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A Comparison on the Efficiency of South African and Chinese Banks

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A Comparison on the Efficiency of South African and Chinese Banks

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A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Business Administration.

Johannesburg, March 2011

ABSTRACT

Policy makers and regulators have been concerned with the issue of how efficiently banks transform their various inputs into multiple financial products, because efficiency in the banking sector is considered a precondition for macroeconomic stability (Ngalande, 2003). Bank efficiency is the comparison of what is actually produced, with what can be achieved with the same consumption of resources (Farrel, 1957). Berger, Hunter and Timme (1993) reviewed the research on bank efficiency and concluded that econometric approaches are more appropriate in determining bank efficiency.

The purpose of this study is to investigate bank profit efficiency and cost efficiency in South Africa and China, and to identify the differences and changes in bank efficiency between the two countries.

The study uses an econometric approach to determine bank efficiency in South Africa and China. The econometric model is based on the specification developed by Battese and Coelli (1995). Bank efficiency includes profit efficiency and cost efficiency. Different models have been developed in this research.

Both profit efficiency and cost efficiency were found to have remained at the same level over the period for all sampled South African and Chinese banks. Advances to customers and banks, investment securities and total equity were found to be the most significant variables in profit model. Deposits and current accounts owned by customers were among the least significant parameters and not an important factor in determining a bank's profit efficiency. In the cost-efficiency frontier model, advances to customers and banks, as well as investment securities were the most significant variables, while total equity was least significant.

When comparing South African and Chinese banks, no significant difference was identified on either profit or cost efficiency.

DECLARATION

I, Zhanqing Chen, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Zhanqing Chen

Signed at ……

On the …….. day of …… 2011

DEDICATION

This study is dedicated to

my grandparents and parents.

ACKNOWLEDGEMENTS

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- Professor Gregory Lee, my supervisor, for his invaluable time and guidance on my research study;
- My wife, Peipei Chen, for her support and sacrifice; and
- All the friends who assisted me with data collection and the choice of econometric and statistical tools.

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CHAPTER 1: INTRODUCTION

Bank efficiency is the comparison of what is actually produced with what can be achieved with the same consumption of resources (Farrel, 1957). A higher degree of efficiency in banking systems can contribute to greater financial stability, product innovation and access by households and firms to financial services, which in turn can improve the prospects for economic growth (Hauner & Peiris, 2005). Research on bank efficiency increased dramatically in the 1990s. Berger and Humphrey (1997) count 130 studies on the efficiency of financial institutions in 21 countries and find 116 of them were published in the years 1992 to 1997.

Bank efficiency is usually measured by financial ratios and figures, such as cost-to-income ratio. While this is useful, using financial ratios and figures as a sole measure of efficiency has been criticised by many researchers (Berger & Humphrey, 1997). Berger, Hunter and Timme (1993) reviewed research studies on bank efficiency and conclude that econometric approaches are more appropriate in determining bank efficiency. Econometric approaches usually develop separate models for profit efficiency and cost efficiency (Shephard, 1970).

According to Fuentes and Vergara (2003), econometric measures of efficiency are the actual level of profit or cost relative to an efficient profit or cost frontier. This represents the bank's ability to transform inputs to outputs and shows deviations from the best-practice frontier.

1.1 Purpose of the study

The purpose of this research is to investigate and compare bank efficiency in South Africa and China, and to identify the development of this construct over time.

1.2 Context of the study

Policy makers, regulators and managers are concerned with the issue of how efficiently banks transform their various inputs into multiple financial yields, because banking-sector efficiency is considered a precondition for macroeconomic stability (Ngalande, 2003). It is also important for effective monetary policy execution, as efficient allocation has positive implications for economic growth (Hartmann, 2004).

While there has been a rapidly growing literature on banking efficiency issues in industrial countries, little attention has been paid so far to the efficiency of banks in developing countries (Hauner & Peiris, 2005).

In the example of South Africa, Siyaka (2006) believes that research done by Oberholzer & Merwe (2004) on South African banks was narrow in scope in that it investigated efficiencies of ten branches of the same bank. Research studies done by Bedari (2004) and Ikhide (2000) used South African banks for comparison purposes, only. To fill in the gaps, Siyaka's study (2006) investigates the efficiency of South African banks.

The recent boom in China-Africa business activity has lead to a strong growth in demand for banking services, and cooperation between Chinese and African banks as a result (Bond, 2010). In March 2008, the Industrial and Commercial Bank of China (ICBC) – the largest bank both in China and the world – acquired 20 percent of Standard Bank Group's share capital at a cost of USD 5.5-billion. This made ICBC the Group's largest shareholder (Standard Bank, 2009). In July 2009, FirstRand signed a strategic cooperation agreement with China Construction bank for their China-Africa corridor business (Moss, 2009).

In the opinion of Bond (2010), medium-term outlook supports continuation of the trends that have driven the strong growth in China-Africa business activity over the past decade. Banks that can provide banking solutions that seamlessly link African branch networks with Chinese banking systems will succeed in this growing market (Bond, 2010).

However, no research was found on investigating and comparing bank efficiency between South Africa and China. It would be meaningful to investigate and compare bank efficiency in developing countries with close economic cooperation. The rapid growth of trade and investment between the two countries will put more values on the study.

The study uses an econometric approach to determine bank efficiency in South Africa and China. The econometric model is based on the log-likelihood function developed by Battese and Coelli (1995). The efficiency was broken down to profit efficiency and cost efficiency, and two separate models were developed respectively.

To get bank profit and cost-efficiency figures, the inputs and outputs of each bank were applied to the models. Statistical analyses and tests were conducted to determine the development of efficiency figures.

1.3 Problem statement

1.3.1 *Main problem*

An investigation of bank profit efficiency and cost efficiency in South Africa and China for the period 2002 to 2009, with particular reference to differences and changes in bank efficiency between the two countries.

1.3.2 *Sub-problems*

The first sub-problem is to determine whether there has been a change in profit and cost efficiency at South African banks over the period 2002 to 2009.

The second sub-problem is to determine whether there has been a change in profit and cost efficiency at Chinese banks over the period 2002 to 2009.

The third sub-problem is to determine whether profit and cost efficiency between South African and Chinese banks were significantly different from 2002 to 2009.

1.4 Significance of the study

This study fills a gap in that the bank efficiency of two major developing economies in Africa and Asia, which have a close level of economic cooperation, is now being measured from profit and cost perspectives.

The study also provides insights on the comparison of efficiency between South African banks and their Chinese counterparts, as well as the relationship between profit efficiency and cost efficiency.

The study will provide guidance to bank management, regulators, researchers and analysts. Berger & Humphrey (1997) believe that evaluating the performance of financial institutions can inform government policy by assessing the effects of deregulation, mergers and market structure on efficiency.

As more cooperation between China and Africa is expected, banks from South Africa – as the leading banks in Africa – will lead the cooperation (Bond, 2010). This study will provide in-depth knowledge to those who need to understand bank efficiency in the two countries.

By identifying best and worst practices measured by efficiency, bank managers can improve managerial performance (Fuentes & Vergara, 2003). It will help them to understand how efficiency has been affected by economic, regulatory and competitive factors (Berger, Clarke, Cull, Klapper & Udell, 2005). Based on analysing the past, the study should help bank managers when they face similar issues in the future and will allow them to take proactive measures to improve efficiency.

1.5 Delimitations of the study

- The study uses econometric theory and models to analyse bank efficiency. By doing so, it will alleviate the limitations of financial ratios and figures, and will present a full view and analysis of bank efficiency.

- The study includes major South African and Chinese banks. By doing so, factors related to bank size will be excluded because all banks are large enough.

- The study lists the banks included, to make sure of the availability and reliability of the financial data.

- The study uses the data of fully-fledged large banks in South Africa and China to eliminate the effect of different business models used by small banks, which may distort the analysis.

- Some banks don’t have a full eight years of financial data available, i.e. the data is unbalanced panel data. Only models and tools that support unbalanced panel data have been considered for the study.

1.6 Definition of terms

The following terms are discussed in this research. For a better understanding of this research, definitions of terms that are used extensively are provided. Well-known terms in the finance and banking industries are not defined here. Terms that are used occasionally are defined or explained at first use.

- Profit efficiency: it measures how close a firm is to producing its maximum possible profit, given a particular level of input prices and output prices (Mester, 2003).

- Cost efficiency: it measures how close a firm's cost is to what a best practice bank's costs would be for producing the same output bundle under the same conditions (Mester, 2003).

- Scale efficiency: efficiency related to scale economies. It refers to how a firm's scale of operations (its size) is related to cost, i.e. what percentage increase in cost relates to a one-percent increase in scale (Mester, 2003).

- Scope efficiency: efficiency related to scope economies. It refers to how a firm's choice of multiple product lines is related to cost. A firm producing multiple products enjoys scope efficiency, if it's less costly to produce those products together than it would be to separate production into specialised firms (Mester, 2003).

- X-efficiency: it measures how productive the firm is in use of inputs to create outputs. If a firm is producing the maximum output it can, with the given resources, it is said to be x-efficient. Firms that exhibit x-inefficiency are either wasting some of their inputs (technical inefficiency), or are using the wrong combination of inputs to product outputs (allocative inefficiency), or both (Mester, 2003).

1.7 Assumptions

- Financial data downloaded from bank websites is reliable and correct.

- All banks prepare financial statements in accordance with International Financial Reporting Standards (IFRS) and understand IFRS in the same way, thus making data comparable.

- This study uses panel data and assumes that inefficiency varies across the observations and over time, therefore use of the stochastic econometric frontier approach is appropriate.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

While financial ratios are widely used in measuring bank efficiency, they have certain limitations (Yeh, 1996). Therefore, a measure that incorporates all banks' available input and output data will be meaningful and the econometric approach attempts to do this (Yeh, 1996). Under the econometric approach, efficiency is measured by comparing the actual level of cost or profit with an efficient frontier (Fuentes & Vegara, 2003). The frontier establishes the optimum benchmark against which deviations are calculated.

Berger, Hunter and Timme (1993) indicate that four different econometric approaches have been developed in literature, each of which maintains a different set of assumptions about probability distributions of inefficiency and random error. The choice of measurement method will affect the level of measured efficiency (Berger *et al* 1993). A professional note from Berger (1994) asserts that the most important efficiency is X-efficiency, which can apply to both profit and cost, and the stochastic frontier approach is the most appropriate to measure X-efficiency.

The first part of the literature review focuses on the background information of bank efficiency. It starts with background information covering common efficiency concepts and approaches that measure bank efficiency. It also introduces different econometric approaches and models that can be applied to the measurement of bank efficiency. After this background information, the literature review will focus on the problems and sub-problems of this research.

2.2. Background discussion

2.2.1 *Efficiency concepts*

Previous studies have sub-divided bank efficiency into three types: scale efficiency dealing with level of output, scope efficiency that deals with mix of

outputs, and X-efficiency to determine how efficiently banks are using inputs, such as labour and capital (Sfiridis & Daniels, 2003). Typically, X-efficiency is measured as a deviation from best practice on profit or cost function, and is a most important source of efficiency difference among banks (Berger *et al* 1993).

A bank has scale efficiency when it operates in the range of constant returns to scale (McAllister & McManus, 1993). In banking industry, it's widely believed that average the cost curve has a relatively flat U-shape, with medium-sized banks being slightly more scale efficient than either very large or very small banks (Berger & Humphery, 1994). However, McAllister and McManus (1993) have suggested that U-shape models – including most commonly used translog cost functions – give a poor approximation when applied to banks of all sizes. They believed that these translog models force large and small banks to lie on a symmetric U-shape curve and disallow other possibilities. For example, large banks tend to have very different produce mixes from the average, which can reduce the accuracy of measuring scale efficiencies. McAllister and McManus's (1993) solution is to replace the translog with non-parametric estimation procedures.

Scope efficiency occurs when a bank operates in different diversified areas or products (Helmers & Shaik, 2003). It measures percentage change in production costs for a bank operating in multiple areas or products, as opposed to a single area or product (Chen, 2001). If the measurement is positive, then scope efficiency exists and the bank is more efficient in producing multiple products or operating in different areas (Chen, 2001). Prior studies on scope efficiency for financial institutions are even more problematic than scale studies (Chen, 2001). According to Chen (2001), three major problems have been recognised. Firstly, there is a problem in applying translog specification to evaluate scope efficiency. Secondly, there is often little or no data on firms that operate a single product. Thirdly, data used for estimation is not on the efficient frontier. Using data off the frontier line could confound scope efficiency with X-efficiency.

The cost or input X-efficiency of a bank refers to how close it is to the efficient cost frontier, where the bank's output bundle is produced at a minimum cost for

the input prices it faces (Ferrier & Lovell, 1990). X-efficiency includes both technical efficiency, or inefficiency resulting from overuse of inputs, and allocative inefficiency, or inefficiency resulting from a poor choice of inputs (Berger, A. N., 1994). Berger & Humphrey (1997) found that X-efficiency differences across banks are relatively large and dominate both scale and scope efficiency differences. They also found out that there is no consensus on the best method for estimating X-efficiency, or on the average level of X-efficiency of the banking industry. Despite a lack of congruity across all methods, it seems clear that X-efficiency differences are much more important than scale and scope efficiencies in the banking industry (Berger & Humphrey, 1997).

As is the case for scale and scope efficiencies, X-efficiencies may also be important on the revenue or output side, even though most studies have only examined the cost or input side (English et al 1993). A bank may be revenue X-inefficient if it produces less of an output than it would like (technical inefficiency) or reacts poorly to output prices in choosing its output bundle (allocative inefficiency) (Berger & Humphery, 1994). Studies of banks that directly examine output X-inefficiency (English et al 1993) and a profit function study that examines both input and output X-inefficiency (Berger and Humphrey 1997) both find that output inefficiencies are at least as large as input inefficiencies.

2.2.2 *Efficiency measurement approaches*

According to Siyaka (2006), there are two approaches used to measure cost and profit efficiency. One is the accounting approach, which makes use of financial ratios and figures, and the other is the econometric approach.

The cost-to-net revenue ratio is often used in measuring the cost efficiency of a bank (Deyoung, 1999). It indicates a bank's ability to generate revenue within a certain cost level. Deyoung (1999) believes that the lower the ratio, the more efficient is the bank. He also believes that a bank with a higher cost-to-income ratio compared to the benchmark, indicates that the bank is cost inefficient.

While financial ratios are widely used in measuring bank efficiency, they have certain limitations (Yeh, 1996). Firstly, they are only meaningful when compared with a suitable benchmark, which may be difficult to establish. Secondly, the measurement is based on a very limited subset of data available to a bank. In this regard, a bank may perform well using one financial ratio but badly with another (Obeholzer and Merwe, 2004). Furthermore these ratios don't capture long-term performance (Sherman and Gold, 1985). Therefore, a measure that incorporates all available input and output data of a bank will be meaningful and the econometric approach attempts to do this (Yeh, 1996).

Under the econometric approach, efficiency is measured by comparing the actual level of cost or profit with an efficient frontier (Fuentes & Vegara, 2003). The frontier establishes the optimum benchmark against which deviations are calculated. What macroeconomic theory tells us is that a production plan is efficient if there is no way to produce more output with a given input or decreased input, thereby leaving the output unchanged (Qayyum & Khan, 2006). Qayyum and Khan (2006) indicate that, in theory, production plans and cost levels are derived from rational and efficient decisions; hence all firms perform at their production frontier. But, in practice, it is not the case due to many factors (e.g. poor production plans, inefficient decisions due to errors, managerial inability etc). A firm which is producing inside or outside frontier is inefficient.

2.2.3 *Econometrics approaches*

Berger, Hunter and Timme (1993) point out that a major econometric problem lies in distinguishing differences from random error, which may temporarily give certain institutions relatively high or low costs. They also indicate that four different approaches have been developed in the literature, each of which maintains a different set of assumptions about probability distributions of inefficiency and random error.

Stochastic frontier approach (SFA) generally assumes that inefficiencies follow an asymmetric half-normal distribution, that random errors follow a symmetric normal distribution, and that both are orthogonal to the cost-function exogenous

variables (Timme and Yang 1991, Bauer *et al* 1993). The thick frontier approach (TFA) assumes that deviations from predicted costs within the lowest average cost quartile of banks in a size class represent random error, while deviations in predicted costs between the highest and lowest quartiles represent X-inefficiencies (Bauer *et al* 1993; Berger 1993). The data envelopment analysis (DEA) approach generally assumes that there are *no* random fluctuations, so that all deviations from the estimated frontier represent inefficiency (Ferrier *et al* 1990). Finally, the distribution-free approach (DFA) assumes that efficiency differences are stable over time, while random error averages out over time (Berger 1994; Bauer *et al* 1993). There is no simple rule for determining which of these methods best describes the true nature of the banking data. This would not be a problem if all methods arrived at essentially the same conclusion (Berger *et al* 1993).

Unfortunately, the choice of measurement method does appear to affect the level of measured inefficiency (Berger *et al* 1993). Berger, Hunter and Timme (1993) reviewed literature on financial institutions and found that the literature applying SFA, TFA and DFA methods to banking usually find average inefficiency to be at between 20 percent and 25 percent of costs, while literature using DEA finds results ranging anywhere from less than 10 percent to over 50 percent of costs. Perhaps a more important problem is that when these methods are compared with one another using the same data set, rankings of individual banks often do not correspond well across methods – even when different method finds similar average-efficiency levels (Berger 1993).

2.2.4 *Econometric models*

As a general definition, efficiency is a measure of deviation between actual performance and desired performance (Mester, 2003). In this regard, Mester (2003) believes that efficiency can be observed from the perspective of profit and cost. A professional note from Berger (1994) asserts that the most important efficiency is X-efficiency and the stochastic frontier approach is the most appropriate to measure this.

This research uses the stochastic frontier model to exam the profit efficiency and cost efficiency of the sampled banks.

2.2.4.1 Original Stochastic Frontier Production Function

Aigner, Lovell & Schmidt (1977) and Meeusen & van den Broeck (1977) independently proposed the stochastic frontier production function. Their specification involved a production function specified for cross-sectional data; this had an error term with two components, one to account for random effects and another to account for technical inefficiency (Coelli, 1996). The model can be expressed in the following form:

$$Y_i = \mathbf{x_i}\boldsymbol{\beta} + (Vi - Ui) \qquad , i = 1,\ldots., N \qquad (1)$$

where

Y_i is the production (or logarithm of the production) of the i-th firm;

$\mathbf{x_i}$ is a k×1 vector of (transformations of the) input quantities of the i-th firm;

$\boldsymbol{\beta}$ is a vector of unknown parameters;

V_i are the random variables, which are assumed to be iid.$N(0,\sigma_v^2)$ and are independent of U_i; and

U_i are the non-negative random variables, which are assumed to account for technical inefficiency in production and are often assumed to be iid.$|N(0,\sigma_u^2)|$.

According to Coelli (1996), this model and its extended specification has been used in a vast number of empirical applications over the past three decades.

2.2.4.2 The Battese and Coelli Specification

Battese and Coelli (1992) propose a stochastic frontier function for the panel data, where the firm effects are assumed to be distributed as truncated normal random variables and where they are also permitted to vary systematically over time. The panel data needs not be complete, i.e. it can be unbalanced panel data. The model can be expressed as:

$$Y_{it} = \mathbf{x}_{it}\boldsymbol{\beta} + (V_{it} - U_{it}) \qquad , i = 1,\ldots., N, t=1,\ldots..,T, \qquad (2)$$

where

Y_{it} is (the logarithm of) the production of the i-th firm in the t-th time period;

$\mathbf{x}_{it}$ is a k×1 vector of (transformations of the) input quantities of the i-th firm in the t-th time period;

$\boldsymbol{\beta}$ is as defined earlier; and

V_{it} are random variables which are assumed to be iid $N(0,\sigma_v^2)$ and are independent of the U_{it}.

$$U_{it} = (U_i \exp(-\eta(t-T))) \qquad (3)$$

where

U_i are non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be iid, as truncations at zero of the $N(0,\sigma_u^2)$ distribution; and

η is a parameter to be estimated.

A number of empirical studies have estimated stochastic frontiers and predicted firm-level efficiencies using the above functions; they have then regressed the predicted efficiencies upon firm-specific variables (such as ownership structure, capital adequacy ratio, etc) in an attempt to identify some of the reasons for differences in predicted efficiencies between firms in an industry (Collie, 1996). This is called two-stage estimation procedure and has long been recognised as a useful exercise.

However, the two-stage estimation is less efficient than single-stage estimation procedure. Battese and Coelli (1995) proposed a model for single-stage estimation. The main function is the same as defined by (2). The U_{it} is different.

U_{it} are non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independently distributed as truncations at zero of the $N(m_{it},\sigma_u^2)$ distribution;

where:

$$\mathbf{m_{it}} = \mathbf{z_{it}}\boldsymbol{\delta} \qquad (4)$$

where:

$\mathbf{z_{it}}$ is a p×1 vector of variables which may influence the efficiency of a firm; and

$\boldsymbol{\delta}$ is a 1×p vector of parameters to be estimated.

2.2.4.3 Cost Function

All of the above specifications have been expressed as a production function, with the U_i interpreted as technical inefficiency factors which cause a firm to operate below the stochastic production frontier. By simply changing the error term from $(V_i - U_i)$ to $(V_i + U_i)$, we can have stochastic frontier cost function. In

this case, the U_i is interpreted as a cost-inefficiency factor which causes a firm to operate above the stochastic cost frontier. The model can be expressed as:

$$\mathbf{Y_i = x_i\beta + (V_i + U_i)} \qquad \mathbf{, i = 1,\ldots., N} \qquad (5)$$

where

Y_i is the cost (or the logarithm of the cost) of the i-th firm;

$\mathbf{x_i}$ is a k×1 vector of (transformations of the) input prices and output of the i-th firm;

$\boldsymbol{\beta}$ is an vector of unknown parameters;

V_i are random variables, which are assumed to be iid.$N(0,\sigma_v^2)$ and are independent of the U_i; and

U_i are non-negative random variables, which are assumed to account for cost inefficiency in production and are often assumed to be iid.$|N(0,\sigma_u^2)|$.

In this cost function, the U_i defines how far above the cost frontier a firm operates.

2.2.4.4 Translog frontier function

The translog function is the most frequently used for estimating production and cost frontier, in the literature. The translog function is a more relatively flexible functional form, as it allows data to indicate actual curvature of the function, rather than imposing prior assumptions (Pascoe *et al,* 2003). It can be expressed as follows:

$$\mathbf{Ln\,(Q_i) = \beta_0 + \sum_{i=1}^{N} \beta_i \ln x_i + (V_i +/- U_i)} \qquad (6)$$

where:

Q_i is output of i-th firm; and **β**, V_i, U_i are as defined earlier.

2.3. Bank efficiency in South Africa

2.3.1 The South African banking sector

Falkena, *et al*. (2004) asserts that the South African banking industry is oligopoly in nature, being dominated by five large commercial banks controlling the majority of the market shares. The five banks are Standard Bank, FirstRand, ABSA, Nedbank and Investec, with Investec being the smallest and also operating with a different business model.

According to the South African Reserve Bank (2010), as at end December 2009, the market share for the top four banks was 84.58 percent and no significant changes have been recorded over the past few years. As at end of December 2009, the average return on assets was 0.94 percent for the four large banks and the return on equity was 15.84 percent. Operating expenses to gross income were 51 percent. The household sector is the largest credit concentration for South African banks, followed by financial intermediation and the insurance sector (South African Reserve Bank, 2010).

2.3.2 Efficiency development in South African banks

Siyaka (2006) uses the stochastic frontier approach to determine both the profit and cost efficiency of four large and four small South African banks. She found that the cost efficiency of South African banks has improved significantly between 2000 and 2005. Profit efficiency remains on the same level over this period, according to her research. In a similar research, Ncube (2009) indicates that no one South African bank was found to be superior to another in terms of achieving efficiency gains in cost reduction and profitability.

Chen (2009) uses the stochastic frontier approach to exam the bank efficiency of 10 sub-Saharan African countries, including South Africa. He found that stable macroeconomic conditions and financial development contribute to a higher efficiency, and so does a higher degree of market competition. As South Africa is much more developed than other sub-Saharan African countries in these respects, higher bank efficiency was observed in his research. However, he indicates that this may constrain South Africa from improving its efficiency as the efficiency remains at quite a high level.

2.3.3 Sub-problem 1

The first sub-problem is to determine whether there was a change in the profit and cost efficiency of South African banks over the period 2002 to 2009, and how this occurred.

Hypothesis 1

H_1: There was a change in the profit efficiency of South African banks over the period 2002 to 2009.

Hypothesis 2

H_2: There was a change in the cost efficiency of South African banks over the period 2002 to 2009.

2.4. Bank efficiency in China

2.4.1 The Chinese banking sector

China achieved an annual GDP growth of nine percent over the past three decades, becoming the third-largest economy in the world after the United States and Japan (Jiang & Yao, 2010). Jiang & Yao (2010) believe that China's banking system has contributed to this economic miracle and has thus made China more influential in world financial market.

The Chinese banking industry is dominated by four very large state-owned banks – the 'Big Four' – possessing about three-quarters of the industry's total assets (Berger, Hasan, & Zhou, 2005). The 'Big Four' are China Construction Bank (CCB), the Industrial and Commercial Bank of China (ICBC), the Bank of China (BOC) and the Agricultual Bank of China. Berger *et al.* (2005) observed that China has been embarking on a significant reform of its banking industry. As a result, three out of four 'Big Four' banks have been publicly listed and have taken minority foreign ownership. Bank of America and Temasek (Singapore) reached deals to buy nine percent and 5.1 percent stakes in CCB, with further purchases options after the Initial Public Offering (IPO). CCB went public by listing at both the Hong Kong Stock Exchange (HKSE) and the Shanghai Stock Exchange (SHSE) in 2005. Goldman Sachs, American Express and Allianz then purchased 10 percent stakes in ICBC. ICBC went public by listing at HKSE and SHSE in 2006 and was the biggest IPO in history. In addition, the Royal Bank of Scotland and Temasek purchased 10 percent of BOC (Berger *et al,* 2005). By 2009, ICBC, CCB and BOC were ranked the world's three largest banks in terms of market capitalisation (Jiang & Yao, 2010).

The rest of the market is shared by a joint stock commercial bank and city commercial banks (Jiang & Yao, 2010).

2.4.2 Efficiency development in Chinese banks

While Berger *et al.* (2005) observed strong, favourable efficiency effects from reforms that reduce state ownership of banks in China and increase the role of foreign ownership, they admitted that predicting the efficiency effects of the reform is difficult due to: 1) there being very little research evidence of Chinese bank efficiency; 2) there being no study to their knowledge on the efficiency effects of minority foreign ownership of banks in any nation; and 3) information about the institutional history and regulation of Chinese banking not being widely disseminated.

Despite all the difficulties, Jiang and Yao (2010) employed the stochastic frontier approach to examine 47 commercial banks in China over the period 1995-2008. The estimated profit efficiency and cost efficiency average of 63

percent and 75 percent respectively, both improved over this period. They also found that joint stock commercial banks outperform state-owned banks on both profit and cost efficiency.

2.4.3 Sub-problem 2

The second sub-problem is to determine whether there was a change in profit and cost efficiency of Chinese banks during the period of 2002 to 2009.

Hypothesis 3

H_3: There was a change in the profit efficiency of Chinese banks over the period 2002 to 2009.

Hypothesis 4

H_4: There was a change in the cost efficiency of Chinese banks over the period 2002 to 2009.

2.5. Comparison of bank efficiency across countries

2.5.1 *International comparison of bank efficiency*

Gee (2008) used the stochastic frontier model to investigate cost efficiency and profit efficiency among the banking sector in selected developing countries in Asia, the Middle East and Africa from 2000 to 2005. He found that banks in the Middle Eastern and North African regions were the most cost efficient, followed by banks in Asia.

Chen and Liao (2009) compared bank efficiency in 16 Asian countries and revealed that domestic banks' profit efficiency is partially and negatively related to institutional goverance, political stability and regulatory quality.

Maudos and Pastor (1999) compared bank profit and cost efficiencies in 11 European countries, using the stochastic frontier approach. They believed that proper evaluation of efficiency should not be restricted to cost efficiency

because, in many cases, banks can achieve better returns from more costly activities.

Maudos *et al*. (1999) analysed the cost and profit efficiency of 14 countries in the European Union, as well as Japan and the US. Their results showed that since the start of 1990, increasing competition has led to gains in profit efficiency in the US and Europe but not in the Japanese banking system. The results also showed that inequalities in profitability between countries would be considerably reduced if inefficiencies were eliminated; efficiency gains are thus a very important source of improvement in profitability.

However, no research comparing bank efficiency between South Africa and China was found. As both countries are developing, it can be assumed that bank efficiency would be at a similar level.

2.5.2 *Sub-problem 3*

The third sub-problem is to determine whether profit and cost efficiency between South African and Chinese banks were significantly different, over the period 2002 to 2009.

Hypothesis 5

H_5: There was a significant difference in profit efficiency between South African and Chinese banks over the period 2002 to 2009.

Hypothesis 6

H_6: There was a significant difference in cost efficiency between South African and Chinese banks over the period 2002 to 2009.

2.6. Conclusion of Literature Review

This section introduced the concepts of bank efficiency, methods of defining bank efficiency and common econometric models. The remaining part of this section focus on literature relating to the problem and sub-problems.

Regarding efficiency development in South Africa, Siyaka (2006) used the stochastic frontier approach and found that the cost efficiency of South African banks improved between 2000 and 2005. Profit efficiency remained on the same level over this period.

Regarding efficiency development in China, Jing and Yao (2010) observed efficiency improvement in Chinese banks, especially amongst the listed commercial banks.

No research focusing on a comparison of bank efficiency between South Africa and China was found. As both countries are developing, it can be assumed that bank efficiency would be at a similar level.

Six hypotheses have been derived for the three sub-problems. There are two hypotheses for each sub-problems. Statistical tests will be conducted to decide whether to accept or reject each hypothesis.

Sub-problem 1

The first sub-problem is to determine whether there was a change in profit and cost efficiency of South African banks over the period 2002 to 2009. Therefore:

Hypothesis 1

H_1: There was a change in the profit efficiency of South African banks over the period 2002 to 2009.

Hypothesis 2

H_2: There was a change in the cost efficiency of South African banks over the period 2002 to 2009.

Sub-problem 2

The second sub-problem is to determine whether there was a change in profit and cost efficiency of Chinese banks over the period 2002 to 2009. Therefore:

Hypothesis 3

H_3: There was a change in the profit efficiency of Chinese banks over the period 2002 to 2009.

Hypothesis 4

H_4: There was a change in the cost efficiency of Chinese banks over the period 2002 to 2009.

Sub-problem 3

The third sub-problem is to determine whether profit efficiency and cost efficiency between South African and Chinese banks were significantly different, over the period 2002 to 2009. Therefore:

Hypothesis 5

H_5: There was a significant difference in profit efficiency between South African and Chinese banks over the period 2002 to 2009.

Hypothesis 6

H_6: There was a significant difference in cost efficiency between South African and Chinese banks over the period 2002 to 2009.

CHAPTER 3: RESEARCH METHODOLOGY

Based on the literature review on econometric models, the first part of this section will discuss and develop functions for estimating profit and cost efficiency. The second part will define the population and sampling methods. The third part will introduce software, tools and methods, followed by data collection and preparation. The last part of this section will cover limitation, validity and the reliability of the research.

3.1 Research design and methodology

This study is quantitative in nature and involves mathematical modelling in order to determine profit and cost efficiency for the sampled banks. The study uses panel data and assumes that inefficiency varies across observations and over a time period, therefore use of the stochastic econometric frontier approach is appropriate.

For modelling purposes, the banks are classified as three-input and two-output firms. Dependent variables are Total Costs (TC) and Profit before Tax (PBT), and independent variables are output and input prices.

Table 1 explains data extracted from the sampled banks' annual reports.

Table 1 Variables and related items extracted from annual reports

Variable	items in annual financial reports
TC	operating expenses (i.e. total costs)
PBT	profit before tax
Outputs	
Q_1	advances to customers and banks
Q_2	investment securities, including trading securities, statutory required assets and financial investments
Inputs	
P_C*	operating expenses
P_D	deposits and current accounts owned by customers
P_E	total equity

*: P_C is not an input in the two-input, two-output cost frontier function.

The inputs are assumed to be equity, deposits owned by customers and total expenses. The outputs are assumed to be advances and investment securities. This assumption regarding inputs and outputs is consistent with the studies conducted by Berger & Mester (1997).

3.1.1 *Profit function*

The model for profit function is derived from equations (2) and (6) in the literature review and can be expressed as follows:

$$\ln PBT = \beta_0 + \alpha_1 \ln Q_1 + \alpha_{11} \ln Q_1^2 + \alpha_2 \ln Q_2 + \alpha_{22} \ln Q_2^2 + \alpha_{12} \ln Q_1 \ln Q_2 + \beta_1 \ln P_C + \beta_2 \ln P_D + \beta_3 \ln P_E + \beta_{11} \ln P_C^2 + \beta_{22} \ln P_D^2 + \beta_{33} \ln P_E^2 + \beta_{12} \ln P_C \ln P_D + \beta_{13} \ln P_C \ln P_E + \beta_{23} \ln P_D \ln P_E + \gamma_{11} \ln Q_1 \ln P_C + \gamma_{12} \ln Q_1 \ln P_D + \gamma_{13} \ln Q_1 \ln P_E + \gamma_{21} \ln Q_2 \ln P_C + \gamma_{22} \ln Q_2 \ln P_D + \gamma_{23} \ln Q_2 \ln P_E + V - U_C \quad (7)$$

U_C is defined earlier. For the profit function, U_C </= 0, in which 0 is the highest profit. In this logarithm, U_C variables are bound between 0 and 1, in which 1 is the highest profit. α, β and γ are coefficient.

In the case that a bank recorded a negative profit, the profit was set to 1 to make sure that the natural log of a positive number could be used.

3.1.2 *Cost Function*

Staff costs, expenses on fixed assets and the total number of employees are the most common inputs used for the cost frontier function (Ferrier & Lovell, 1990). As staff costs and expenses on fixed assets are part of the total expenses (TC, the dependent variable) and a high correlation was usually observed between them, it was decided that all the cost inputs should be left out in the cost frontier function. In this regard, a two-input (deposit owned to

customers, equity), two-output (advances, investments securities) model was applied to the cost frontier function.

The cost frontier function is derived from equations (5) and (6) in the literature review and is very similar to the profit frontier equation (7). The difference is that it is a two-input and two-output model and has a positive U_C. It can be expressed as follows:

$$\ln TC = \beta_0 + \alpha_1 \ln Q_1 + \alpha_{11} \ln Q_1^2 + \alpha_2 \ln Q_2 + \alpha_{22} \ln Q_2^2 + \alpha_{12} \ln Q_1 \ln Q_2 + \beta_2 \ln P_D + \beta_3 \ln P_E + \beta_{22} \ln P_D^2 + \beta_{33} \ln P_E^2 + \beta_{23} \ln P_D \ln P_E + \gamma_{12} \ln Q_1 \ln P_D + \gamma_{13} \ln Q_1 \ln P_E + \gamma_{22} \ln Q_2 \ln P_D + \gamma_{23} \ln Q_2 \ln P_E + V + U_C \quad (8)$$

3.2 Population and sample

3.2.1 Population

The research population is all the large listed banks in South Africa and China.

3.2.2 Sample and sampling method

For practical reasons, the sample is the top four listed banks in South Africa and China, respectively.

South Africa's top four listed banks are FirstRand Bank, Standard Bank, ABSA and Nedbank. China's top four listed banks are China Construction Bank (CCB), the Industrial and Commercial Bank of China (ICBC), the Bank of China (BOC) and the Bank of Communications (BOCom).

3.3 The research procedure

Stochastic frontier analysis was applied in estimating equations (7) and (8). A software package Frontier 4.1, developed by Coelli (1996), was used to estimate profit and cost efficiency levels for all the banks sampled during the

observation period. All the variables were first converted to logarithm values before being applied to the model. Truncated normal distribution was assumed for the error term. The number of samples (eight banks) and time period (eight years) were also defined.

Statools 1.01, developed by the Palisade Corporation in 2004, was used to conduct the One-way Anova test and two-sample t-test.

3.3.1 *Procedure for data collection*

Data required by the model was obtained from the annual reports of the sampled banks. Eight years of data from the Financial Year End (FYE) 2002 to FYE 2009 was collected from these annual reports. Annual reports are available from each bank's website.

For FirstRand Bank and ABSA, there are only seven full sets of annual financial reports available. Nedbank and Standard Bank both have eight (or more) full sets of financial reports available. As CCB, ICBC and BOC were only listed in 2005 and 2006, it is difficult to obtain a full set of financial figures for eight years. All sets of financial data were downloaded from the banks' websites. There are eight years available for ICBC, seven years for BOC and six years for BOCom, respectively. For CCB, only five years of financial figures were available. The model supports unbalanced cross-sectional data. In this regard, any cross-sectional data with incomplete observations were applied to the model in the same way as a full set of cross-sectional data.

The following financial information was obtained from the financial reports of each bank:

- Operating expenses;
- Profit before tax;
- Advances to customers (including advances to other banks);
- Investment securities (including trading securities, statutory required assets and financial investments);

- Total equity; and
- Deposits owned by customers (including deposits in current accounts).

A database was created for all banks in Excel and panel data became available in this database. The data set was checked for completeness and accuracy, and was applied to Frontier 4.1 to determine the annual profit and cost efficiency for each bank during the observed period.

For the purpose of modelling, all bank names have been replaced with a bank identification number. Table 2 lists each bank's identification number and the number of years of financial information that could be obtained from its respective annual reports.

Table 2 Banks and years of financial data extracted

Bank Name	Bank Number	Years
FirstRand Bank	1	7
Standard Bank	2	8
ABSA	3	7
Nedbank	4	8
China Construction Bank	5	5
Industrial and Commercial Bank of China	6	8
Bank of China	7	7
Bank of Communications	8	6

3.4 Data analysis and interpretation

The source data for Frontier 4.1 is translog financial data, collected from annual reports. The results from Frontier 4.1 are profit and cost efficiency values. These values were then applied to Statools 1.01 to conduct a hypothesis test.

3.4.1 *One-way Anova test*

Hypothesis 1 to hypothesis 4 involves determining if there has been a change in profit and cost efficiency for South African and Chinese banks, respectively. The One-way Anova test was conducted to determine if efficiency levels were significantly different.

The One-way Anova procedure is usually run in two stages. In the first stage, a null hypothesis of equal means will be tested. If the resulting p-value is not sufficiently small, then there is not enough evidence to reject the equal-means hypothesis and the analysis stops. However, if the p-value is sufficiently small, it can be concluded in a given confident level that the means are not all equal. The second stage attempts to discover which means are significantly different from others and it is usually accomplished with confidence intervals (Albright, Winston & Zappe, 2006).

The essence of an Anova test is to compare variances within the individual samples to variance between the sample means (Albright *et al* 2006). Only if the variance between sample means is large relative to the variance between individual samples, can it be concluded that there are differences between samples means – thus allowing us to reject the equal-means hypothesis.

3.4.2 *Two-sample t-test*

Hypothesis 5 and hypothesis 6 involve determining if there was a significant difference in profit efficiency and cost efficiency between South African and Chinese banks. The two-sample t-test was conducted to determine if the efficiency was significantly different.

Two-sample t-tests are applicable in determining the difference between means in two populations. The two samples can be independent or paired. The samples are independent for both hypothesis 5 and hypothesis 6.

3.5 Limitations of the study

- The econometric models applied in this research are utilised to determine profit and cost efficiency. These models do not cover root reasons that may cause differences in efficiency, such as ownership structure and bank size. A different econometric model will have to be set up to identify the root reasons, and that is beyond the scope of this study.

- There are different models available for X-efficiency analysis. Different models may result in different findings. Stochastic frontier is regarded as the most appropriate for X-efficiency (Berger, 1994) and is applied in this research.

- The observed period is limited to eight years due to limited availability of financial data. Financial data from before the observed period is available for some banks, but it is non-comparable with other banks due to different accounting standards at the time.

- The sampled banks are the large ones in the two countries. This may not reflect the whole banking industry. It is difficult to include all banks as some small banks are run on a different business model, which results in different profit and cost efficiencies.

3.6 Validity and reliability

As defined by Leedy & Ormrod (2001:103) the validity of a research study refers to the 'accuracy, meaningfulness and credibility' of the study as a whole.

3.6.1 External validity

External validity is the extent to which the results of a specific study can be generalised to other contexts (Leedy & Ormrod, 2001). External validity may be a concern in this study as there is no consensus in the literature regarding the most appropriate frontier model for efficiency. The applied model was chosen after comparing different models and referring to a few other literature reports. The conclusion of the research may not applicable to other countries due to different macroeconomic and business environments. However, it may not be necessary to apply the conclusion of this research to other countries, as its purpose is to compare only South Africa and China.

One method of improving the external validity here is through replication of this study in another context (Leedy & Ormrod, 2001), and by comparing these

results with those of the other study. In this regard, the model can apply to other countries, but not the figures and conclusion.

3.6.2 Internal validity

According to Leedy & Ormrod (2001:103), ‘internal validity is the extent to which a researcher is able to draw accurate conclusions about cause-and-effect and other relationships within the data’. To ensure that the results of this study are valid, the same model was applied to two different countries and the same input and output variables were applied to all the banks sampled.

3.6.3 Reliability

Reliability is defined as the extent to which similar research, conducted in the future, will result in similar outcomes (Leedy & Ormrod, 2001). The modelling software package was developed over a long period and proven reliable. The theory and model used were applied by other researchers, both domestically and internationally. The original data was extracted from audited annual financial reports and deemed reliable.

CHAPTER 4: PRESENTATION OF RESULTS

4.1 Input data

The financial data extracted from annual reports is tabulated in Appendix A. Units for the financial figures are Rand Million and Yuan Million at South African and Chinese banks, respectively. There is no direct exchange rate between South African Rand (ZAR) and Chinese Yuan (CNY) in the market. The United States Dollar (USD) is often used as an intermediate currency. At the close of 30 June 2010, USD/ZAR = 7.6387 and USD/CNY = 6.7705. For the frontier model: as the inputs (equity, deposit owned by customers, total expenses) and outputs (advances, investment securities) are either all in ZAR or CNY, the exchange rate has no impact on the modelling and analysis.

ABSA changed its financial year end from 31 March to 31 December during 2005, after having been taken over by Barclays. Annual figures in the years 2005, 2004 and 2003 were taken as at 31 March in respective years. The financial year end for First Rand is on 30 June and has been consistent during the observed period. All other banks use the calendar year end, 31 December, as their financial year end.

All financial data has been logged before applying it to the model. Nedbank recorded a loss of -755 million Rand. This negative figure was replaced with the number 1 as translog models require positive input data. As all other Profit Before Tax (PBT) inputs are at least 1 000 times bigger than 1, this replacement from -755 to 1 had no significant impact on the profit analysis. Profit- and cost-efficiency input data, placed in the Frontier 4.1 software, are attached as Appendix B.

4.2 Efficiency estimates

The translogged input data was applied to Frontier 4.1. The stochastic translog profit and cost efficiency was calculated for the maximum likelihood of the estimates. This is shown in Table 3.

Table 3 Maximum likelihood profit and cost frontier parameter estimates

Parameter	Variable	Profit Function Estimates	Cost Function Estimates
β_0	Constant	24.533547	25.153838
α_1	Q_1	-61.55069	0.5912658
α_{11}	Q_1^2	12.793117	4.9273062
α_2	Q_2	64.456744	-6.6416294
α_{22}	Q_2^2	24.188169	-1.3595655
α_{12}	Q_1Q_2	-31.055336	0.21472353
β_1	P_C	20.354682	n.a.
β_2	P_D	2.6401868	0.26724924
β_3	P_E	6.6370155	-0.31019832
β_{11}	P_C^2	-16.748552	n.a.
β_{22}	P_D^2	1.5325032	0.03733861
β_{33}	P_E^2	10.064104	0.48417812
β_{12}	P_CP_D	6.9742765	n.a.
β_{13}	P_CP_E	25.762381	n.a.
β_{23}	P_DP_E	21.733048	0.28444676
γ_{11}	Q_1P_C	-5.9138197	n.a.
γ_{12}	Q_1P_D	-22.282027	0.36952442
γ_{13}	Q_1P_E	-18.20275	-0.65117151
γ_{21}	Q_2P_C	-2.2788678	n.a.
γ_{22}	Q_2P_D	-6.4625773	-0.22238803
γ_{23}	Q_2P_E	-4.8258665	-0.35897814

A two-output and three-input profit function model and two-output and two-input cost function model were developed in this research. Compared with profit function, the cost function excludes Operating Expenses (P_C) as an input. In the above table, parameters related to P_C are not applicable to cost function.

Frontier 4.1 output files include standard error and the t-ratio of the estimates. The output file from Frontier 4.1 for profit- and cost efficiency is attached as Appendix C.

4.3 Efficiency values

Profit- and cost-efficiency values from 2002 to 2009 for the South African and Chinese banks sampled, are listed in Table 4.

Table 4 Efficiency values of all sampled banks

Bank Efficiency	2002	2003	2004	2005	2006	2007	2008	2009
Prod_FirstRand		0.37	0.65	0.71	0.90	0.32	0.56	0.77
Prod_Standard Bank	0.94	0.37	0.58	0.78	0.91	0.99	0.56	0.42
Prod_ABSA		0.97	0.56	0.76	0.67	0.29	0.16	0.77
Prod_Nedbank	0.35	0.00	0.18	0.56	0.56	0.57	0.98	0.50
Mean_SA_prod efficiency	0.64	0.43	0.49	0.70	0.76	0.54	0.57	0.61
Prod_CCB				0.92	0.69	0.83	0.65	0.83
Prod_ICBC	0.75	0.38	0.30	0.89	0.45	0.98	0.71	0.78
Prod_BOC		0.28	0.27	0.26	0.58	0.94	0.85	0.87
Prod_BOCCom			0.40	0.57	0.38	0.95	0.47	0.38
Mean_CN_prod efficiency	0.75	0.33	0.33	0.66	0.53	0.92	0.67	0.72
Cost_FirstRand		1.04	1.07	1.15	1.02	1.16	1.20	1.32
Cost_Standard Bank	1.34	1.05	1.15	1.05	1.11	1.23	1.17	1.22
Cost_ABSA		1.14	1.03	1.19	1.12	1.11	1.05	1.07
Cost_Nedbank	1.01	1.22	1.18	1.11	1.15	1.14	1.02	1.06
Mean_SA_cost efficiency	1.18	1.11	1.11	1.12	1.10	1.16	1.11	1.17
Cost_CCB				1.02	1.03	1.17	1.06	1.13
Cost_ICBC	1.53	1.42	1.05	1.33	1.11	1.34	1.27	1.01
Cost_BOC		1.13	1.39	1.08	1.06	1.10	1.44	1.05
Cost_BOCCom			1.13	1.03	1.09	1.07	1.27	1.13
Mean_CN _cost efficiency	1.53	1.27	1.19	1.11	1.07	1.17	1.26	1.08

Profit efficiency measures how close a firm is to producing the maximum possible profit given a particular level of input and output prices (Mester, 2003). This is usually presented in percentages, representing the level of efficiency that a firm can achieve, compared to maximum efficiency of 100 percent.

Cost efficiency measures how close a firm's cost is to what a best practice bank's costs would be, for producing the same output bundle under the same conditions (Mester, 2003). This is usually presented in decimals, representing how many times greater the cost of a firm is when compared to best practice.

Figure 1 shows mean profit efficiency for all the sampled banks over the observed period. CCB is the most efficient bank overall, with a profit efficiency of 78 percent. Standard Bank is the most efficient South African bank, with a

profit efficiency of 69 percent. Nedbank is the least efficient bank, with a profit efficiency of 46 percent.

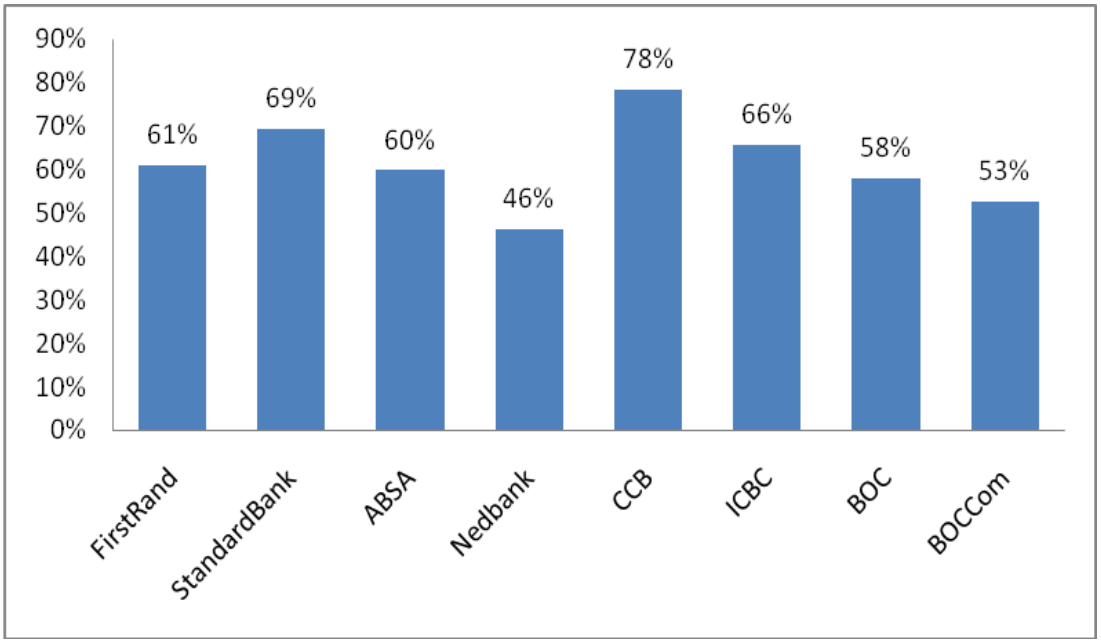


Figure 1 Average profit efficiency for all the banks sampled

Figure 2 shows the mean cost efficiency for all the banks sampled over the observed period. All values are greater than 1, indicating a level of cost inefficiency amongst the sampled banks. CCB is the most cost-efficient bank and ABSA is the most cost-efficient South African bank, with their cost-efficiency values being at 1.08 and 1.10 respectively. ICBC is the most cost-inefficient bank, with a cost-efficiency value of 1.26.

4.4 Results of hypothesis testing

The One-way Anova was used to test hypotheses 1 to 4. The two-sample t-test was used to test hypotheses 5 and 6. The meanings of all the hypotheses are summarised in Table 5.

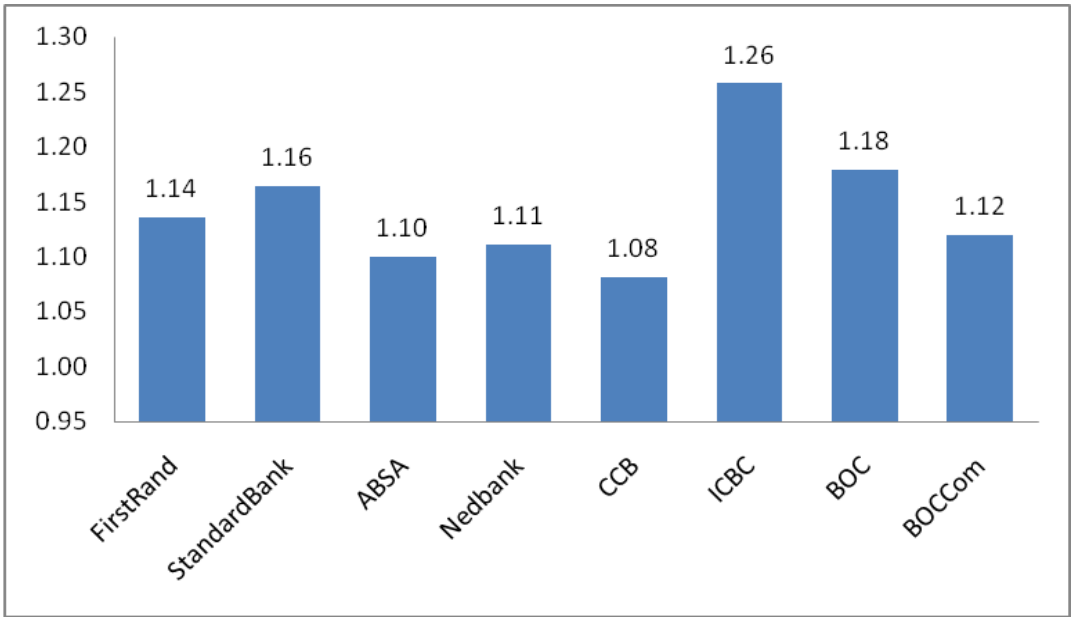


Figure 2 Average cost efficiency for all the banks sampled

Table 5 Summary of the hypotheses

Hypothesis	Meaning of Hypothesis	Test	Criteria to accept Hypothesis
Hypothesis 1	At the least one year's average profit efficiency is different from another year at South African banks	One-way Anova	Significant small p-value
Hypothesis 2	At the least one year's average cost efficiency is different from another year at South African banks	One-way Anova	Significant small p-value
Hypothesis 3	At the least one year's average profit efficiency is different from another year at Chinese banks	One-way Anova	Significant small p-value
Hypothesis 4	At the least one year's average cost efficiency is different from another year at Chinese banks	One-way Anova	Significant small p-value
Hypothesis 5	Average profit efficiency at all South African banks is different from that of Chinese banks	Two-sample t-test	Significant small p-value
Hypothesis 6	Average cost efficiency at all South African banks is different from that of Chinese banks	Two-sample t-test	Significant small p-value

4.4.1 *Profit- and cos- efficiency change*

The One-way Anova test was chosen to determine whether there was a change in profit and cost efficiency at South African and Chinese banks, over the period 2002 to 2009. The One-way Anova test has therefore been conducted to determine profit and cost efficiency, respectively.

Table 6 provides a summary of the One-way Anova test results. As none of the p-values is significantly small, there is insufficient reason to accept the hypotheses.

Table 6 Summary of the One-way Anova test results

Hypothesis	Grand Mean	Pooled Standard Deviation	Pooled Variance	Confidence Level	p-Value	F-Ratio (Degrees of Freedom)	Decision
Hypothesis 1	.59	.27	.08	95%	.73	.62(7,22)	No support for H_1
Hypothesis 2	1.13	.09	.01	95%	.91	.36(7,22)	No support for H_2
Hypothesis 3	.70	.20	.04	95%	.13	2.13(4,15)	No support for H_3
Hypothesis 4	1.14	.11	.01	95%	.18	1.79(4,15)	No support for H_4

Sub-problem 1: Change in South African Banks' Profit and Cost Efficiency

The first sub-problem is to determine whether there was a change in profit and cost efficiency at South African banks, over the period 2002 to 2009.

The p-values of both hypothesis 1 and hypothesis 2 are not significantly small enough to accept the alternative hypotheses. In other words, none of the years during the period 2002 to 2009 can be identified as significantly different from any other years, in terms of either profit or cost efficiency.

When examining confidence interval tests of Anova-test reports (attached as Appendix D: Anova test reports_Anova test report for South African bank profit efficiency, and Appendix D: Anova test reports_Anova test report for South African bank cost efficiency), there was no significant difference identified for either profit- or cost efficiency.

Conclusion to sub-problem 1: There has been no change in South African banks' efficiency, either in profit or cost, over the period 2002 to 2009.

Sub-problem 2: Change in Chinese Banks' Profit and Cost Efficiency

The second sub-problem is to determine whether there was a change in profit and cost efficiency at Chinese banks, over the period 2002 to 2009.

The p-values of both hypothesis 3 and hypothesis 4 are not significantly small enough to accept the alternative hypotheses. In other words, none of the years over the period 2002 to 2009 was identified as significantly different from any other year, in terms of either profit or cost efficiency at Chinese banks.

Average profit efficiency between 2006 and 2007, and average cost efficiency between 2006 and 2008, were identified as significantly different. However, these were not significant enough to accept the alternative hypotheses. The identified differences have been bolded in the section titled 'confidence interval tests' in Anova test reports. The Anova test reports for sub-problem 2 have been attached as Appendix D: Anova test reports_Anova test report for Chinese bank profit efficiency, and Appendix D: Anova test reports_Anova test report for Chinese bank cost efficiency.

Conclusion to sub-problem 2: There has been no change in Chinese banks' efficiency, either in profit or cost, over the period 2002 to 2009.

4.4.2 *Profit- and cost efficiency difference*

The two-sample t-test was chosen to determine whether profit and cost efficiency were significantly different between South African and Chinese banks,

over the period 2002 and 2009. The two-sample t-test has been conducted to determine profit and cost efficiency, respectively.

Table 7 provides a summary of two-sample t-test results. As none of the p-values is significantly small, there is no enough evidence to accept the alternative hypotheses at one percent, five percent and 10 percent significance.

Table 7 Summary of Two-sample t-test Results

Hypothesis	Mean	Standard Deviation	Percentage Significance	t-Value	Degrees of Freedom	p-Value	Decision
Hypothesis 5	0.59	0.26	1%, 5% and 10%	-0.59	54	0.56	No support for H_5
Hypothesis 6	1.13	0.09	1%, 5% and 10%	-1.31	54	0.19	No support for H_6

Sub-problem 3: Difference in bank efficiency between South Africa and China

The third sub-problem is to determine whether profit efficiency and cost efficiency were significantly different between South African and Chinese banks, over the period 2002 to 2009.

For both hypothesis 5 and hypothesis 6, the p-value was not small enough to accept the alternative hypotheses. The two-sample t-test report is attached as Appendix E: Two-sample t-test report for cost-efficiency comparison.

Conclusion to Sub-problem 3: There has been no significant difference between South African and Chinese banks' efficiency, either in profit or cost, over the period 2002 to 2009.

4.5 Summary of the results

The results of the hypothesis tests are summarised in Table 8.

Table 8 Summary of hypothesis test results

Hypothesis Test	p-value	Decision	Finding
Hypothesis test 1	.73	No support for H_1	No change in profit efficiency at South African banks over the observed period
Hypothesis test 2	.91	No support for H_2	No change in cost efficiency at South African banks over the observed period
Hypothesis test 3	.13	No support for H_3	No change in profit efficiency at Chinese banks over the observed period
Hypothesis test 4	.18	No support for H_4	No change in cost efficiency at Chinese banks over the observed period
Hypothesis test 5	.56	No support for H_5	No significant difference in profit efficiency between South African and Chinese banks
Hypothesis test 6	.19	No support for H_6	No significant difference in cost efficiency between South African and Chinese banks

CHAPTER 5: DISCUSSION OF THE RESULTS

This section will discuss findings of the estimates (coefficient on profit and cost functions), profit efficiency, cost efficiency and comparison of efficiency between South Africa and China.

By examining the T-ratio in the Frontier 4.1 output (attached as Appendix C), the significance of different variables was identified. Q_1 (advances to customers and banks), Q_2 (investment securities) and P_E (total equity) were the most significant variables in profit efficiency. P_D (deposits and current accounts owned by customers) were among the least significant parameters. For cost efficiency, Q_1 and Q_2 were the most significant variables, while P_E was least significant.

One-way Anova tests, conducted on sub-problem 1 and 2, found no significant change in profit efficiency and cost efficiency at both South African and Chinese banks. Two-sample t-tests, conducted on sub-problem 3, found no significant difference in profit and cost efficiency between South African and Chinese banks.

5.1 Analysis of estimates

Table 3 shows the maximum profit and cost frontier parameter estimates that are likely. By examining these estimates and the T-ratio in the Frontier 4.1 output (attached as Appendix C), the significance of different parameter estimates can be identified.

In the profit-efficiency frontier model, Q_1 (advances to customers and banks), Q_2 (investment securities) and P_E (total equity) are the most significant variables. Q_1 and Q_2 are significant variables, which is self-explanatory as they represent two outputs in the model. $P_{E,}$ another significant variable, can indicate a strong correlation between equity and profit efficiency. P_D (deposits and current accounts owned by customers) is the least significant parameter. This finding shows that P_D isn't an important factor in increasing a bank's profit efficiency.

In the cost-efficiency frontier model, Q_1 and Q_2 were the most significant variables, while P_E was the least significant. Again, Q_1 and Q_2 were self-explanatory, as they were the two outputs in the model. P_E, the least significant variable, is not an important factor in determining a bank's cost efficiency.

5.2 Profit efficiency

The average profit efficiency for the South African banks sampled during the observed period was 59.36 percent, similar to 61.33 percent achieved by the Chinese banks. There was no significant difference between the two means in profit efficiency, which concurred with the hypothesis test findings.

The results show that the average profit efficiency of South African banks improved from 42.73 percent in 2003 to 76.10 percent in 2006, and declined to 54.40 percent and 56.53 percent respectively in 2007 and 2008. The reason behind this was the financial crisis or recession. Banks operate more cautiously during a financial crisis. An increase in the provision for bad debts will affect the mix of inputs and outputs, and will decrease profit efficiency accordingly.

At Chinese banks, the difference in profit efficiency between 2006 and 2007, and cost efficiency between 2006 and 2008, can be identified as significant in an Anova test – though it was not sufficiently significant to accept the hypotheses. CCB, ICBC and BOC were listed in 2005 and 2006, which may have positively impacted the profit efficiency. Firstly, a higher efficiency should be expected with some logic, both before and after listing. Secondly, a change in accounting standards will affect the input data. All Chinese banks are duelly listed on the Shanghai and Hong Kong Stock Exchanges. Accounting standards were changed to ensure they were in line with international standards.

The highest profit efficiency recorded at South African banks was 98.97 percent (Standard Bank, 2007) and the lowest was 0.07 percent (Nedbank, 2003; a loss was also recorded this year!). Standard Bank was the most efficient South African bank with a profit efficiency of 69.29 percent, and Nedbank was the least profit efficient at 46.27 percent. Interestingly, the rank of efficiency was in line with the rank of total number of assets.

CCB was found to be the most efficient Chinese bank, with a profit efficiency of 78.46 percent. The alignment between efficiency ranking and asset ranking was not observed among Chinese banks.

One-way Anova tests were conducted to determine the significance of the change in profit efficiency for South African and Chinese banks, over the observed period. According to the hypothesis test, there has been no significant change in profit efficiency at both South African and Chinese banks.

The same findings were observed in South African and China, i.e. no significant change in profit efficiency was found over the observed period. This can be explained as follows: while a bank's output can vary from one year to another, the profit efficiency should be adjusted by controlling the input. In this regard, profit efficiency can remain at a similar level. It is very common to observe banks controlling operating and staff costs, during difficult times.

5.3 Cost efficiency

The average cost efficiency for South African and Chinese banks from 2002 to 2009 was 1.13 and 1.16 respectively. There was no significant difference between the two mean-cost efficiencies, which concurred with the hypothesis test findings.

Standard Bank proved the most cost-inefficient bank (with the highest average cost efficiency of 1.16) and ABSA was found to be the most cost efficient bank (with the lowest cost efficiency of 1.10). The difference was not significant, though. The highest figure observed was 1.34 (Standard Bank, 2002) and the lowest was 1.01 (Nedbank, 2002). The average cost efficiency was maintained well between 1.10 and 1.17, from 2002 to 2009.

CCB, with average an cost efficiency of 1.08, was the most cost-efficient bank among Chinese banks and ICBC was the least, with an average cost efficiency of 1.26. The average cost efficiency of Chinese banks improved from 1.53 in 2002 to 1.07 in 2006. This may hav been due to the listing of CCB in 2005, and

ICBC and BOC in 2006. Better governance and cost control were expected from pre-IPO stage to listing.

One-way Anova tests were conducted to determine the significant change in cost efficiency at South African and Chinese banks. As the results of the tests indicate, there was no significant change in cost efficiency at either South African or Chinese banks, during the observed period.

5.4 Comparison between South Africa and China

Two-sample t-test was conducted to determine whether there was a significant difference in efficiency between South African and Chinese banks, and how this occurred. The test led to the conclusion that there was no significant difference in profit and cost efficiency between banks in the two countries.

There are different factors affecting bank efficiency in the two countries. Some factors benefit the efficiency of Chinese banks, while others are more favourable towards South African banks. For example, Chinese companies are much larger than South African companies, resulting in bigger amounts received for a single loan. The efficiency of Chinese banks may benefit from this, as larger single loan amounts usually have a higher efficiency on the base of similar inputs. To take a contrary example, South African banks are better governed and managed. Pressure from shareholders and members of the board make South African banks operate in more efficient way. This is not the case for Chinese banks, as the controlling shareholder is the government. Some other factors that could affect efficiencies include staff and operating costs, social security, differences in culture, etc.

The average profit efficiency observed was higher than that achieved in the literature review for developed countries. As both South Africa and China are developing countries, higher profit efficiency may still result from their under-developed financial markets and lack of market competition.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions of the study

This research used the stochastic frontier approach to determine the efficiency of South African and Chinese banks, over a period of eight years. The intermediary approach was adopted. A three-input and two-output model was set up for profit efficiency, and a two-input and two-output model was set up for cost efficiency.

Both profit efficiency and cost efficiency were found to have remained at the same level over this period. Though there were some changes within the period, they were not significant enough to allow us to reject the null hypotheses.

Advances to customers and banks, investment securities and total equity were the most significant variables in the profit model. Deposits and current accounts owned by customers were among the least significant parameters i.e. they were not an important factor in determining a bank's profit efficiency. In the cost-efficiency frontier model advances to customers and banks, as well as investment securities were the most significant variables, while total equity was the least significant variable.

When comparing South African and Chinese banks, no significant difference was identified on either profit or cost efficiency.

6.2 Recommendations for future research

A number of issues were identified during this research, which could be explored further in the future. These issues can be highlighted as follows:

- Include other major developing economies and compare the level of efficiency across a greater number of countries;

- Include major developed economies and compare the deciding factors of efficiency between developed and developing countries;
- Build a macroeconomic model and identify the relationship between bank efficiency and the macroeconomic environment; and
- Include non-financial factors, such as size and ownership structure, to determine their relationship to bank efficiency.

This research study has fulfilled its purpose in using econometric methods to investigate and compare bank efficiency in South Africa and China, and to identify its development over a period of time.

REFERENCES

Aigner, D. J., Lovell, C. A., & Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics* (6), pp. 21-37.

Albright, S. C., Winston, W. L. & Zappe, C. J. (2006). *Data Analysis & Decision Making.* New York: Thomson.

Battese, G. E. & Coelli, T. J. (1992.). Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India. *Journal of Productivity Analysis* (3), pp. 153-169.

Battese, G. & Coelli, T. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics* (20), pp. 325-332.

Bauer, P. W., Berger, A. N. & Humphrey, D. B. (1993). *Efficiency and Productivity Growth in US Banking.* Oxford: Oxford University Press.

Bedari, D. (2004). Cost and Profit Efficiency of some Banks in Botswana, Namibia and South Africa. Retrieved July 25, 2010, from http://www.nepru.org.na/index.php?id=21&no_cache=1&file...

Berger, A. N. (1994). 'Distribution-Free' Estimates of Efficiency in the US Banking Industry and Tests of the Standard Distributional Assumptions. *Journal of Productivity Analysi* (9), pp. 261-292.

Berger, A. N. & Humphrey, D. B. (1997). Efficiency of Financial Institutions: International survey and directions for future research. *European Journal of Operational Research* (98), pp. 175-212.

Berger, A. N. & Humphrey, D. B. (1997). The Dominance of Inefficiencies over Scale and Product Mix Economies in Banking. *Journal of Monetary Economics* (28), pp. 117-148.

Berger, A. N., Clarke, G., Cull, R., Klapper, L. & Udell, G. (2005). Corporate Governance and Bank Performance: A Joint Analysis of the Static, Selection, and Dynamic Effects of Domestic, Foreign and State ownership. *Journal of Banking & Finance* (29), pp. 2179-2221.

Berger, A. N., Hunter, W. C. & Timme, S. G. (1993). The Efficiency of Financial Institutions: A Review and Preview of Research Past, Present and Future. *Journal of Banking and Finance* (17), pp. 221-249.

Berger, A. & Humphery, D. B. (1994). Bank Scale Economies, Mergers, Concentration and Efficiency: The US Experience. *Working Paper*. The Wharton School, University of Pennsylvania.

Berger, A. & Mester, L. (1997). Inside the Black Box: What Explains Differences in the Efficiencies of Financial Institutions? *Journal of Banking and Finance* (21), pp. 895-947.

Berger, A., Hasan, I. & Zhou, M. (2005). Bank ownership and efficiency in China: What will happen in the world's largest nation? Retrieved July 27, 2010, from http://fic.wharton.upenn.edu/fic/papers/07/p0703.htm

Bond, C. (2010). *An Overview of China's Expansion into Africa.* Johannesburg: Standard Bank.

Chen, C. (2009). Bank efficiency in Sub-Saharan African Middle-Income Countries. *Working Paper* . IMF.

Chen, S. & Liao, C. (2009). Determinants of Bank Profitability in 16 Asian Coutries: Does Cross-country Difference in Banking Market Structure Matter? *Research Paper*. China, Taiwan: Institute of Finance Management, Nanhua University.

Chen, Y.-K. (2001). *Three Essays on Bank Efficiency.* Retrieved on Aug 1, 2010, from Http://idea.library.drexel.edu/bitstream/1860/29/9/chen_y_thesis.pdf

Coelli, T. (1996). A guide to Frontier Version 4.1: A Computer Programme for Stochastic Frontier Production and Cost Function Estimation. *CEPA Working Paper 96/07*. Armidale, Australia: Centre for Efficiency and Productivity Analysis, University of New England.

Deyoung, R. (1999). Measuring Bank Cost Efficiency: Don't Count on Accounting Ratios. *Working Paper*. Washington DC: Office of the Comptroller of the Currency.

English, M., Grosskopf, S., Hayes, K. & Yaisawarng, S. (1993). Output Allocative and Technical Efficiency of Banks. *Journal of Banking and Finance* (17), pp. 349-366.

Falkena, H., Davel, G., Hawkins, P., Llewellyn, D., Luus, C., Masilela, E. et al. (2004). Competition in South African banking. *Task Group Report for the National Treasury and the South African Reserve Bank*.

Farrel, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society* (120), pp. 253-281.

Ferrier, G. D. & Lovell, C. (1990). Measuring Cost Efficiency in Banking: Econometric and Linear Programming Evidence. *Journal of Econometric* (46), pp. 229-245.

Fuentes, R. & Vergara, M. (2003). *Explaining Bank Efficiency: Bank Size or Ownership Structure?* Santiago: Central Bank of Chile.

Gee, C. S. (2008). Bank Efficiency in Selected Developing Countries. University of Utara, Malaysia.

Hartmann, P. (2004). The Impact of Financial Infrastructure Transformation on Monetary Policy Execution – the Namibian Experience. *BIS Review 53*. South Africa.

Hauner, D. & Peiris, S. J. (2005). Bank Efficiency and Competition in Low-Income Countries: The Case of Uganda. *IMF Working Paper WP/05/240*. International Monetary Fund.

Helmers, G. & Shaik, S. (2003). Economics of scope and scale efficiency gains due to diversification. University of Nebraska.

Ikhide, S. (2000, July). Efficiency of Commerical Banks in Namibia. *Occasional Paper No. 4*. Windhoeak: Bank of Namibia.

Jiang, C. & Yao, S. (2010). Banking reform and efficiency in China: 1995-2008. *Research Paper Series: China and the World Economy*.

Leedy, P. & Ormrod, J. (2001). *Practical Research -- Planning and Design* (7th ed.). New Jersey: Prentice Hall.

Maudos, J. & Pastor, J. (1999). Cost and Profit Efficiency in Banking: An International Comparison of Europe, Japan and the USA. University of Valençia.

Maudos, J., Pastor, J. M., Perez, F. & Quesada, J. (1999). Cost and profit efficiency in European banks. *IVIE Working Paper* .

McAllister, P. & McManus, D. (1993). Resolving the Scale Efficiency Puzzle in Banking. *Journal of Banking and Finance* (17), pp. 389-405.

Meeusen, W. & Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review* (18), pp. 435-444.

Mester, L. J. (2003). Applying Efficiency Measurement Techniques to Central Banks. *Working Paper*. Wharton School, University of Pennsylvania.

Moss, S. (2009, July 30). *FirstRand and China Construction Bank Agree on Strategic Co-operation*. Retrieved July 25, 2010, from FirstRand: http://www.firstrand.co.za/live/content.php?Item_ID=230&Category_ID=7

Ncube, M. (2009). Efficiency of the Banking Sector in South Africa. Retrieved on July 10, 2010, from http://www.afdb.org/fileadmin/uploads/afdb/Documents/Knowledge/2009%20AEC-%20Efficiency%20of%20the%20Banking%20 Sector%20in%20South%20Africa.pdf

Ngalande, E. (2003). The Importance of Financial System Modernisation in Africa. *BIS Review 27*. Johannesburg, South Africa.

Obeholzer, M. & Van Der Merwe, W. (2004). An Empirical Study on Measuring Efficiency and Profitability of Bank Regions. *Meditarian Accountancy Research, 12* (1), pp. 165-178.

Pascoe, S., Kirkley, J. E., Gréboval, D. & Morrison-Paul, C. J. (2003). Measuring and assessing capacity in fisheries 2. Issues and methods. *Working Paper*. Food and Agriculture Organisation of the United Nations.

Qayyum, A. & Khan, S. (2006). X-Efficiency, Economy of Scale, Technological Progress and Competition of Pakistani's Banks. *Working Paper*. Islamabad: Parkistan Institute of Development Economics,.

Sfiridis, J. M. & Daniels, K. N. (2003). Efficiency estimation of US commercial banking: A stochastical frontier approach using Gibbs sampling. *Working Paper*. Connecticut: University of Connecticut.

Shephard, R. (1970). *Theory of Cost and Production Functions.* Princeton, NJ: Princeton University Press.

Sherman, H. & Gold, F. (1985). Bank Branch Operation Efficiency: Evaluation with Data Envelopment Analysis. *Journal of Banking and Finance* (9), pp. 297-215.

Siyaka, N. (2006). Cost and Profit Efficiency of South African Banks. *Research report submitted to the Faculty of Commerce, Law and Management*. University of the Witwatersrand.

South African Reserve Bank. (2010, March). Financial Stability Review.

Standard Bank. (2009). *Annual Report.* Johannesburg.

Timme, S. & Yang, W. (1991). On the Use of a Direct Measure of Efficiency in Testing Structure-Performance Relationships. *Working Paper*. Georgia: Georgia State University.

Yeh, Q. J. (1996). The Application of Data Envelopment Analysis in Conjunction with Financial Ratios for Bank Performance Evaluation. *The Journal of the Operational Research Society* (47), pp. 980-988.

Appendix A: Financial data

Financial Data abstracted from annual reports

ZAR Million or RMB Million

Bank	Financial Year	Profit Before Tax	Advances	Investment Securities	Operating Expenses	Deposit	Equity
FirstRand	2009	9322	416488	209249	27933	478083	52097
FirstRand	2008	15202	446286	220105	26192	488423	51066
FirstRand	2007	18799	278945	221950	27088	416507	43548
FirstRand	2006	15028	313885	173848	22481	340649	36530
FirstRand	2005	9626	222495	43047	12389	237612	29856
FirstRand	2004	7126	208874	36131	10503	219061	24015
FirstRand	2003	5706	188112	36379	9537	215637	20793
Standard Bank	2009	10324	525700	84652	18286	577860	44159
Standard Bank	2008	10772	527452	84098	17120	608168	39074
Standard Bank	2007	12027	445535	70064	15998	527118	33066
Standard Bank	2006	10693	370066	54509	13273	401603	26655
Standard Bank	2005	8285	293964	54366	12078	320531	21724
Standard Bank	2004	7457	201864	44666	10876	254024	19019

Bank	Financial Year	Profit Before Tax	Advances	Investment Securities	Operating Expenses	Deposit	Equity
Standard Bank	2003	6128	154424	39440	9351	204325	15237
Standard Bank	2002	5623	125710	21951	8233	177579	11744
ABSA	2009	9842	539662	125286	20857	350757	56490
ABSA	2008	15305	576806	138902	21114	382281	53293
ABSA	2007	14067	509983	78108	19209	310512	42560
ABSA	2006	11417	395625	64990	17029	279848	34921
ABSA	2005	7633	279182	41330	12761	278582	23965
ABSA	2004	6223	235244	46657	11679	234380	19521
ABSA	2003	4565	214852	32596	10780	222056	17107
Nedbank	2009	6719	450301	47008	14974	469335	44984
Nedbank	2008	8872	434233	50593	13547	466890	40073
Nedbank	2007	8984	373956	37955	13341	384541	30193
Nedbank	2006	6994	308563	29351	11740	324685	25116
Nedbank	2005	5437	248408	29533	10609	261311	26309
Nedbank	2004	2511	221008	32785	10314	259747	21787
Nedbank	2003	1	210096	30032	9950	259757	15101
Nedbank	2002	1142	194862	20076	7366	236526	19536
CCB	2009	138725	4692947	2060281	129582	8001323	559202
CCB	2008	119741	3683575	1592621	99193	6375915	467562

Bank	Financial Year	Profit Before Tax	Advances	Investment Securities	Operating Expenses	Deposit	Equity
CCB	2007	100816	3183229	1620655	92327	5329507	422281
CCB	2006	65717	2795976	1909392	66662	4721256	330204
CCB	2005	55364	2395313	1413871	58092	4006046	287677
ICBC	2009	167248	5583174	2446647	143460	9771277	678934
ICBC	2008	145301	4436011	1851920	166227	8223446	607138
ICBC	2007	115114	3957542	1861326	142371	6898413	544252
ICBC	2006	71521	3533978	2855321	96658	6351423	466896
ICBC	2005	62876	3205861	2300385	88307	5736866	256974
ICBC	2004	52878	3705274	1255550	68734	5060718	162983
ICBC	2003	2658	3392937	1172761	84517	4606202	170501
ICBC	2002	6902	3002283	988391	81771	4100517	178208
BOC	2009	111097	4797408	1367000	121640	6685049	545394
BOC	2008	86251	3189652	1118440	142135	5173352	493901
BOC	2007	89955	2754493	1129642	92462	4400111	454993
BOC	2006	67630	2337726	1276318	80120	4091118	417325
BOC	2005	55140	2235046	1562320	56589	3703777	233842
BOC	2004	34576	2146462	1218467	65712	3342477	205351
BOC	2003	38573	2157473	977630	50473	3035956	203752
BoCCom	2009	38240	1801538	640747	42718	2372055	164425

Bank	Financial Year	Profit Before Tax	Advances	Investment Securities	Operating Expenses	Deposit	Equity
BoCCom	2008	35818	1298776	509362	40877	1865815	145642
BoCCom	2007	31038	1082758	472937	31472	1555809	128797
BoCCom	2006	17558	907285	336775	26106	1344548	87439
BoCCom	2005	12843	758773	285971	22301	1220839	83146
BoCCom	2004	7750	631612	215523	20207	1029941	52103

Appendix B: Input Data

Profit efficiency input data to Frontier 4.1

Column	Variable
A	Bank Number
B	Year
C	Ln(PBT)
D	$Ln(Q_1)$
E	$Ln(Q_2)$
F	$Ln(P_C)$
G	$Ln(P_D)$
H	$Ln(P_E)$
I	$Ln(Q_1)^2$
J	$Ln(Q_2)^2$
K	$Ln(Q_1)*Ln(Q_2)$
L	$Ln(P_C)^2$
M	$Ln(P_D)^2$
N	$Ln(P_E)^2$
O	$Ln(P_C)*Ln(P_D)$

Column	Variable
P	$Ln(P_C)*Ln(P_E)$
Q	$Ln(P_D)*Ln(P_E)$
R	$Ln(Q_1)*Ln(P_C)$
S	$Ln(Q_1)*Ln(P_D)$
T	$Ln(Q_1)*Ln(P_E)$
U	$Ln(Q_2)*Ln(P_C)$
V	$Ln(Q_2)*Ln(P_D)$
W	$Ln(Q_2)*Ln(P_E)$
X	Random Varible

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	2	8.6	12.1	10.5	9.2	12.3	9.9	147.5	110.3	127.5	84.0	150.8	98.9	112.5	91.1	122.1	111.3	149.2	120.7	96.2	129.0	104.4	0.15
1	3	8.9	12.2	10.5	9.3	12.3	10.1	150.0	110.1	128.6	85.7	151.2	101.7	113.9	93.4	124.0	113.4	150.6	123.6	97.2	129.1	105.9	0.60
1	4	9.2	12.3	10.7	9.4	12.4	10.3	151.6	113.8	131.4	88.8	153.2	106.2	116.7	97.1	127.5	116.0	152.4	126.9	100.6	132.1	109.9	1.00
1	5	9.6	12.7	12.1	10.0	12.7	10.5	160.2	145.6	152.7	100.4	162.3	110.4	127.6	105.3	133.8	126.8	161.2	133.0	120.9	153.7	126.8	0.59
1	6	9.8	12.5	12.3	10.2	12.9	10.7	157.2	151.5	154.4	104.2	167.4	114.1	132.1	109.0	138.2	128.0	162.2	133.9	125.6	159.3	131.5	0.26
1	7	9.6	13.0	12.3	10.2	13.1	10.8	169.2	151.3	160.0	103.5	171.6	117.5	133.3	110.3	142.0	132.3	170.4	141.0	125.1	161.1	133.4	0.73
1	8	9.1	12.9	12.3	10.2	13.1	10.9	167.4	150.1	158.5	104.8	171.0	118.0	133.9	111.2	142.0	132.5	169.2	140.5	125.4	160.2	133.1	0.35
2	1	8.6	11.7	10.0	9.0	12.1	9.4	137.9	99.9	117.4	81.3	146.1	87.8	109.0	84.5	113.3	105.9	141.9	110.0	90.1	120.8	93.7	0.33
2	2	8.7	11.9	10.6	9.1	12.2	9.6	142.7	112.0	126.4	83.6	149.5	92.8	111.8	88.1	117.8	109.2	146.1	115.1	96.8	129.4	101.9	0.63
2	3	8.9	12.2	10.7	9.3	12.4	9.9	149.2	114.6	130.8	86.4	154.9	97.1	115.7	91.6	122.6	113.5	152.0	120.4	99.5	133.3	105.5	0.09
2	4	9.0	12.6	10.9	9.4	12.7	10.0	158.5	118.9	137.3	88.3	160.7	99.7	119.2	93.9	126.6	118.3	159.6	125.7	102.5	138.2	108.9	0.96

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
2	5	9.3	12.8	10.9	9.5	12.9	10.2	164.4	118.9	139.8	90.1	166.5	103.9	122.5	96.7	131.5	121.7	165.4	130.7	103.5	140.7	111.1	0.29
2	6	9.4	13.0	11.2	9.7	13.2	10.4	169.2	124.5	145.1	93.7	173.6	108.3	127.5	100.7	137.1	125.9	171.4	135.4	108.0	147.0	116.1	0.25
2	7	9.3	13.2	11.3	9.7	13.3	10.6	173.6	128.6	149.4	95.0	177.4	111.8	129.8	103.1	140.8	128.4	175.5	139.3	110.5	151.0	119.9	0.11
2	8	9.2	13.2	11.3	9.8	13.3	10.7	173.5	128.7	149.5	96.3	176.0	114.4	130.2	105.0	141.9	129.3	174.8	140.9	111.4	150.5	121.4	0.40
3	2	8.4	12.3	10.4	9.3	12.3	9.7	150.7	108.0	127.6	86.2	151.6	95.0	114.3	90.5	120.0	114.0	151.1	119.7	96.5	127.9	101.3	0.11
3	3	8.7	12.4	10.8	9.4	12.4	9.9	153.0	115.6	133.0	87.7	152.9	97.6	115.8	92.5	122.2	115.8	152.9	122.2	100.7	132.9	106.2	0.63
3	4	8.9	12.5	10.6	9.5	12.5	10.1	157.2	113.0	133.3	89.4	157.2	101.7	118.5	95.3	126.4	118.6	157.2	126.5	100.5	133.3	107.2	0.36
3	5	9.3	12.9	11.1	9.7	12.5	10.5	166.1	122.8	142.8	94.9	157.3	109.4	122.2	101.9	131.2	125.6	161.6	134.8	108.0	139.0	115.9	0.62
3	6	9.6	13.1	11.3	9.9	12.6	10.7	172.7	126.9	148.1	97.3	159.9	113.6	124.7	105.1	134.8	129.6	166.2	140.1	111.1	142.5	120.1	0.32
3	7	9.6	13.3	11.8	10.0	12.9	10.9	176.0	140.2	157.1	99.2	165.2	118.5	128.0	108.4	139.9	132.1	170.5	144.4	117.9	152.2	128.9	0.24
3	8	9.2	13.2	11.7	9.9	12.8	10.9	174.2	137.8	154.9	98.9	163.0	119.7	127.0	108.8	139.7	131.3	168.5	144.4	116.7	149.9	128.4	0.36
4	1	7.0	12.2	9.9	8.9	12.4	9.9	148.4	98.2	120.7	79.3	153.1	97.6	110.2	88.0	122.3	108.5	150.7	120.3	88.2	122.6	97.9	0.80
4	2	0.0	12.3	10.3	9.2	12.5	9.6	150.2	106.3	126.4	84.7	155.4	92.6	114.8	88.6	120.0	112.8	152.8	117.9	94.9	128.5	99.2	0.31
4	3	7.8	12.3	10.4	9.2	12.5	10.0	151.4	108.1	128.0	85.4	155.4	99.8	115.2	92.3	124.5	113.7	153.4	122.9	96.1	129.6	103.9	0.94
4	4	8.6	12.4	10.3	9.3	12.5	10.2	154.3	106.0	127.9	85.9	155.6	103.6	115.6	94.3	127.0	115.2	155.0	126.4	95.4	128.4	104.8	0.33
4	5	8.9	12.6	10.3	9.4	12.7	10.1	159.8	105.8	130.0	87.8	161.1	102.6	118.9	94.9	128.6	118.4	160.4	128.1	96.4	130.5	104.2	0.83
4	6	9.1	12.8	10.5	9.5	12.9	10.3	164.7	111.2	135.3	90.2	165.4	106.4	122.2	98.0	132.7	121.9	165.0	132.4	100.2	135.6	108.8	0.26
4	7	9.1	13.0	10.8	9.5	13.1	10.6	168.5	117.3	140.6	90.5	170.4	112.3	124.2	100.8	138.4	123.5	169.5	137.6	103.1	141.4	114.8	0.82
4	8	8.8	13.0	10.8	9.6	13.1	10.7	169.5	115.7	140.0	92.4	170.5	114.8	125.6	103.0	139.9	125.2	170.0	139.5	103.4	140.5	115.3	0.98
5	4	10.9	14.7	14.2	11.0	15.2	12.6	215.8	200.6	208.0	120.3	231.1	158.0	166.8	137.9	191.1	161.1	223.3	184.6	155.4	215.3	178.0	0.16
5	5	11.1	14.8	14.5	11.1	15.4	12.7	220.3	209.2	214.7	123.4	236.2	161.5	170.7	141.1	195.3	164.9	228.1	188.6	160.6	222.3	183.8	0.58
5	6	11.5	15.0	14.3	11.4	15.5	13.0	224.2	204.4	214.1	130.7	239.9	167.8	177.1	148.1	200.6	171.2	231.9	194.0	163.5	221.5	185.2	0.98
5	7	11.7	15.1	14.3	11.5	15.7	13.1	228.6	203.9	215.9	132.4	245.5	170.4	180.3	150.2	204.6	173.9	236.9	197.4	164.3	223.8	186.4	0.49
5	8	11.8	15.4	14.5	11.8	15.9	13.2	236.0	211.4	223.3	138.6	252.7	175.1	187.1	155.8	210.4	180.8	244.2	203.3	171.1	231.1	192.4	0.79
6	1	8.8	14.9	13.8	11.3	15.2	12.1	222.5	190.5	205.9	128.0	231.9	146.2	172.2	136.8	184.1	168.7	227.1	180.3	156.1	210.2	166.9	0.92
6	2	7.9	15.0	14.0	11.3	15.3	12.0	226.1	195.3	210.1	128.7	235.4	145.1	174.1	136.7	184.8	170.6	230.7	181.1	158.5	214.4	168.3	0.72
6	3	10.9	15.1	14.0	11.1	15.4	12.0	228.8	197.2	212.4	124.1	238.3	144.0	171.9	133.7	185.3	168.5	233.5	181.5	156.4	216.8	168.5	0.64

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
6	4	11.0	15.0	14.6	11.4	15.6	12.5	224.4	214.6	219.4	129.7	242.2	155.2	177.2	141.9	193.9	170.6	233.1	186.6	166.8	228.0	182.5	0.27
6	5	11.2	15.1	14.9	11.5	15.7	13.1	227.3	221.0	224.1	131.8	245.4	170.4	179.8	149.8	204.5	173.1	236.2	196.8	170.6	232.8	194.0	0.72
6	6	11.7	15.2	14.4	11.9	15.7	13.2	230.8	208.4	219.3	140.8	248.0	174.4	186.9	156.7	208.0	180.3	239.2	200.6	171.3	227.3	190.7	0.11
6	7	11.9	15.3	14.4	12.0	15.9	13.3	234.3	208.3	220.9	144.5	253.5	177.3	191.4	160.1	212.0	184.0	243.7	203.8	173.5	229.8	192.2	0.95
6	8	12.0	15.5	14.7	11.9	16.1	13.4	241.3	216.4	228.5	141.0	259.0	180.3	191.1	159.4	216.1	184.5	250.0	208.6	174.7	236.8	197.5	0.92
7	2	10.6	14.6	13.8	10.8	14.9	12.2	212.7	190.2	201.2	117.3	222.8	149.4	161.6	132.4	182.5	157.9	217.7	178.3	149.4	205.9	168.6	0.58
7	3	10.5	14.6	14.0	11.1	15.0	12.2	212.6	196.4	204.3	123.1	225.7	149.6	166.6	135.7	183.8	161.7	219.0	178.3	155.4	210.5	171.4	0.31
7	4	10.9	14.6	14.3	10.9	15.1	12.4	213.7	203.4	208.5	119.8	228.8	152.8	165.5	135.3	187.0	160.0	221.1	180.7	156.1	215.7	176.3	0.07
7	5	11.1	14.7	14.1	11.3	15.2	12.9	215.1	197.7	206.2	127.5	231.8	167.5	171.9	146.1	197.0	165.6	223.3	189.8	158.7	214.0	182.0	0.34
7	6	11.4	14.8	13.9	11.4	15.3	13.0	219.9	194.3	206.7	130.7	234.0	169.7	174.9	149.0	199.3	169.6	226.8	193.2	159.4	213.2	181.6	0.83
7	7	11.4	15.0	13.9	11.9	15.5	13.1	224.3	194.0	208.6	140.8	239.0	171.9	183.4	155.5	202.7	177.7	231.5	196.3	165.2	215.3	182.6	0.51
7	8	11.6	15.4	14.1	11.7	15.7	13.2	236.7	199.6	217.3	137.1	247.0	174.5	184.0	154.7	207.6	180.1	241.8	203.2	165.4	222.0	186.6	0.46
8	3	9.0	13.4	12.3	9.9	13.8	10.9	178.4	150.8	164.0	98.3	191.7	118.0	137.3	107.7	150.4	132.4	184.9	145.1	121.7	170.0	133.4	0.00
8	4	9.5	13.5	12.6	10.0	14.0	11.3	183.3	157.8	170.1	100.2	196.4	128.3	140.3	113.4	158.8	135.6	189.8	153.4	125.8	176.1	142.3	0.01
8	5	9.8	13.7	12.7	10.2	14.1	11.4	188.2	162.0	174.6	103.4	199.1	129.5	143.5	115.7	160.6	139.5	193.6	156.1	129.4	179.6	144.8	0.60
8	6	10.3	13.9	13.1	10.4	14.3	11.8	193.1	170.7	181.6	107.3	203.3	138.4	147.7	121.9	167.8	143.9	198.1	163.5	135.3	186.3	153.7	0.97
8	7	10.5	14.1	13.1	10.6	14.4	11.9	198.2	172.7	185.0	112.7	208.5	141.3	153.3	126.2	171.7	149.5	203.3	167.4	139.5	189.7	156.2	0.89
8	8	10.6	14.4	13.4	10.7	14.7	12.0	207.5	178.8	192.6	113.7	215.5	144.2	156.5	128.1	176.3	153.6	211.4	173.0	142.6	196.3	160.6	0.01

* Due to constrain of paper size, variable names have been put in a separate table.

* Due to constrain of page size, one decimal place was included in above table, except the last column for random variable. There were 8 decimal places on the actual input data to Frontier 4.1

Cost Efficiency input data to Frontier 4.1

Column	Variable
A	Bank Number
B	Year
C	Ln(TC)
D	$Ln(Q_1)$
E	$Ln(Q_2)$
F	$Ln(P_D)$
G	$Ln(P_E)$
H	$Ln(Q_1)^2$
I	$Ln(Q_2)^2$
J	$Ln(Q_1)*Ln(Q_2)$
K	$Ln(P_D)^2$
L	$Ln(P_E)^2$
M	$Ln(P_D)*Ln(P_E)$
N	$Ln(Q_1)*Ln(P_D)$
O	$Ln(Q_1)*Ln(P_E)$
P	$Ln(Q_2)*Ln(P_D)$
Q	$Ln(Q_2)*Ln(P_E)$
R	Random Variable

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	2	9.16	12.15	10.50	12.28	9.94	147.50	110.29	127.54	150.83	98.85	122.11	149.15	120.75	128.98	104.41	.22
1	3	9.26	12.25	10.50	12.30	10.09	150.05	110.14	128.56	151.22	101.74	124.03	150.63	123.55	129.06	105.86	.20
1	4	9.43	12.31	10.67	12.38	10.30	151.60	113.85	131.38	153.23	106.18	127.55	152.41	126.87	132.08	109.95	.25
1	5	10.02	12.66	12.07	12.74	10.51	160.19	145.59	152.72	162.27	110.37	133.83	161.23	132.97	153.70	126.76	.04
1	6	10.21	12.54	12.31	12.94	10.68	157.22	151.54	154.36	167.44	114.10	138.22	162.25	133.93	159.29	131.49	.86
1	7	10.17	13.01	12.30	13.10	10.84	169.23	151.34	160.03	171.58	117.53	142.00	170.40	141.03	161.14	133.36	.26
1	8	10.24	12.94	12.25	13.08	10.86	167.43	150.09	158.53	171.02	117.96	142.03	169.22	140.54	160.22	133.06	.65
2	1	9.02	11.74	10.00	12.09	9.37	137.87	99.93	117.38	146.10	87.82	113.27	141.92	110.03	120.83	93.68	.93
2	2	9.14	11.95	10.58	12.23	9.63	142.74	111.99	126.43	149.51	92.77	117.77	146.09	115.07	129.40	101.93	.57
2	3	9.29	12.22	10.71	12.45	9.85	149.22	114.64	130.79	154.88	97.09	122.63	152.02	120.36	133.25	105.50	.91
2	4	9.40	12.59	10.90	12.68	9.99	158.54	118.89	137.29	160.73	99.72	126.60	159.63	125.74	138.23	108.88	.81
2	5	9.49	12.82	10.91	12.90	10.19	164.39	118.94	139.83	166.49	103.85	131.49	165.44	130.66	140.72	111.14	.45
2	6	9.68	13.01	11.16	13.18	10.41	169.18	124.48	145.12	173.59	108.29	137.10	171.37	135.36	147.00	116.10	.76
2	7	9.75	13.18	11.34	13.32	10.57	173.60	128.59	149.41	177.38	111.79	140.82	175.48	139.31	151.03	119.90	.70
2	8	9.81	13.17	11.35	13.27	10.70	173.51	128.74	149.46	176.02	114.40	141.90	174.76	140.89	150.53	121.36	.40
3	2	9.29	12.28	10.39	12.31	9.75	150.74	107.99	127.59	151.55	95.01	120.00	151.15	119.67	127.93	101.29	.89
3	3	9.37	12.37	10.75	12.37	9.88	152.98	115.58	132.97	152.89	97.60	122.15	152.93	122.19	132.93	106.21	.36
3	4	9.45	12.54	10.63	12.54	10.08	157.24	112.98	133.29	157.19	101.69	126.43	157.22	126.45	133.27	107.19	.83
3	5	9.74	12.89	11.08	12.54	10.46	166.11	122.81	142.83	157.30	109.43	131.20	161.64	134.82	138.99	115.93	.26
3	6	9.86	13.14	11.27	12.65	10.66	172.72	126.92	148.06	159.92	113.61	134.79	166.20	140.08	142.47	120.08	.97
3	7	9.96	13.27	11.84	12.85	10.88	175.97	140.22	157.08	165.22	118.45	139.90	170.51	144.37	152.21	128.88	.11
3	8	9.95	13.20	11.74	12.77	10.94	174.21	137.79	154.93	163.02	119.72	139.70	168.52	144.42	149.87	128.44	.22
4	1	8.91	12.18	9.91	12.37	9.88	148.35	98.15	120.67	153.11	97.62	122.25	150.71	120.34	122.59	97.88	.31
4	2	9.21	12.26	10.31	12.47	9.62	150.19	106.30	126.35	155.44	92.59	119.97	152.79	117.93	128.54	99.21	.18
4	3	9.24	12.31	10.40	12.47	9.99	151.44	108.11	127.95	155.44	99.78	124.54	153.42	122.93	129.63	103.86	.16

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
4	4	9.27	12.42	10.29	12.47	10.18	154.33	105.95	127.87	155.59	103.59	126.95	154.96	126.44	128.39	104.76	.04
4	5	9.37	12.64	10.29	12.69	10.13	159.76	105.82	130.03	161.05	102.64	128.57	160.41	128.06	130.55	104.22	.61
4	6	9.50	12.83	10.54	12.86	10.32	164.66	111.18	135.30	165.38	106.41	132.65	165.02	132.37	135.60	108.77	.29
4	7	9.51	12.98	10.83	13.05	10.60	168.52	117.32	140.61	170.40	112.33	138.35	169.46	137.58	141.39	114.80	.84
4	8	9.61	13.02	10.76	13.06	10.71	169.46	115.74	140.05	170.54	114.79	139.92	170.00	139.47	140.49	115.26	.15
5	4	10.97	14.69	14.16	15.20	12.57	215.77	200.56	208.02	231.14	158.00	191.10	223.32	184.64	215.31	178.01	.29
5	5	11.11	14.84	14.46	15.37	12.71	220.34	209.16	214.67	236.16	161.48	195.28	228.11	188.63	222.25	183.78	.57
5	6	11.43	14.97	14.30	15.49	12.95	224.20	204.44	214.10	239.90	167.79	200.63	231.92	193.96	221.46	185.21	.03
5	7	11.51	15.12	14.28	15.67	13.06	228.60	203.94	215.92	245.49	170.44	204.55	236.89	197.39	223.75	186.44	.64
5	8	11.77	15.36	14.54	15.90	13.23	235.98	211.36	223.33	252.66	175.15	210.36	244.17	203.30	231.09	192.40	.79
6	1	11.31	14.92	13.80	15.23	12.09	222.45	190.55	205.88	231.85	146.19	184.10	227.10	180.33	210.19	166.90	.27
6	2	11.35	15.04	13.98	15.34	12.05	226.12	195.30	210.14	235.41	145.12	184.83	230.72	181.15	214.42	168.35	.88
6	3	11.14	15.13	14.04	15.44	12.00	228.77	197.21	212.41	238.30	144.03	185.27	233.49	181.52	216.78	168.54	1.00
6	4	11.39	14.98	14.65	15.56	12.46	224.42	214.58	219.44	242.19	155.17	193.86	233.13	186.61	227.97	182.47	.45
6	5	11.48	15.08	14.87	15.66	13.05	227.34	220.96	224.13	245.37	170.40	204.48	236.18	196.83	232.84	194.04	.29
6	6	11.87	15.19	14.44	15.75	13.21	230.77	208.42	219.31	247.96	174.43	207.97	239.21	200.63	227.33	190.67	.43
6	7	12.02	15.31	14.43	15.92	13.32	234.25	208.28	220.88	253.53	177.33	212.03	243.70	203.81	229.79	192.18	.01
6	8	11.87	15.54	14.71	16.10	13.43	241.35	216.39	228.53	259.05	180.32	216.13	250.04	208.61	236.76	197.53	.52
7	2	10.83	14.58	13.79	14.93	12.23	212.71	190.24	201.16	222.79	149.44	182.47	217.69	178.29	205.87	168.61	.26
7	3	11.09	14.58	14.01	15.02	12.23	212.56	196.37	204.30	225.67	149.63	183.76	219.01	178.34	210.51	171.42	.41
7	4	10.94	14.62	14.26	15.13	12.36	213.74	203.40	208.50	228.76	152.83	186.98	221.12	180.74	215.71	176.31	.33
7	5	11.29	14.67	14.06	15.22	12.94	215.05	197.67	206.18	231.78	167.49	197.03	223.26	189.79	214.05	181.95	.28
7	6	11.44	14.83	13.94	15.30	13.03	219.89	194.25	206.67	234.00	169.73	199.29	226.84	193.19	213.20	181.58	.27
7	7	11.87	14.98	13.93	15.46	13.11	224.26	193.97	208.57	238.98	171.87	202.67	231.51	196.33	215.31	182.59	.66
7	8	11.71	15.38	14.13	15.72	13.21	236.66	199.60	217.34	246.97	174.49	207.59	241.76	203.21	222.03	186.62	.36

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
8	3	9.91	13.36	12.28	13.85	10.86	178.38	150.82	164.02	191.68	117.96	150.37	184.91	145.06	170.03	133.38	.27
8	4	10.01	13.54	12.56	14.02	11.33	183.32	157.85	170.11	196.42	128.33	158.77	189.76	153.38	176.08	142.33	.97
8	5	10.17	13.72	12.73	14.11	11.38	188.19	161.98	174.59	199.14	129.48	160.57	193.59	156.10	179.60	144.82	.50
8	6	10.36	13.90	13.07	14.26	11.77	193.07	170.74	181.56	203.28	138.44	167.75	198.11	163.49	186.30	153.74	.02
8	7	10.62	14.08	13.14	14.44	11.89	198.16	172.68	184.98	208.49	141.35	171.67	203.26	167.36	189.74	156.23	.10
8	8	10.66	14.40	13.37	14.68	12.01	207.48	178.77	192.59	215.48	144.25	176.30	211.44	173.00	196.27	160.58	.85

* Due to constrain of paper size, variable names have been put in a separate table.

* Decimal places have been rounded up to two digits. There were 8 decimal places on the actual input data to Frontier 4.1

Appendix C: Output Data

Profit efficiency output data from Frontier4.1

Output from the program FRONTIER (Version 4.1c)

instruction file = pall-ins.txt

data file = pall-in.txt

Tech. Eff. Effects Frontier (see B&C 1993)

The model is a production function

The dependent variable is logged

the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	2.453355E+01	9.327234E-01	2.630313E+01
beta 1	-6.155069E+01	7.109808E-01	-8.657152E+01
beta 2	1.279312E+01	8.413509E-01	1.520545E+01
beta 3	6.445674E+01	4.929347E-01	1.307612E+02
beta 4	2.418817E+01	8.646846E-01	2.797340E+01
beta 5	-3.105534E+01	8.498504E-01	-3.654212E+01
beta 6	2.035468E+01	5.306634E-01	3.835705E+01
beta 7	2.640187E+00	1.613603E-01	1.636206E+01
beta 8	6.637016E+00	1.052068E-01	6.308543E+01
beta 9	-1.674855E+01	7.392146E-01	-2.265723E+01
beta10	1.532503E+00	6.186916E-01	2.477007E+00
beta11	-1.006410E+01	2.995032E-01	-3.360266E+01
beta12	6.974277E+00	5.567010E-01	1.252787E+01
beta13	2.576238E+01	6.949328E-01	3.707176E+01
beta14	2.173305E+01	7.953505E-01	2.732512E+01
beta15	-5.913820E+00	6.009729E-01	-9.840411E+00
beta16	-2.228203E+01	5.230578E-01	-4.259955E+01
beta17	-1.820275E+01	3.590767E-01	-5.069321E+01
beta18	-2.278868E+00	3.884187E-01	-5.867039E+00
beta19	-6.462577E+00	5.136225E-01	-1.258235E+01

beta20	-4.825867E+00	4.736106E-01	-1.018952E+01
delta 0	-5.405760E+00	4.582847E-01	-1.179564E+01
delta 1	-4.769500E+00	9.351205E-01	-5.100412E+00
sigma-squared	6.611787E+00	5.780018E-01	1.143904E+01
gamma	9.999769E-01	6.004393E-04	1.665409E+03

log likelihood function = -0.38074343E+02

LR test of the one-sided error = 0.67463843E+02

with number of restrictions = 3

[note that this statistic has a mixed chi-square distribution]

number of iterations = 36

(maximum number of iterations set at : 500)

number of cross-sections = 8

number of time periods = 8

total number of observations = 56

thus there are: 8 obsns not in the panel

profit efficiency estimates :

Firm	Year	Eff-est
2	1	9.367421E-01
4	1	3.494445E-01
6	1	7.507353E-01
1	2	3.675577E-01
2	2	3.727467E-01
3	2	9.681359E-01
4	2	6.640886E-04
6	2	3.834978E-01
7	2	2.808492E-01
1	3	6.509740E-01
2	3	5.756512E-01

3	3	5.638147E-01
4	3	1.834651E-01
6	3	3.006071E-01
7	3	2.739887E-01
8	3	4.033931E-01
1	4	7.116973E-01
2	4	7.783726E-01
3	4	7.553812E-01
4	4	5.584615E-01
5	4	9.152528E-01
6	4	8.913883E-01
7	4	2.641078E-01
8	4	5.686776E-01
1	5	8.978434E-01
2	5	9.137927E-01
3	5	6.729856E-01
4	5	5.594387E-01
5	5	6.947759E-01
6	5	4.547649E-01
7	5	5.796541E-01
8	5	3.787482E-01
1	6	3.210385E-01
2	6	9.896769E-01
3	6	2.943204E-01
4	6	5.708582E-01
5	6	8.315908E-01
6	6	9.767580E-01
7	6	9.393764E-01
8	6	9.473127E-01
1	7	5.558359E-01
2	7	5.615278E-01
3	7	1.644943E-01
4	7	9.792358E-01
5	7	6.465674E-01
6	7	7.049990E-01
7	7	8.536322E-01
8	7	4.727832E-01
1	8	7.726526E-01
2	8	4.149565E-01
3	8	7.676670E-01
4	8	5.002787E-01
5	8	8.347328E-01
6	8	7.848278E-01
7	8	8.700124E-01
8	8	3.805700E-01

mean efficiency = 0.6088

summary of panel of observations:

(1 = observed, 0 = not observed)

		Year								
		1	2	3	4	5	6	7	8	
Firm Number	1	0	1	1	1	1	1	1	1	7
	2	1	1	1	1	1	1	1	1	8
	3	0	1	1	1	1	1	1	1	7
	4	1	1	1	1	1	1	1	1	8
	5	0	0	0	1	1	1	1	1	5
	6	1	1	1	1	1	1	1	1	8
	7	0	1	1	1	1	1	1	1	7
	8	0	0	1	1	1	1	1	1	6
		3	6	7	8	8	8	8	8	56

Cost efficiency output data from Frontier4.1

Output from the program FRONTIER (Version 4.1c)

instruction file = call-ins.txt

data file = call-in.txt

Tech. Eff. Effects Frontier (see B&C 1993)

The model is a cost function

The dependent variable is logged

the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	2.515384E+01	7.785966E-01	3.230664E+01
beta 1	5.912658E-01	7.904505E-01	7.480112E-01
beta 2	4.927306E+00	8.231478E-01	5.985932E+00
beta 3	-6.641629E+00	7.507280E-01	-8.846918E+00
beta 4	-1.359566E+00	7.160415E-01	-1.898725E+00
beta 5	2.147235E-01	3.748945E-01	5.727571E-01
beta 6	2.672492E-01	6.642264E-02	4.023466E+00
beta 7	-3.101983E-01	3.771413E-01	-8.224990E-01
beta 8	3.733861E-02	4.801849E-01	7.775881E-02
beta 9	4.841781E-01	2.243142E-01	2.158481E+00
beta10	2.844468E-01	4.615746E-01	6.162530E-01
beta11	3.695244E-01	6.640830E-01	5.564431E-01
beta12	-6.511715E-01	5.955769E-01	-1.093346E+00
beta13	-2.223880E-01	2.161246E-01	-1.028981E+00
beta14	-3.589781E-01	2.716370E-01	-1.321536E+00
delta 0	3.866805E-02	8.538917E-02	4.528449E-01
delta 1	9.725918E-02	5.079959E-02	1.914566E+00
sigma-squared	1.663086E-02	2.371115E-03	7.013940E+00
gamma	9.933143E-01	2.041379E-01	4.865899E+00

log likelihood function = 0.57649781E+02

LR test of the one-sided error = 0.90354023E+01

with number of restrictions = 3

[note that this statistic has a mixed chi-square distribution]

number of iterations = 14

(maximum number of iterations set at : 500)

number of cross-sections = 8

number of time periods = 8

total number of observations = 56

thus there are: 8 obsns not in the panel

cost efficiency estimates :

firm	year	eff.-est.
2	1	1.340988E+00
4	1	1.012736E+00
6	1	1.525884E+00
1	2	1.037683E+00
2	2	1.046451E+00
3	2	1.136644E+00
4	2	1.217573E+00
6	2	1.422726E+00
7	2	1.126814E+00
1	3	1.069865E+00
2	3	1.151590E+00
3	3	1.025041E+00
4	3	1.183651E+00
6	3	1.053722E+00
7	3	1.392235E+00
8	3	1.126688E+00
1	4	1.147900E+00
2	4	1.049271E+00
3	4	1.187814E+00
4	4	1.109000E+00
5	4	1.019362E+00

6	4	1.326239E+00
7	4	1.080889E+00
8	4	1.030167E+00
1	5	1.016328E+00
2	5	1.109194E+00
3	5	1.118213E+00
4	5	1.149952E+00
5	5	1.026186E+00
6	5	1.112582E+00
7	5	1.064641E+00
8	5	1.092826E+00
1	6	1.156008E+00
2	6	1.227772E+00
3	6	1.109870E+00
4	6	1.135530E+00
5	6	1.170439E+00
6	6	1.344624E+00
7	6	1.103691E+00
8	6	1.067110E+00
1	7	1.200196E+00
2	7	1.169595E+00
3	7	1.054782E+00
4	7	1.024549E+00
5	7	1.057850E+00
6	7	1.268512E+00
7	7	1.440789E+00
8	7	1.266265E+00
1	8	1.319359E+00
2	8	1.222544E+00
3	8	1.069438E+00
4	8	1.057112E+00
5	8	1.134469E+00
6	8	1.007251E+00
7	8	1.045676E+00
8	8	1.133457E+00

mean efficiency = 0.11481739E+01

summary of panel of observations:

(1 = observed, 0 = not observed)

		Year								
		1	2	3	4	5	6	7	8	
Firm Number	1	0	1	1	1	1	1	1	1	7
	2	1	1	1	1	1	1	1	1	8
	3	0	1	1	1	1	1	1	1	7
	4	1	1	1	1	1	1	1	1	8
	5	0	0	0	1	1	1	1	1	5
	6	1	1	1	1	1	1	1	1	8
	7	0	1	1	1	1	1	1	1	7
	8	0	0	1	1	1	1	1	1	6
		3	6	7	8	8	8	8	8	56

Appendix D: Anova test reports

Anova test report for South African bank profit efficiency

StatTools (Core Analysis Pack)
Analysis: One-Way ANOVA
Performed By:
Date: July 10, 2010
Updating: Live

ANOVA Summary	
Total Sample Size	30
Grand Mean	.59
Pooled Std Dev	.27
Pooled Variance	.08
Number of Samples	8
Confidence Level	95%

	2002	2003	2004	2005	2006	2007	2008	2009
ANOVA Sample Stats	Anova_SA_Prod	Anova_SA_Prod	Anova_SA_Prod	Anova_SA_Prod	Anova_SA_Prod	Anova_SA_Prod	Anova_SA_Prod	Anova_SA_Prod
Sample Size	2	4	4	4	4	4	4	4
Sample Mean	.64	.43	.49	.70	.76	.54	.57	.61
Sample Std Dev	.42	.40	.21	.10	.17	.32	.33	.18
Sample Variance	.17	.16	.04	.01	.03	.10	.11	.03
Pooling Weight	.05	.14	.14	.14	.14	.14	.14	.14

OneWay ANOVA Table	Sum of Squares	Degrees of Freedom	Mean Squares	F-Ratio	p-Value
Between Variation	.33	7	.05	.62	.73
Within Variation	1.65	22	.08		
Total Variation	1.98	29			

Confidence Interval Tests	Difference of Means	No Correction		Bonferroni		Tukey		Scheffe	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
2002-2003	0.22	-0.28	0.71	-0.63	1.06	-0.58	1.01	-0.77	1.20
2002-2004	0.15	-0.34	0.64	-0.69	0.99	-0.64	0.94	-0.84	1.13
2002-2005	-0.06	-0.55	0.43	-0.90	0.78	-0.85	0.73	-1.04	0.93
2002-2006	-0.12	-0.61	0.37	-0.96	0.72	-0.91	0.67	-1.10	0.87
2002-2007	0.10	-0.39	0.59	-0.74	0.94	-0.69	0.89	-0.89	1.08
2002-2008	0.08	-0.41	0.57	-0.76	0.92	-0.71	0.87	-0.91	1.06
2002-2009	0.03	-0.46	0.52	-0.81	0.87	-0.76	0.82	-0.96	1.01
2003-2004	-0.07	-0.47	0.34	-0.75	0.62	-0.71	0.58	-0.87	0.74
2003-2005	-0.27	-0.68	0.13	-0.96	0.41	-0.92	0.37	-1.08	0.53
2003-2006	-0.33	-0.74	0.07	-1.02	0.35	-0.98	0.31	-1.14	0.47
2003-2007	-0.12	-0.52	0.29	-0.80	0.57	-0.76	0.53	-0.92	0.69
2003-2008	-0.14	-0.54	0.26	-0.83	0.55	-0.78	0.51	-0.94	0.67
2003-2009	-0.19	-0.59	0.22	-0.87	0.50	-0.83	0.46	-0.99	0.62
2004-2005	-0.21	-0.61	0.19	-0.90	0.48	-0.85	0.44	-1.01	0.60
2004-2006	-0.27	-0.67	0.13	-0.96	0.42	-0.91	0.38	-1.07	0.54
2004-2007	-0.05	-0.45	0.35	-0.74	0.64	-0.70	0.60	-0.85	0.75
2004-2008	-0.07	-0.47	0.33	-0.76	0.62	-0.72	0.58	-0.88	0.73
2004-2009	-0.12	-0.52	0.28	-0.81	0.57	-0.77	0.53	-0.92	0.68
2005-2006	-0.06	-0.46	0.34	-0.75	0.63	-0.71	0.59	-0.86	0.74
2005-2007	0.16	-0.24	0.56	-0.53	0.85	-0.49	0.80	-0.65	0.96
2005-2008	0.14	-0.27	0.54	-0.55	0.82	-0.51	0.78	-0.67	0.94

2005-2009	0.09	-0.31	0.49	-0.60	0.78	-0.56	0.73	-0.72	0.89
2006-2007	0.22	-0.18	0.62	-0.47	0.91	-0.43	0.86	-0.59	1.02
2006-2008	0.20	-0.21	0.60	-0.49	0.88	-0.45	0.84	-0.61	1.00
2006-2009	0.15	-0.25	0.55	-0.54	0.84	-0.50	0.79	-0.66	0.95
2007-2008	-0.02	-0.42	0.38	-0.71	0.67	-0.67	0.63	-0.83	0.78
2007-2009	-0.07	-0.47	0.33	-0.76	0.62	-0.72	0.58	-0.87	0.73
2008-2009	-0.05	-0.45	0.35	-0.74	0.64	-0.70	0.60	-0.85	0.76

Anova test report for South African bank cost efficiency

StatTools (Core Analysis Pack)
Analysis: One-Way ANOVA
Performed By:
Date: July 10, 2010
Updating: Live

ANOVA Summary	
Total Sample Size	30
Grand Mean	1.13
Pooled Std Dev	.09
Pooled Variance	.01
Number of Samples	8
Confidence Level	95%

	2002	2003	2004	2005	2006	2007	2008	2009
ANOVA Sample Stats	Anova_SA_Cost	Anova_SA_Cost	Anova_SA_Cost	Anova_SA_Cost	Anova_SA_Cost	Anova_SA_Cost	Anova_SA_Cost	Anova_SA_Cost
Sample Size	2	4	4	4	4	4	4	4
Sample Mean	1.18	1.11	1.11	1.12	1.10	1.16	1.11	1.17
Sample Std Dev	.23	.08	.07	.06	.06	.05	.09	.13
Sample Variance	.05	.01	.01	.00	.00	.00	.01	.02
Pooling Weight	.05	.14	.14	.14	.14	.14	.14	.14

OneWay ANOVA Table	Sum of Squares	Degrees of Freedom	Mean Squares	F-Ratio	p-Value
Between Variation	.02	7	.00	.36	.91
Within Variation	.19	22	.01		
Total Variation	.21	29			

Confidence Interval Tests	Difference of Means	No Correction		Bonferroni		Tukey		Scheffe	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
2002-2003	0.07	-0.10	0.23	-0.22	0.35	-0.20	0.34	-0.27	0.40
2002-2004	0.07	-0.10	0.24	-0.22	0.35	-0.20	0.34	-0.26	0.40
2002-2005	0.05	-0.11	0.22	-0.23	0.34	-0.21	0.32	-0.28	0.39
2002-2006	0.08	-0.09	0.25	-0.21	0.36	-0.19	0.35	-0.26	0.41
2002-2007	0.02	-0.15	0.19	-0.27	0.30	-0.25	0.29	-0.31	0.35
2002-2008	0.06	-0.10	0.23	-0.22	0.35	-0.20	0.33	-0.27	0.40
2002-2009	0.01	-0.16	0.18	-0.28	0.30	-0.26	0.28	-0.32	0.34
2003-2004	0.00	-0.13	0.14	-0.23	0.24	-0.22	0.22	-0.27	0.27
2003-2005	-0.01	-0.15	0.12	-0.25	0.22	-0.23	0.21	-0.29	0.26
2003-2006	0.01	-0.12	0.15	-0.22	0.24	-0.21	0.23	-0.26	0.28
2003-2007	-0.05	-0.18	0.09	-0.28	0.19	-0.27	0.17	-0.32	0.22
2003-2008	0.00	-0.14	0.13	-0.24	0.23	-0.22	0.22	-0.28	0.27
2003-2009	-0.06	-0.19	0.08	-0.29	0.18	-0.28	0.16	-0.33	0.21
2004-2005	-0.02	-0.15	0.12	-0.25	0.22	-0.24	0.20	-0.29	0.26
2004-2006	0.01	-0.13	0.15	-0.22	0.24	-0.21	0.23	-0.26	0.28
2004-2007	-0.05	-0.19	0.09	-0.28	0.18	-0.27	0.17	-0.32	0.22
2004-2008	0.00	-0.14	0.13	-0.24	0.23	-0.22	0.21	-0.28	0.27
2004-2009	-0.06	-0.20	0.08	-0.29	0.17	-0.28	0.16	-0.33	0.21
2005-2006	0.03	-0.11	0.16	-0.21	0.26	-0.19	0.24	-0.25	0.30

2005-2007	-0.03	-0.17	0.10	-0.27	0.20	-0.25	0.19	-0.31	0.24
2005-2008	0.01	-0.12	0.15	-0.22	0.24	-0.21	0.23	-0.26	0.28
2005-2009	-0.04	-0.18	0.09	-0.28	0.19	-0.26	0.18	-0.32	0.23
2006-2007	-0.06	-0.19	0.08	-0.29	0.17	-0.28	0.16	-0.33	0.21
2006-2008	-0.01	-0.15	0.12	-0.25	0.22	-0.23	0.21	-0.29	0.26
2006-2009	-0.07	-0.20	0.07	-0.30	0.16	-0.29	0.15	-0.34	0.20
2007-2008	0.05	-0.09	0.18	-0.19	0.28	-0.17	0.26	-0.23	0.32
2007-2009	-0.01	-0.15	0.13	-0.24	0.22	-0.23	0.21	-0.28	0.26
2008-2009	-0.05	-0.19	0.08	-0.29	0.18	-0.27	0.16	-0.33	0.22

Anova test report for Chinese bank profit efficiency

StatTools (Core Analysis Pack)
Analysis: One-Way ANOVA
Performed By:
Date: June 25, 2010
Updating: Live

ANOVA Summary	
Total Sample Size	20
Grand Mean	.70
Pooled Std Dev	.20
Pooled Variance	.04
Number of Samples	5
Confidence Level	95%

	2005	**2006**	**2007**	**2008**	**2009**
ANOVA Sample Stats	**Anova_CN_Prod**	**Anova_CN_Prod**	**Anova_CN_Prod**	**Anova_CN_Prod**	**Anova_CN_Prod**
Sample Size	4	4	4	4	4
Sample Mean	.66	.53	.92	.67	.72
Sample Std Dev	.31	.14	.06	.16	.23
Sample Variance	.09	.02	.00	.02	.05
Pooling Weight	.20	.20	.20	.20	.20

OneWay ANOVA Table	Sum of Squares	Degrees of Freedom	Mean Squares	F-Ratio	p-Value
Between Variation	.33	4	.08	2.13	.13
Within Variation	.58	15	.04		
Total Variation	.91	19			

Confidence Interval Tests	Difference of Means	No Correction		Bonferroni		Tukey		Scheffe	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
2005-2006	0.13	-0.16	0.43	-0.33	0.59	-0.30	0.56	-0.35	0.62
2005-2007	-0.26	-0.56	0.03	-0.72	0.19	-0.69	0.17	-0.75	0.22
2005-2008	-0.01	-0.31	0.29	-0.47	0.45	-0.44	0.42	-0.50	0.48
2005-2009	-0.06	-0.35	0.24	-0.52	0.40	-0.49	0.37	-0.55	0.43
2006-2007	-0.40	**-0.69**	**-0.10**	-0.86	0.06	-0.83	0.03	-0.88	0.09
2006-2008	-0.14	-0.44	0.15	-0.60	0.32	-0.57	0.29	-0.63	0.35
2006-2009	-0.19	-0.49	0.11	-0.65	0.27	-0.62	0.24	-0.68	0.30
2007-2008	0.25	-0.04	0.55	-0.20	0.71	-0.18	0.69	-0.23	0.74
2007-2009	0.21	-0.09	0.50	-0.25	0.66	-0.22	0.64	-0.28	0.69
2008-2009	-0.05	-0.35	0.25	-0.51	0.41	-0.48	0.38	-0.54	0.44

Anova test report for Chinese bank cost efficiency

StatTools (Core Analysis Pack)
Analysis: One-Way ANOVA
Performed By:
Date: June 25, 2010
Updating: Live

ANOVA Summary	
Total Sample Size	20
Grand Mean	1.14
Pooled Std Dev	.11
Pooled Variance	.01
Number of Samples	5
Confidence Level	95%

	2005	**2006**	**2007**	**2008**	**2009**
ANOVA Sample Stats	**Anova_CN_Cost**	**Anova_CN_Cost**	**Anova_CN_Cost**	**Anova_CN_Cost**	**Anova_CN_Cost**
Sample Size	4	4	4	4	4
Sample Mean	1.11	1.07	1.17	1.26	1.08
Sample Std Dev	.14	.04	.12	.16	.06
Sample Variance	.02	.00	.02	.02	.00
Pooling Weight	.20	.20	.20	.20	.20

OneWay ANOVA Table	Sum of Squares	Degrees of Freedom	Mean Squares	F-Ratio	p-Value
Between Variation	.09	4	.02	1.79	.18
Within Variation	.20	15	.01		
Total Variation	.29	19			

Confidence Interval Tests	Difference of Means	No Correction		Bonferroni		Tukey		Scheffe	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
2005-2006	0.04	-0.13	0.21	-0.23	0.31	-0.21	0.29	-0.24	0.32
2005-2007	-0.06	-0.23	0.12	-0.32	0.21	-0.31	0.19	-0.34	0.23
2005-2008	-0.14	-0.32	0.03	-0.41	0.12	-0.39	0.11	-0.43	0.14
2005-2009	0.03	-0.14	0.21	-0.23	0.30	-0.22	0.28	-0.25	0.32
2006-2007	-0.10	-0.27	0.08	-0.36	0.17	-0.35	0.15	-0.38	0.19
2006-2008	-0.18	**-0.36**	**-0.01**	-0.45	0.08	-0.44	0.07	-0.47	0.10
2006-2009	-0.01	-0.18	0.17	-0.27	0.26	-0.26	0.24	-0.29	0.28
2007-2008	-0.09	-0.26	0.09	-0.35	0.18	-0.34	0.16	-0.37	0.20
2007-2009	0.09	-0.08	0.26	-0.18	0.36	-0.16	0.34	-0.19	0.38
2008-2009	0.18	**0.01**	**0.35**	-0.09	0.44	-0.07	0.43	-0.11	0.46

Appendix E: Two-sample t-test reports

Two-sample t-test report for profit efficiency comparison

StatTools	(Core Analysis Pack)
Analysis:	Hypothesis Test
Performed By:	
Date:	Nov 27, 2010
Updating:	Live

Sample Summaries	Prod_SA_Period SA_CN_Prod_Period	Prod_CN_Period SA_CN_Prod_Period
Sample Size	30	26
Sample Mean	0.5903	0.6301
Sample Std Dev	0.2612	0.2446

Hypothesis Test (Difference of Means)	Equal Variances	Unequal Variances
Hypothesized Mean Difference	0	0
Alternative Hypothesis	<> 0	<> 0
Sample Mean Difference	-0.0398	-0.0398
Standard Error of Difference	0.0680	0.0676
Degrees of Freedom	54	53
t-Test Statistic	-0.5858	-0.5886
p-Value	0.5604	0.5586
Null Hypoth. at 10% Significance	Don't Reject	Don't Reject
Null Hypoth. at 5% Significance	Don't Reject	Don't Reject
Null Hypoth. at 1% Significance	Don't Reject	Don't Reject

Equality of Variances Test	
Ratio of Sample Variances	1.1409
p-Value	0.7428

Two-sample t-test report for cost efficiency comparison

StatTools	(Core Analysis Pack)
Analysis:	Hypothesis Test
Performed By:	
Date:	Nov 27, 2010
Updating:	Live

Sample Summaries	Cost_SA_Period SA_CN_Cost_Period	Cost_CN_Period SA_CN_Cost_Period
Sample Size	30	26
Sample Mean	1.1286	1.1708
Sample Std Dev	0.0854	0.1507

Hypothesis Test (Difference of Means)	Equal Variances	Unequal Variances
Hypothesized Mean Difference	0	0
Alternative Hypothesis	<> 0	<> 0
Sample Mean Difference	-0.0423	-0.0423
Standard Error of Difference	0.0322	0.0334
Degrees of Freedom	54	38
t-Test Statistic	-1.3131	-1.2648
p-Value	0.1947	0.2136
Null Hypoth. at 10% Significance	Don't Reject	Don't Reject
Null Hypoth. at 5% Significance	Don't Reject	Don't Reject
Null Hypoth. at 1% Significance	Don't Reject	Don't Reject

Equality of Variances Test	
Ratio of Sample Variances	0.3208
p-Value	0.0038