ Approach	Efficiency Change	Technical Change	Pure Technical Efficiency Change	Scale Efficiency Change	Total Factor Productivity Change
Intermediation Approach					
Macquarie Bank	1.34	1.595	1	1.34	2.138
Commonwealth Bank	1.036	1.174	1	1.036	1.217
Suncorp	1	1.149	1	1	1.149
Bank of Queensland	0.907	1.265	1	0.907	1.147
West Pac	0.874	1.271	1	0.874	1.111
National Bank of Australia	0.855	1.261	0.971	0.88	1.078
Australia & New Zealand Bank	0.805	1.178	0.96	0.838	0.948
Value-Added Approach					
Macquarie Bank	1.337	1.159	1.179	1.135	1.55
Suncorp	1	1.185	1	1	1.185
National Bank of Australia	1.038	1.041	0.997	1.041	1.081
Australia & New Zealand Bank	1	1.064	1	1	1.064
Bank of Queensland	1	1.054	1	1	1.054
West Pac	1	1.053	1	1	1.053
Commonwealth Bank	1	1.029	1	1	1.029

As explained above, changes in efficiency and technology will result in the movements in the total factor productivity and also, the overall efficiency movement is caused due to changes in pure technical efficiency and scale efficiency. The total factor productivity of greater / less than 1 indicates a productivity growth/loss, a rise/decline in efficiency or improvement/ corrosion in technology. As can be seen from the above table, employing different sets of inputs and outputs result in various efficiency scores for each institution.

The results obtained from Malmquist analysis under intermediation approach exhibit the maximum 14 percent growth of the total factor productivity by the Macquarie Bank from 2004 to 2010 and the ANZ Bank presented 5 percent decline in its productivity over this period. Only two banks have presented positive catch-up which are the Commonwealth Bank (4 percent) and the Macquarie Bank (34 percent) but all banks have shifted positively over their frontier. The level of negative catch-up of the banks have been found between 9 (the BOQ) and 19 percent (the ANZ). Four banks have presented regress in scale efficiency which are correspondingly the ANZ (16 percent), the NAB (12 percent), Westpac (13 percent) and the BOQ (9.3 percent).

All of the studied banks have presented productivity progress over the investigation period under value-added approach from the minimum change of 3 percent (the Commonwealth Bank) to the maximum of 55 percent (Macquarie Bank) which is mainly due their positive shift on the frontier. The minimum technical change has been presented by the Commonwealth Bank which is 3 percent and the maximum technical change has been 18 percent acquired by the Suncorp Group. On the other hand, only two banks have positively caught up with their frontier by the NAB (4 percent) and the Macquarie Bank (34 percent) and the other banks in the sample have been remained on their frontier and presented no change in their efficiency. The NAB and the Macquarie Bank have been the only two banks

presenting positive movement in their scale efficiency by 4 percent and 13 percent respectively and no change in the scale efficiency has been experienced by the other banks.

Under intermediation approach, the ANZ has presented a decline in its total factor productivity by 5 percent which is due to the negative movements of the efficiency, pure technical efficiency and scale efficiency. This bank has experienced 18 percent improvement in its technical progress. Under value-added approach, the technical change has been 6 percent and all other factors have been stable over the studied period leading to 6 percent change in the total factor productivity.

The total factor productivity of the NAB has been changed by 8 percent under intermediation approach which is the result of the poor efficiency, pure technical efficiency and scale efficiency over the investigation period. The technical progress of this bank has been improved by 26 percent. Under value-added approach, the NAB has presented positive catch up and frontier shifts and increased scale efficiency and 3 percent decline in the pure technical efficiency resulted in 8 percent productivity change.

The efficiency, pure technical efficiency and scale efficiency of the Westpac have been stable under value-added approach and only its frontier shift has been positive (5 percent rise) during the studied period resulted in 5 percent change in the total factor productivity of this bank. Under intermediation approach, this bank presented a positive movement on its frontier by 27 percent while, the efficiency and scale efficiency of this bank have decreased by 13 percent and the pure technical efficiency has been stable.

The Commonwealth Bank has presented the second highest change in the total factor productivity (22 percent) among all the banks under intermediation approach but the lowest under value-added approach (3 percent). This bank has exhibited positive change in its efficiency, technology progress and scale efficiency and a constant pure technical efficiency under intermediation approach. On the other hand, under value-added approach, the

Commonwealth Bank has presented only technical change and have been remained on its frontier for the other three items.

The Macquarie Bank has presented the maximum change in the total factor productivity among all the banks in the sample under both intermediation (114 percent productivity change) and value-added (55 percent productivity change) approaches. This bank has increased its efficiency, technology progress and scale efficiency under both approaches but its pure technical efficiency has been stable under intermediation approach.

Under value-added approach, the second highest score of productivity change has been obtained by the Suncorp Group which is 18 percent and is due to the only change in the technical progress of this bank by 18 percent since the other factors have been stable. This trend has been the same under intermediation approach and only the technical progress of the bank has been changed over the studied period leading to the total factor productivity change by 15 percent.

The BOQ has presented 9 percent decline in the efficiency and scale efficiency and 26 percent improvement in its technical progress resulted in 15 percent increase in the total factor productivity under intermediation approach. Under value-added approach, this bank has experienced 5 percent technical change but no movement in the efficiency, pure technical efficiency and scale efficiency resulted in 5 percent productivity change.

A glance at the Table 5.8 verified that the technological progress has been the most influential factor in the productivity growth of the studied banks whilst, the other factors posed negative impact on the banks productivity movement.

Table 5.8 displays the means for all of the banks in the sample in each year based on intermediation approach and value-added approach. The Malmquist averages of the whole period are calculated for each of the approaches.

Table 5.8: Malmquist Index Summary of Annual Means, 2004/2005-2009/2010

Bank	Efficiency Change	Technical Change	Pure Technical Efficiency Change	Scale Efficiency Change	Total Factor Productivity Change
Intermediation Approach					
2005	0.993	0.982	1.013	0.98	0.975
2006	1.319	1.174	0.998	1.322	1.549
2007	0.758	1.175	0.998	0.759	0.891
2008	0.67	0	0.972	0.689	0
2009	1.18		1.005	1.175	
2010	1.006	1.046	0.957	1.051	1.052
Mean	0.961	1.263	0.99	0.971	1.214
Value-added Approach					
2005	1.03	0.901	0.963	1.07	0.928
2006	1.263	1.263	1.169	1.081	1.27
2007	0.82	1.295	1.295	0.931	1.061
2008	1.198	1.144	1.162	1.031	1.37
2009	1.032	0.932	0.994	1.038	0.961
2010	1.006	1.286	1.003	1.002	1.293
Mean	1.048	1.082	1.023	1.024	1.134

Note: The change in the technical progress and total factor productivity could not be measured through the year 2009 because these factors did not change during the previous year.

Under intermediation approach, the Australian banks have presented 4 percent decline in the mean efficiency over the studied period which is as a result of poor efficiency over the years 2005, 2007 and 2008. The maximum improvement in the efficiency of these banks has been 32 percent obtained in 2006 and the minimum of 0.6 percent in 2010. The technical change of the studied banks has been positive in 2006, 2007 and 2010 and has been reduced by 2 percent in 2005. The Australian banks have exhibited no technical change over 2008 and

their mean technical change was 26 percent. The pure technical efficiency of the studied banks have been fairly low in whole the period except 2005 and 2009 in which the banks presented very slight increase (1 percent and 0.5 percent respectively) in the pure technical efficiency resulted in the 1 percent decline in the average pure technical efficiency. As well, a 3 percent decline has been exhibited in the average scale efficiency of the banks which is the consequence of their poor scale efficiency over the years 2005, 2007 and 2008 beside the 32 percent increase in 2006, 17 percent growth in 2009 and 5 percent rise in 2010. The average change in the total factor productivity has been 21 percent during the studied period. The total factor productivity of the banks has not been changed in 2008 and 2009 and it has been decreased by 2.5 percent in 2005 and 11 percent in 2007.

Under value-added approach, the efficiency, technical progress, pure technical efficiency, scale efficiency and total factor productivity of the studied banks have been raised in average over the whole period under study. The efficiency movement of the banks have been always positive (from the low of 0.6 percent in 2010 to the high of 26 percent in 2006) excepting the 18 percent decline presented in 2007. As well, the banks have positively shifted on their frontiers during all the studied years (from the minimum of 14 percent in 2008 and the maximum of 29 percent in 2007) except for the 10 percent decline in 2005 and 7 percent decline in 2009. The same as the technical changed that has been reduced in 2005 and 2009, the pure technical efficiency of the banks has also been decreased in the same years by 4 and 0.6 percent respectively. The Australian banks in the sample have experienced a fair growth in their pure technical efficiency in the rest of the period and 2 percent rise in the mean pure technical efficiency. The average scale efficiency of these banks has been raised by 2 percent as a result of less than 10 percent growth during the studied period and 7 percent decline in 2007. The total factor productivity of the banks has been increased in average by 13 percent.

The total factor productivity of banks has been declined by 7 percent in 2005 and 4 percent in 2009 but it has been raised over the other years.

A glance at the Table 5.8 reveals that under value-added approach, all the items have been increased more than the rise under intermediation approach. However, the total factor productivity change of the Australian banks in the sample under intermediation approach presents a growth of 8 percent more than its change under value-added approach.

5.5 The Relationship between the Institutional Size and its Efficiency

By applying a univariate approach, the determinants of efficiency will be evaluated by cross-tabulating it to the size of the financial institutions in the sample. In the present study, the size of the each bank is determined by the value of its total asset appeared on the balance sheet. Table 5.9 has classified the studied Australian banks into two categories:

- Category A: small banks with the total asset of less than AUD\$100000 million
- Category B: large banks with the total asset of more than AUD\$100000 million

It should be noted that this classification is entirely subjective and has been chosen by the author and any other kind of categorization could be also applied.

Table 5.9: Technical Efficiency and Institution Size, 2004-2010

Year	Asset size Categories	
	A	B
Production Approach		
2004	0.934	1
2005	0.989	1
2006	0.953	0.999
2007	0.964	1
2008	0.983	1
2009	0.966	1
2010	1	0.998
Average	0.97	0.999
Intermediation Approach		
2004	0.845	0.91
2005	0.718	0.974
2006	0.833	0.977
2007	0.737	0.974
2008	0.653	0.934
2009	0.765	0.939
2010	0.702	0.878
Average	0.75	0.941
Value-Added Approach		
2004	0.835	0.986
2005	0.829	0.966
2006	0.963	0.963
2007	0.848	0.967
2008	1	1
2009	1	0.986
2010	1	0.996
Average	0.925	0.981

Note: A = Total assets > AUD\$100000 m; B = Total assets < AUD\$100000 m

According to the Table 5.9, the average technical efficiency of both groups has been at its highest level under production approach than the other two approaches. Under production approach, the small banks have exhibited a slight lower efficiency score during whole the studied period except in 2010 through which the large banks (which are the Big 4) have been only 0.2 percent less efficient than the small banks. The average technical efficiency of the small banks has been 3 percent lower than the large banks.

The efficiency scores of the studied bank of both groups are lower under intermediation approach compare to the other two approaches. The small banks have presented the technical efficiency level from the minimum of 65 percent in 2008 to the maximum of 84 percent in 2004. Under this approach, the small banks have been considerably less efficient (with the mean technical efficiency of 75 percent) than the large banks (with the mean technical efficiency of 94 percent).

Under value-added approach, the small banks have been more efficient than the large banks in 2009 and 2010. Both groups presented efficiency score of 1 in 2008 and from 2004 to 2007, the efficiency level of the small banks has been less than the efficiency level of the large banks. The mean technical efficiency of the large banks is 6 percent higher than the mean technical efficiency of the small banks.

5.6 Summary

The technical efficiency and productivity change of the Australian banks have been empirically analyzed applying the DEA method during the period 2004-2010. Three alternative approaches to DEA model, i.e. production approach, intermediation approach and value-added approach have been applied to appraise the sensitivity and strength of the results.

The obtained results indicate that the overall efficiency of the studied banks have been at the highest level under production approach and at the lowest level under

intermediation approach. Under value-added approach, the banks were found to be less efficient than under the production approach. The banks technical efficiency has been persistently raised during the global financial crisis, 2007 to 2009, under the production approach. Under the value-added approach, the studied banks exhibited 10 percent efficiency growth since 2007 to 2010, throughout and after the crisis.

Table 5.3 revealed that under both production and value-added approach, the Bendigo and Adelaide bank (that has been created in 2008) as well as the Bendigo bank and Adelaide bank before their merger have been noticeably efficient. But under intermediation approach, the Bendigo and Adelaide bank has been the lowest efficient bank among all other banks in the sample that is attributable to the low level of investments and borrowings during the crisis.

The technical efficiency of the studied banks has been decomposed into its components, pure technical efficiency and scale efficiency which are presented in Tables 5.5 and 5.6. Under all three approaches, banks exhibited considerably high pure technical efficiency. Their scale efficiency has been also high under production and value-added approaches and very low under intermediation approach. This outcome is consistent with the results obtained in the work of Rangan et al. (1988), Favero and Papi (1995), Taylor et al. (1997), Sathye (2001), Drake (2001) and Neal (2004) (see Chapter 3).

The Malmquist index has been utilized to measure the productivity movement of the Australian banks in the sample under intermediation approach and value-added approach. The production approach is excluded from this analysis because of the non-interest loss occurred by the Macquarie bank in 2009 which is a bad input. Another issue regarding this analysis is the number of studied banks. Because of the merger between the Bendigo bank and Adelaide bank and creation of the Bendigo and Adelaide bank as well as the acquisition of the St. George bank by the West Pac, these banks have not been operating from the

beginning or till the end of the studied period and therefore, the productivity change of 7 banks could be explored. As presented in Tables 5.7 and 5.8 the Australian banks included in the sample have exhibited total productivity growth over the investigation period under both intermediation and value-added approaches.

It is obvious that under both intermediation and value-added approaches, the productivity growth of the banks has been mostly due to the technological progress throughout the studied period. The investigated banks exhibited constant or decreased pure technical efficiency and scale efficiency as well as the decline in the efficiency over the sample period under intermediation approach; excepting the Macquarie bank and Commonwealth bank that presented a slight growth in their efficiency and the Suncorp bank showing no efficiency movement. Under value-added approach, the Macquarie bank has exhibited positive movement in all the factors of the total productivity and the NAB has been positively catching up with its frontier and presented a rise in its scale efficiency. However, the other banks in the sample have only positively shifted through their frontier and other factors of their total productivity have been remained constant.

Table 5.8 has summarized the annual movements of the banks average productivity. The results exhibited a decline in the mean productivity change during the financial crisis since 2007 to 2009 under intermediation approach and productivity growth under value-added approach except in 2005 and 2009 that has been reduced. To evaluate the relationship between the size of the financial institution and its efficiency, the banks in the sample are classified into two categories based on their total asset size appeared on their balance sheet. According to the results presented in Table 5.9, the banks included in the Category A, i.e. the Big 4, have been more efficient than the other banks in Category B under all three approaches throughout the sample period. Though, the major banks (the Big 4) have been found to be less efficient than the other banks during 2009 and 2010 under value-added approach.

Chapter 6 : Policy Implications and Conclusion

6.1 Introduction

Efficiency and productivity of the financial sector is an essential factor in the in the context of economic growth. It has been claimed that Australia has not experienced a severe domestic financial crisis during the global financial crisis 2007 (see for example Pomfert 2009 and Perlich 2010). However, since the global crisis Australian financial sector seems to be faced with major problems which includes low interest rates leading to the decline in the level of investments, the instability of offshore markets affecting the funding capacity of the banks, increased concentration in the banking industry and the application of the G20's international regulatory response to the financial crisis.

Taking into account of all the issues mentioned above, the present thesis aimed at empirically examining the efficiency and productivity of the Australian banks throughout the recent global financial crisis on an analysis based on DEA technique. The findings obtained through the study will address the following five questions: (1) what is the mean efficiency score of the major Australian banks (Big 4) and the regional banks? (2) What is the total factor productivity change for these banks? (3) How did the efficiency and productivity of the Banking System affect by the Global Financial Crisis 2007? (4) Have the mergers and acquisitions occurred in the Australian banking system been successful in improving the efficiency and performance of the banking sector? And (5) what is the effect of institutional size on the efficiency of the banks?

This study attempts to answer these questions through an examination of the efficiency level of the Australian banks on Data Envelopment Analysis (DEA) and the extent of change in the banks productivity on the basis of Malmquist indices. The DEA method, a non-parametric approach, is favored to conduct the present study considering its various

advantages relative to parametric approaches explained in Chapter 4. Furthermore, in order to evaluate the sensitivity and strength of the results, three commonly used approaches—production approach, intermediation approach and value-added approach—are used in this study.

The rest of the chapter is organized as follows: Section 6.2 provides a summary of the major conclusions based on the findings of the study illustrated in the previous chapter. Section 6.3 underlined policy implications. The explicit contributions made by the present research will be highlighted through Section 6.4. Limitations of this study will be presented in Section 6.5 and the final section will provide direction for future research.

6.2 Findings

The main findings of this study are as follows:

- **The efficiency level of the Australian banks:**

According to the obtained results illustrated in Chapter 5, the yearly technical efficiency of banks appeared to be at its highest level under production approach and lowest level under intermediation approach. The mean technical efficiency of the Australian banks under value-added approach has been slightly lower than the mean efficiency level under production approach despite the results of the study of Das and Ghosh (2006) acquiring the highest efficiency scores under value-added approach. According to the results, the pure technical efficiency of all the studied banks has been very high under all three approaches. Scale efficiency of the banks has been also high under production and value-added approach but much lower under intermediation approach. Hence, most of the banks inefficiency (specifically under intermediation approach) could be due the scale of their operations as well as the under utilization of resources. According to the relevant literature in chapter 3, the

same consequence has been obtained through the studies of Rangan et al. (1988), Favero and Papi (1995), Taylor et al. (1997), Sathye (2001), Drake (2001) and Neal (2004).

- **Level of productivity changes for the studied banks:**

Exploring the productivity changes of the Australian banks included in the sample exhibited positive movements through the investigation period under both intermediation and value-added approaches. To do the productivity analysis applying the Malmquist indices, the production approach could not be employed due to the existence of bad output (non-interest loss occurred by the Macquarie bank in 2009). In addition, the productivity change of 7 banks that have been operating throughout the whole studied period could be explored (the Bendigo Bank, Adelaide Bank, the Bendigo Bank and Adelaide Bank and the St. George Bank are the banks excluded from the productivity analysis). The productivity growth of the banks under both intermediation and value-added approaches has been mainly due to the technological progress throughout the studied period. The studied banks have experienced a decline in the mean productivity change during the financial crisis since 2007 to 2009 under intermediation approach. On the other hand, productivity of the studied banks has been raised during the sample period under value-added approach except in 2005 and 2009 that has been reduced.

- **Impact of GFC on the efficiency and productivity of the Banking System:**

Throughout the financial crisis, the period of 2007-2009, the banks technical efficiency exhibited constant growth under production approach. Under value-added approach, the technical efficiency of the studied banks has been raised around 10 percent from 2007 to 2008, by the early period of the crisis and remained fairly high during and after the crisis in 2010. However, under intermediation approach, the technical efficiency has dramatically declined from 82 percent in 2007 to 54 percent in 2008 and has been at a low level till 2010, during and after the crisis. As explained earlier in chapter 5, the amount of investments and loans, which are the selected outputs under intermediation approach,

considerably decreased. The major reason for this decline is the low rates of interests during the financial crisis. This outcome is similar to the results obtained by Anayiotos et al. (2010) in the efficiency measurement of 125 commercial banks in fourteen emerging European countries over and after the financial crisis 2007. They applied asset approach to the DEA methodology and found that the efficiency of banks was increasing before the crisis and dropped over the crisis (see chapter 3).

- **Effectiveness of the mergers and acquisitions in improving the efficiency and performance of the banking sector:**

Assessing the annual performance of each bank (Chapter 5, Table 5.3) revealed the noticeably high technical efficiency of Bendigo and Adelaide bank (that has been started to operate in 2008) as well as the Bendigo bank and Adelaide bank before their merger under both production and value-added approach. But under intermediation approach, the mean technical efficiency of Bendigo and Adelaide bank has been the lowest among all other banks in the sample. It's much low efficiency could be attributed to the low level of investments and borrowings during the crisis.

- **The effect of institutional size on the efficiency of the banks:**

The banks included in the sample have been categorized into two groups based on their asset size (total assets appeared on the balance sheet) to assess the relationship of institutional size and the firms technical efficiency. The results presented in Table 5.9 in chapter 5 declare that the four major banks (Category A) have been more efficient under all three approaches and during the whole investigation period. However, under value-added approach, the Big 4 have performed a slightly less efficient than the other banks in 2009 and after the financial crisis in 2010.

6.3 Policy Implications

Inefficiency of the financial institutions entails various implications. Inefficiency may lead to the waste of resources in the economy. In case of banks, the inefficiency will cause the misuse of resources in the banking system as well as in the various economic sectors in which these institutions distribute funds. In addition, the inefficiency of an institution will not only affect its profitability, but also its endurance in a competitive environment. Therefore, policy makers will be required to create circumstances providing opportunity of growing efficiency and productivity for the financial institutions.

Based on the results obtained from the efficiency analysis under production and value-added approach, one can find out that the mergers and acquisitions happened in the Australian banking industry have had positive effect on its efficiency growth. The specified inputs under both production and value-added approaches are interest expenses and operating expenses. Since there are economies of scale in fund management activities, the transaction costs will be decreased by the enlargement of the institution size. Due to this fact, the Wallis committee recommended the regulators to encourage the mergers in the banking industry (Valentine 2011).

Have a look at the efficiency results based on the institution size in Table 5.9, presents a slight difference (either lower or higher) between the two groups of banks. Therefore, the present study recommends the Big 4 banks following the Four-Pillar policy and not to become larger. Since this policy improves the financial stability by eradicating the possibility of takeovers between the major banks (Gruen 2009).

6.4 Limitation of the Study

This study can be expanded on quite a few aspects. The first limitation of the present study could be due the bad debts which are not reported by the banks. This may lead to achieve high efficiency scores by the banks which are not precise.

The DEA technique evaluates inefficiency of a particular firm relative to the similar firms and does not attempt to correlate a firm's performance with statistical averages. Hence, the possible outliers associated with this method might influence the empirical findings, specifically in case of studies with small sample size like the present study. In addition, it is not possible to measure the errors through the DEA-based methods incorporated in this thesis.

Due to the insufficient data, the present study does not involve the nondiscretionary factors. Therefore, it would be difficult to understand the grounds of changes in efficiency and productivity of the financial institutions.

The univariate approach does not properly illustrate the correlation of the banks efficiency with their financial factors. However, because of the small sample size in this study, a multivariate analysis of the efficiency determinants cannot be conducted. Besides, the selected sample in this study is constituted of the Australian-owned banks which have been operation in the Australian financial system for more than 15 years (except the Bendigo and Adelaide Bank). Therefore, only the size factor has been evaluated relative to the banks efficiency as a determinant of efficiency and the link of other factors like the ownership and age of the institutions to their performance cannot be assessed.

6.5 Future Research

The findings and limitations of this thesis provides various grounds for further research to better analyzed the effect of the global financial crisis on the financial sector of Australia as well as other countries using both DEA models or frontier approaches.

As explained earlier in Section 6.4, there is no allowance to measure the errors when the DEA-based approaches are utilized. On the other hand, the Malmquist index can be generally applied in other frontier analyses such as the stochastic frontier analysis (SFA) to measure the productivity change of the firms. But it has rarely been done as stated by Worthington (2000) and hence, could be of a significant issue for future studies.

To incorporate the other banks operating in the Australian financial sector, will provide the opportunity to conduct the broader and hence more precise investigation on the efficiency and productivity of the Australian banks. Furthermore, the influence of different determinants in the banks efficiency can be assessed when a greater number of banks are included in the sample.

As explained earlier in this study, the numerous financial crises are the consequences of rapid financial growth all over the world. It might be beneficial to compare the situation of financial sectors of various countries over the various financial crises (preferably the post 1990s crises) in order to find superior policies and procedures to cope with the future crises.

6.6 Conclusion

The recent global financial crisis has posed changes in the efficiency and productivity of the Australian banks in the sample studied. As mentioned in Chapter 2, it has been argued through the previous literature that the Australian banks have outperformed the banking sectors of other homogenous economies during the recent financial crisis. However, there has

been no empirical study on the performance of the banking system of Australia during and after the crisis.

As it can be observed through the analysis, the efficiency scores of the studied banks have been found to be at different levels by the analysis of different mixes of inputs and outputs under each approach. The main point of this analysis is that considerable decline in the investment level due to the low interest rates over the crisis era, has importantly affected the banks efficiency under intermediation approach. In addition, through the analysis of the productivity movements of the studied banks, the enhancement of technology in the banking system has been the most important factor in the productivity growth of the banks while, other factors have had negative impact or exhibited no change during the investigation period.

In conclusion, the present thesis has made the following contributions to the literature:

- as observed through the relevant literature, there is no empirical study on the consequences of the recent global financial crisis (2007-2009) by the means of DEA methodology. Therefore, this thesis would be the first study in this context;
- this is the first study to analyze the efficiency and productivity of the Australian banking industry before and after the financial crisis;
- the effects of the recent mergers and acquisitions through the Australian banking sector have been evaluated for the first time through the present study.

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