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TRENDS IN THE EFFICIENCY OF SINGAPORE COMMERCIAL BANKS: A NON-STOCHASTIC FRONTIER DEA WINDOW ANALYSIS APPROACH

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This paper utilizes the non-parametric Data Envelopment Analysis (DEA) windows analysis method to investigate the long-term trend in efficiency change of Singapore commercial banks during the period of 1993-2003. We found that listed Singapore commercial banks have exhibit average overall efficiency of 95.4% and that the inefficiency was largely attributed to scale rather than pure technical. Our results suggest that small Singapore commercial banks have outperformed their large and very large counterparts. We find that large banks exhibit slightly higher pure technical efficiency scores compared to its small and very large peers while the smaller banks outperform their larger counterparts on scale efficiencies. We also find that while the smaller banking groups tend to operate at CRS and IRS, the large banking groups on the other hand tend to operate at DRS and CRS at best.

JEL Classification: G21

Keywords: Bank efficiency, DEA Window Analysis, Singapore

I. INTRODUCTION

Examining banking performance has been a common practice among banking and finance researchers for a number of years. The main reason for continued interest in this area of research is the ever-changing banking business environment throughout the world. Many countries that adopted financial deregulation policies are now experiencing competitive banking practices. Singapore is no exception and is becoming a competitive and important market not only for financial products and for other products. Singapore banking is a considerable component in Asian financial activities, which has not been subjected to substantial research compared to the other countries in the developed world. As efficient banking systems contribute in an extensive way for higher economic growth in any country, studies in this nature are very important for policy makers, industry leaders and many others who are reliant on the banking sector.

The motivation of this study comes firstly from the fact that despite the importance of the Singapore banking sector to the domestic, regional and international economy, there are only a few microeconomic studies performed in this area of research. Although some studies have examined the performance of commercial banks in Singapore, to the best of our knowledge there is currently no study that has analyzed a long time period, enough to shed some light on the trends in the efficiency changes of Singapore banks over time. This study thus attempts to fill a demanding gap in that case and provide the most recent evidence on the performance of Singapore commercial banks.

Secondly, unlike earlier studies performed on Singapore banks, the importance of this study would not only be limited to regulators and policymakers but also to investments analysts, industry consultants and shareholders alike. As banks with higher efficiency scores tend to post higher profits (see among others Chu and Lim, 1998), it could be argued that the listed banks performance/efficiency may in future reflect the banks ability to pay higher dividends as dividends are expected to be paid out of net profits. Nevertheless, as DEA is a relative study of Decision-Making Units (DMUs), we believe that it is more appropriate to investigate the efficiency of the publicly listed banks in the same frontier without contaminating it with the results from other non-listed commercial banks. This, we believe would be a better comparison and provide a more accurate result.

The study also attempts to investigate the nature of returns to scale of Singapore commercial banks, which have yet been examined in previous research with respect to the Singapore commercial banks. Although a good deal of empirical analysis has been conducted into returns to scale in U.S. and European countries banking sector, to the best of our knowledge, analysis has yet been conducted into this issue in Singapore banking. This dearth of analysis is possibly due to the relatively small sample size of Singapore banks relative to U.S. and European banks. Viewed in this context therefore, the study provides some extremely important insights into the nature of returns to scale in Singapore banking.

This paper also makes several contributions regarding both data and methodology. In terms of data, we are not aware of any other studies in the literature that have investigated the Singaporean banking sector using a relatively long time period, enough to shed some lights on the efficiency trends in the Singaporean banking sector over-time. In terms of methodology, given the small sample size of the Singaporean banking sector, we believe that it is more appropriate to investigate Singapore banks efficiency using the DEA window analysis, which could provide a greater degree of freedom to the sample. Nevertheless, this study will be the first to investigate Singapore banks efficiency using the DEA window analysis method.

The paper is structured as follows: the next section gives an overview of the Singapore banking system; section 3 reviews related studies in the main literature with respect to the study on banks efficiency; section 4 outlines the approaches to the measurement and estimation of efficiency change; section 5 discusses the results and finally section 6 provides some concluding remarks.

II. BRIEF OVERVIEW OF THE SINGAPORE BANKING SYSTEM

The development of Singapore as a financial center was the move of deliberate government policy to broaden the country's economic base in the 1970s. With the introduction of Monetary Authority of Singapore (MAS) in 1970, the government has introduced fiscal incentives, removed exchange controls and encouraged competition to spur the financial sector development. Supported by its sound macroeconomic fundamentals and prudent policies, today, Singapore ranks among the leading international financial centers after New York, London and Tokyo. This is evidenced by the presence of a wide network of financial institutions providing a range of services that facilitate domestic, regional and international flow of funds for trade and investments. By the end of 2000, there were 141 commercial banks (full, wholesale and offshore licenses) in Singapore.

The Singapore domestic banking sector is closely regulated and largely protected until the later half of the 1990s. The entry of foreign banks was restricted to the wholesale banking markets since 1971. While locally incorporated banks are given permission to expand its branch networks, foreign incorporated full licensed banks admitted prior to 1971 are subjected to restrictions in terms of opening up new branches and re-locating existing branches. As such, locally incorporated banks are relatively sheltered from foreign competition. The result is a banking industry with many international players but where domestically incorporated commercial banks, dominates the local banking market.

At present, Singapore is an established financial center and is one of the key centers in Asia. Singapore lags only behind London, New York and Tokyo in foreign exchange trading. Growth in the financial services sector has contributed significantly to its economic growth and development, which today accounts for approximately 13 to 15% of its GDP. During the Asian Financial Crisis 1997-1998, its sound economic and financial fundamental has enabled the sector to weather the crisis relatively well. Despite incurring losses from defaulted loans, which escalated during the crisis, Singapore commercial banks were adequately capitalized and insolvency was not an issue. Nonetheless, the immediate lessons from the financial turmoil for the local financial institutions are the need for the creation of strong incentive for banks to merge, which would create large institutions to cope with international competition.

Looking ahead, the Singaporean banking sector is faced with the challenges to maintain its competitiveness whilst maintaining a prudent regime for financial regulation at the same time. At a national level, the challenges are deemed as one of the key drivers for Singapore to become a developed nation. In the 2001 World Competitiveness Yearbook published by the Institute for Management Development (IMD), Singapore was ranked as the second, most competitive economy in the world for the fifth year running.

To remain competitive in the new global economy, Singapore has recognized the need to deregulate closed sectors and shift into a knowledge-based economy. To this end, the MAS have taken steps to open the domestic banking and insurance industries to greater foreign participation. It has also shifted the emphasis of regulation to risk focused supervision. The challenge would be to develop a flexible and integrated risk focused supervisory framework that is well grounded in prudential principles and yet attuned to evolving global financial trends.

At the same time, the paradigm shift to the knowledge-based economy has several implications for the banking sector as well. As new technologies fuel the transformation of the global economy, resulting in a globally integrated marketplace, the banking sector must learn to ride and attune to the waves of change. To this end, financial institutions need to strengthen its IT capabilities. Recognizing that human and intellectual capital are the key competitive factors in a knowledge-based economy, the financial institutions should encourage greater innovation and continual retraining and re-skilling of their workforce as well as investing in foreign talent for modern skill intensive positions.

The MAS embarked on a fundamental review of its policies in regulating and developing Singapore's banking sector in late 1997. In February 1998, the MAS unveiled several series of reforms aimed at making Singapore a pre-dominant financial center in an increasingly competitive global market. In developing the reforms, MAS worked closely with industry players and other government agencies to review the regulatory framework and formulate strategies to stimulate growth and intensity the development in specific industries in the financial services sector over the next five to ten years.

Hitherto, the MAS have launched two reform packages in October 1999 and June 2001. The core essence of these two packages is aimed at strengthening Singapore's banking system and local banks through liberalization, which would allow greater access to foreign players, consolidation of local banks, strengthening system of corporate governance to enhance greater transparency and restructuring as in the shedding of non-core banking businesses.

The first package started with the award of new [1] Qualifying Full Bank (QFB) privileges to four foreign banks namely, ABN Amro Bank NV, Banque Nationale de Paris, Citibank N.A and Standard Chartered Bank to increase competition. Eight new [2] Restricted Banking licenses and [3] Offshore Banking licenses privileges were also issued respectively to foreign banks to promote greater flexibility in business activities.

In June 2001, the MAS unveiled the second round of the financial reform package, which will free entry to the Singapore Dollar (SG$) wholesale market and intensify retail competition by giving foreign QFBs more business opportunities. Under the blueprint, the three-tier regime of full, restricted and offshore banks will be crunched into two-tiers by merging the restricted and offshore categories under the "wholesale" license. This will allow the banks to accept SGD fixed deposits above SG$250,000. It will also remove limits on the amount of SGD lending.

Under revisions to the QFBs license, foreign banks can open at up to 15 locations, of which 10 can be branches and the rest of-site automated teller machines (ATMs). The old license only allowed up to 10 locations, of which five could be branches. QFBs will also be allowed to provide debt services by negotiating with vendors like Nets, Visa or MasterCard for access to their EFTPos network from July 2002. Consequently, this will allow QFBs to issue debit cards. Finally, the revision also allows a QFB to apply to operate supplementary retirement scheme accounts (or known as CPF investment accounts).

With this in mind, the two liberalization programs could be regarded as significant milestones in the history of Singapore's financial sector and is hoped that these initiatives will enable local banks to grow into sound, well-capitalized institutions.

III. RELATED STUDIES

In the past few years, DEA has frequently been applied to banking industry studies. The first application analyzed efficiencies of different branches of a single bank. Sherman and Gold (1985) studied the overall efficiency of 14 branches of a U.S. savings bank. DEA results showed that six branches were operating inefficiently compared to the others. Similar study by Parkan (1987) suggested that eleven branches out of thirty-five were relatively inefficient.

Rangan *et al.* (1988) shifted the unit of assessment from branches to consolidated banking institutions. They applied DEA to a larger sample of 215 U.S. banks and attempted to break down inefficiency to that stemming from pure technical inefficiency and scale inefficiency. They employed the intermediation approach by using three inputs (labor, capital and purchased funds) and five outputs (three types of loans and two types of deposits). Their results indicated that banks could have produced the same level of output with only 70% of the inputs actually used, while scale inefficiencies of the banks were relatively small, suggesting that the sources of inefficiency to be pure technical rather than scale.

In addition to the heavy concentration on the US, DEA has fast become a popular method in assessing financial institutions efficiency among banking researchers in other nations. Fukuyama (1993 and 1995) was among the early researchers particularly among countries in Asia to employ DEA to investigate banking efficiency. Employing labor, capital, and funds from customers as inputs and revenue from loans and revenue from other business activities as outputs, Fukuyama (1993) considers the efficiency of 143 Japanese banks in 1990. He found that the pure technical efficiency to average around 0.86 and scale efficiency around 0.98 implying that the major source of overall technical inefficiency is pure technical inefficiency. The scale inefficiency is found to be mainly due to increasing returns to scale. He also found that banks of different organizational status perform differently with respect to all efficiency measures (overall, scale, pure technical). Scale efficiency is found to be positively but weakly associated with bank size.

1 Banks Efficiency Studies Utilizing DEA Window Analysis

Although studies investigating banks efficiency by DEA are voluminous, there are only a few papers, which have utilized the DEA window analysis approach to banking (see Avkiran, 2004; Reisman *et al.*, 2003; Webb, 2003 and Hartman and Storbeck, 1996). Asmild *et al.* (2004) combined a DEA like Malmquist Productivity Index with DEA window analysis on a sample of five Canadian banks over a 20-year period.

Applying a three-year window to a sample of 10 Australian trading banks during the period 1986-1995, Avkiran (2004) found that Australian trading banks have exhibit deteriorating efficiency levels during the earlier part of the studies, before progressively trending upwards in the latter part. During the period of study, he found that interest expenses to be the main source of inefficiency of Australian trading banks. He suggest that most Australian banks have exhibited CRTS during the early period, DRTS and IRTS in the early 1990s and turn to exhibit CRTS during the latter part of the studies.

Webb (2003) utilizes DEA window analysis to investigate the relative efficiency levels of large UK retail banks during the period of 1982-1995. Following the intermediation approach, three inputs are considered namely deposits, interests expense and operational expenses while total income and total loans are outputs. He found that during the period the mean inefficiency levels of UK retail banks were low compared to past studies on UK banking industry. He suggested that the overall long run average efficiency level is falling and that all the six large UK banks shows declining levels of efficiency over thee entire period. He concludes that scale inefficiency dominates pure technical inefficiencies; less big banks are more likely to report technical inefficiency; and during the period of study banks with asset levels over £105 billion suffers declining returns to scale (DRS).

Reisman *et al*. (2003) investigates the impact of deregulation on the efficiency of eleven Tunisian commercial banks during 1990 to 2001. Applying three inputs namely fixed assets, number of employees, and deposits and loans and securities portfolios as outputs, they followed the intermediation approach to DEA with an extended window analysis. They find that deregulation had a positive impact on Tunisian commercial banks overall efficiency. They suggest that public banks outperformed private banks in transforming deposits into loans. The decomposition of overall efficiency into its pure technical and scale efficiency components indicates that private banks experienced predominantly pure technical inefficiency during the period. The public banks on the other hand were pure technically inefficient during the early period, which was mostly, scale inefficient towards the end of the period of study. They also suggest that both public and private banks were inefficient in their investments.

2 Studies on Singapore Banks Efficiency

Using DEA with three inputs and two outputs, Chu and Lim (1998) evaluate the relative cost and profit efficiency of a panel of six Singapore listed banks during the period 1992-1996. They found that during the period the six Singapore listed banks have exhibit higher overall efficiency at 95.3% compared to profit efficiency at 82.6%. They also found that the large Singapore banks have reported higher efficiency of 99.0% compared to the 92.0% for the small banks. The also suggest that scale inefficiency dominates pure technical inefficiency during the period of study.

More recently, Randhawa and Lim (2005) utilize DEA to investigate the locally incorporated banks in Hong Kong and Singapore x-efficiencies during the period 1995 to 1999. They found that during the period the seven domestic incorporated Singapore banks have exhibit an average overall efficiency score of 80.4% under the intermediation approach and 97.2% under the production approach. They suggest that the large Singapore banks have reported higher overall efficiency compared to the small banks under the production approach while on the other hand the small banks exhibits higher overall efficiency under the intermediation approach. The also suggest that pure technical inefficiency dominates scale inefficiency under both approaches during the period of study.

IV. DATA AND METHODOLOGY

Following Avkiran (2004), Reisman *et al.* (2003) and Webb (2003) among others, a non-parametric method, DEA, will be used in measuring the efficiency of the Singapore banks. The methods allows for the decomposition of the efficiency and productivity differences into one representing the banks' efficiency and productivity levels relative to their peers best practice frontiers. The DEA is a linear (mathematical) programming technique which forms a non-parametric surface / frontier (more formally a piecewise-linear convex isoquant) over the data points to determine the efficiencies of each DMU relative to this frontier.

The small number of banks is a serious handicap in studying efficiency of the Singapore banking system. The small sample size is among other reasons, which leads us to DEA as the tool of choice for evaluating X-efficiency of Singapore banks. Furthermore, DEA is less data demanding as it works fine with small sample size and does not require knowledge of the proper functional form of the frontier, error and inefficiency structures (Evanoff and Israelvich, 1991, Grifell-Tatje and Lovell, 1997, Bauer *et al*., 1998). The stochastic models on the other hand, necessitate a large sample size to make reliable estimations. Nevertheless, given the small sample size of the Singaporean banking sector, we believe that it is more appropriate to investigate Singapore banks efficiency using the DEA window analysis, which could provide a greater degree of freedom to the sample.

The study by Farrell (1957) created basic concepts for efficiency measurement and discussion of frontiers. Farrell posited that the overall cost efficiency (CE) of a firm could be decomposed into two components; technical efficiency (TE) and allocative efficiency (AE). Technical efficiency reflects the ability of a firm to generate maximum output from a given set of factors of production while on the other hand, allocative efficiency reflects the ability of a firm to use the factors of production in optimal proportions, given their respective prices. His idea was to measure efficiency as a relative distance from the efficient frontier by keeping the input proportions fixed. In his analysis, Farrell assumed that production technology is known and that returns to scale are constant.

Farrell's concept are best illustrated, for the single output/two input case, in the unit isoquant diagram, Figure 3.1, where the unit isoquant (yy') shows the various combinations of the two inputs (x1, x2) which can be used to produce 1 unit of the single output (y). The DMU at E is productively (or overall) efficient in choosing the cost minimizing production process given the relative input prices (represented by the slope of WW'). As illustrated in Figure 1, the ratio OQ/OR measures the technical efficiency of the production at point R, whereas, OQ/OR compares the minimum input required for production of one unit to the observed input usage in the firm. Thus, 1-OQ/OR measures the proportion of inputs that could be reduced without reducing output. Hence,

$$TE = OQ/OR \tag{1}$$

The ratio OP/OQ measures allocative efficiency of the firms input usage. The costs in point P are equal to the costs in the overall productively efficient point E but lower than in point Q. The ratio of 1-OP/OQ then measures the possible input savings that could be reduced if the inputs were used in the right proportions. Hence,

$$AE = OP/OQ \tag{2}$$

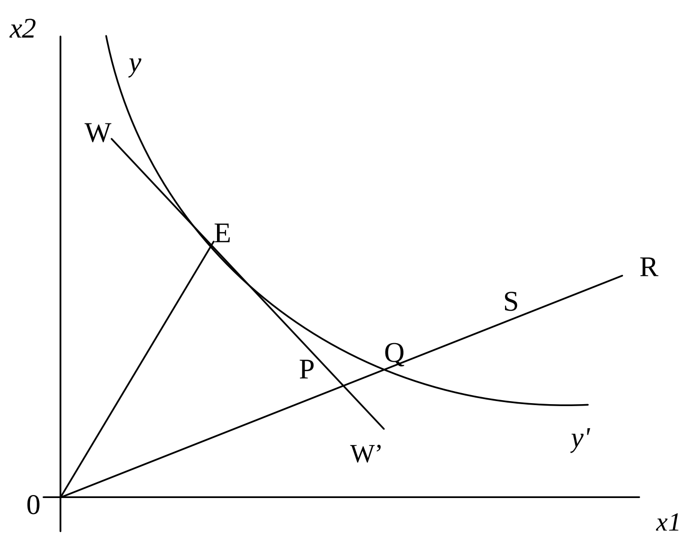
A measure for overall efficiency (productively efficient) can be obtained by adding technical and allocative efficiency together. In Figure 1, the total efficiency is represented by the ratio of OP/OR. Total inefficiency reveals total waste of inputs, thus shows how much costs could be reduced if the firm operated in the efficient point E instead of point R. Hence,

$$OE = OP/OR \tag{3}$$

In short, a DMU at Q is allocatively inefficient in choosing an appropriate inputs mix, while a DMU at R is both allocatively (in the ratio of OP/OR) and technically inefficient (in the ratio of OQ/OR), resulted from excessive amount of both inputs usage (x1 and x2), compared to the DMU at Q in producing the same level of output (y).

Figure 1

Farrell Efficiency



The term Data Envelopment Analysis (DEA) was first introduced by Charnes, Cooper and Rhodes (1978), (hereafter CCR), to measure the efficiency of each Decision Making Units (DMUs), that is obtained as a maximum of a ratio of weighted outputs to weighted inputs. This denotes that the more the output produced from given inputs, the more efficient is the production. The weights for the ratio are determined by a restriction that the similar ratios for every DMU have to be less than or equal to unity. This definition of efficiency measure allows multiple outputs and inputs without requiring pre-assigned weights. Multiple inputs and outputs are reduced to single 'virtual' input and single 'virtual' output by optimal weights. The efficiency measure is then a function of multipliers of the 'virtual' input-output combination.

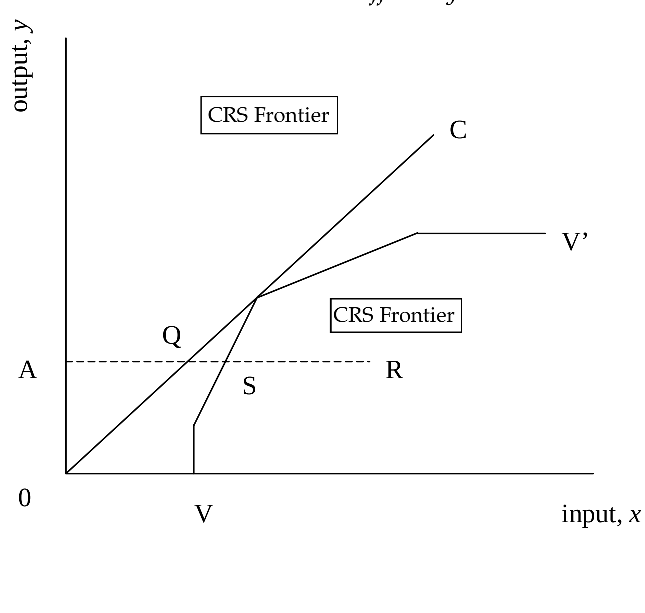
The CCR model presupposes that there is no significant relationship between the scale of operations and efficiency by assuming constant returns to scale (CRS), and it delivers the overall technical efficiency (OTE). The CRS assumption is only justifiable when all DMUs are operating at an optimal scale. However, firms or DMUs in practice might face either economies or diseconomies of scale. Thus, if one makes the CRS assumption when not all DMUs are operating at the optimal scale, the computed measures of technical efficiency will be contaminated with scale efficiencies.

Banker *et al*. (1984) extended the CCR model by relaxing the CRS assumption. The resulting "BCC" model was used to assess the efficiency of DMUs characterized by variable returns to scale (VRS). The VRS assumption provides the measurement of purely technical efficiency (PTE), which is the measurement of technical efficiency devoid of the scale efficiency effects. If there appears to be a difference between the TE and PTE scores of a particular DMU, then it indicates the existence of scale inefficiency.

To further illustrate this, a DMU at point R in Figure 2 is technically inefficient under both the CRS and VRS assumption. The technical inefficiency of point R under the CRS assumption is thus the distance QR, while under the VRS would only be SR. Hence, the

Figure 2

Scale and Technical Efficiency



difference between these two measures, QS, is attributable to scale inefficiency, which indicates that the DMU at point R can produce its current level of output with fewer inputs if it attains CRS.

In summary, the technical efficiency ratio OQ/OR may be further decomposed into scale efficiency, OQ/OS, and pure technical efficiency, OS/OR, with point Q representing the case of constant returns to scale. The former arises because a DMU is at an input-output combination that differs from the equivalent constant returns to scale situation. The latter, pure technical efficiency represents the failure of a DMU to extract the maximum output from its adopted input levels, and hence it may be thought of as measuring the unproductive use of resources. In summary,

Pure Technical Efficiency (PTE) = AS/AR

Scale Efficiency (SE) = AQ/AS

Technical Efficiency = Pure Technical Efficiency (PTE) x Scale Efficiency (SE) = (AS/AR) x (AQ/AS) = AQ/AR

$$max\ \lambda_0\ \theta_0 \qquad (4)$$

$$subject\ to\ \sum_{j=1}^{n}\lambda_{0j}y_{rj} \geq y_{r0} \qquad (r = 1, \ldots, s)$$

$$\theta_0 x_{i0} \geq \sum_{j=1}^{n}\lambda_{0j}x_{ij} \qquad (i = 1, \ldots, n)$$

$$\sum_{j=1}^{n}\lambda_{0j} = 1$$

$$\lambda_{0j} \geq 0 \qquad (j = 1, \ldots, n)$$

The first constraint states that output of the reference unit must be at least at the same level as the output of DMU 0. The second constraint tells that the efficiency corrected input usage of DMU 0 must be greater than or the same as the input use of the reference unit. Since the correction factor is same for all types of inputs, the reduction in observed inputs is proportional. The third constraint ensures convexity and thus introduces variable returns to scale. If convexity requirement is dropped, the frontier technology changes from VRS to CRS. The efficiency scores always have smaller or equal values in the case of CRS. Efficiency can also be measured into output direction in the case of VRS.

Although the scale efficiency measure will provide information concerning the degree of inefficiency resulting from the failure to operate with CRS, it does not provide information as to whether a DMU is operating in an area of increasing returns to scale (IRS) or decreasing returns to scale (DRS). Hence, in order to establish whether scale inefficient DMUs exhibit IRS or DRS, the technical efficiency problem (4) is solved under the assumption of variable returns to scale (VRS) to provide

$$max\ \lambda_0\ \theta_0 \qquad (5)$$

$$subject\ to\ \sum_{j=1}^{n}\lambda_{0j}y_{rj} \geq y_{r0} \qquad (r = 1, \ldots, s)$$

$$\theta_0 x_{i0} \geq \sum_{j=1}^{n} \lambda_{0j} x_{ij} \qquad (i = 1, \ldots, n)$$

$$\sum_{j=1}^{n} \lambda_{0j} \leq 1$$

$$\lambda_{0j} \geq 0 \qquad (j = 1, \ldots, n)$$

1. Window Analysis

In order to capture the variations of efficiency over time, Charnes *et al.* (1985) proposed a technique called 'window analysis' in DEA. The window analysis assesses the performance of a DMU over time by treating it as a different entity in each time-period. This method allows for tracking the performance of a unit or DMU over time and provides a better degree of freedom (Avkiran, 2004 and Reisman *et al.*, 2003). If a DMU is found to be efficient in one year despite the window in which it is placed, it is likely to be considered strongly efficient compared to its peers (Avkiran, 2004).

As there is no theory or justification underpins the definition of the window size (Tulkens and van den Eeckaut, 1995), this paper utilizes a three-year window, which is consistent with the original work by Charnes *et al.* (1985). Furthermore, Avkiran (2004), Webb (2003) and Reisman *et al.*, (2003) have also utilized a three-year window to investigate banks' efficiency in Australia, U.K. and Tunisia respectively.

To illustrate, from Table 1 below the first window incorporates years 1993, 1994 and 1995. When a new period is introduced into the window, the earliest period is dropped. In window two, year 1993 will be dropped and year 1996 will be added to the window. Subsequently in window 3, years 1995, 1996 and 1997 will be assessed. The analysis is performed until window 9 analyzes years 2001, 2002 and 2003. As DEA window analysis treats a DMU as different entity in each year, a three-year window with six DMUs is equivalent to 18 DMUs. Subsequently, by applying a nine, three-year window, would considerably increase the number of observations of the sample to 162, providing a greater degree of freedom.

Table 1
Window Breakdown

Window 1	1993	1994	1995								
Window 2		1994	1995	1996							
Window 3			1995	1996	1997						
Window 4				1996	1997	1998					
Window 5					1997	1998	1999				
Window 6						1998	1999	2000			
Window 7							1999	2000	2001		
Window 8								2000	2001	2002	
Window 9									2001	2002	2003

2. Variables Definition

The definition and measurement of inputs and outputs in the banking function remains a contentious issue among researchers. To determine what constitutes inputs and outputs of banks, one should first decide on the nature of banking technology. In the banking theory literature, there are two main approaches competing with each other in this regard: the production and intermediation approaches (Sealey and Lindley, 1977).

Under the production approach, a financial institution is defined as a producer of services for account holders, that is, they perform transactions on deposit accounts and process documents such as loans. Hence, according to this approach, the number of accounts or its related transactions is the best measures for output, while the number of employees and physical capital is considered as inputs. Previous studies that adopted this approach are by Sherman and Gold (1985), Ferrier and Lovell (1990) and Fried *et al.* (1993).

The intermediation approach on the other hand assumes that financial firms act as an intermediary between savers and borrowers and posits total loans and securities as outputs, whereas deposits along with labor and physical capital are defined as inputs. Previous banking efficiency studies research that adopted this approach are among others Charnes *et al.* (1990), Bhattacharyya *et al.* (1997) and Sathye (2001).

For the purpose of this study, a variation of the intermediation approach or asset approach originally developed by Sealey and Lindley (1977) will be adopted in the definition of input and output definition [4]. According to Berger and Humphrey (1997), the production approach might be more suitable for branch efficiency studies as at most times bank branches basically process customer documents and bank funding, while investment decisions are mostly not under the control of branches. Furthermore, Sathye (2001) also noted that this approach is more relevant to financial institutions as it is inclusive of interest expenses, which often accounts for one-half to two-thirds of total costs depending on the phase of the interest rate cycles.

The aim in the choice of variables for this study is to provide a parsimonious model and to avoid the use of unnecessary variables that may reduce the degree of freedom [5]. Accordingly, we model commercial banks as multi-product firms, producing 3 outputs and employing 2 inputs. All variables are measured in millions of Singapore Dollars. The input vector includes ($x1$) *Total Deposits*, which includes deposits from customers and other banks and ($x2$) *Interest Expenses* while ($y1$) *Total Loans*, which includes loans to customers and other banks and ($y2$) *Interest Income* are the output vectors. The variables selected for this study could be argued to fall under the intermediation approach to modeling bank behavior.

To recognize that banks in recent years have increasingly been generating income from 'off-balance sheet' business and fee income generally, following Drake and Hall (2003) and Isik and Hassan (2003) among others, ($y3$) *Non-Interest Income* would be incorporated as a proxy to non-traditional activities as output. Non-interest income is defined as fee income, investment income and other income, which among others consist of commission, service charges and fees, guarantee fees, net profit from sale of investment securities and foreign exchange profit.

For the empirical analysis, *all* Singapore commercial banks that are publicly listed on the SES from 1993-2003 would be used (see Table 2). During the study period, banks that were acquired or failed are dropped from the sample so that the final sample contains only surviving banks as of 2003. So as to focus on commercial banks and to maintain homogeneity, only commercial banks that make commercial loans and accept deposits from the public are included in the analysis. Therefore, Development Banks and Investment Banks are excluded from the sample. The annual balance sheet and income statement used to construct the variables for the empirical analysis were taken from published balance sheet information in annual reports of each individual bank.

Table 2
Singapore Listed Commercial Banks

Bank	*Abbreviation Used*
DBS Group Holdings Ltd	**DBS**
Keppel Capital Holdings Ltd	**KEP**
Oversea-Chinese Banking Corporation Ltd	**OCB**
Overseas Union Bank Ltd	**OUB**
Tat Lee Bank Ltd	**TLB**
United Overseas Bank Ltd	**UOB**

V. EMPIRICAL RESULTS

As has been stated earlier, to the best of our knowledge, the study would be the first in the literature to investigate Singapore commercial banks efficiency by DEA window analysis approach. Therefore, the results reported below provide valuable information on the long-term trend in efficiency change of Singapore commercial banks. The DEA model is applied in 9, three-year windows and the results are reported for the general trend in overall efficiency for each window and then decomposed into pure technical efficiency and scale efficiency. Changes over time for the sequence of windows is then considered.

The average of all scores, for each bank, is given in the column denoted "Mean". The column labeled "SD" indicates the standard deviation for the score of each bank during the entire period. The column labeled "LDY" indicates the largest difference in a bank's scores in the same year but in different windows. The column labeled "LDP" indicates the largest difference in a bank's scores for the entire period. A bank can have different efficiency scores in different windows. A bank that is efficient in one year regardless of the window is said to be stable in its efficiency rating (Cooper *et al*., 2000).

1. General Trends

Looking at the average overall efficiency levels for each window in Table 3, it is clear that Singapore banks average efficiency levels was on the uptrend in windows 2 to 4, stabilizing at the 97% levels in windows 4 to 6, before staging upwards again in window 7. The overall efficiency level however declined slightly in window 8 and dropped further in window 9. One clear reason for the decline in efficiency levels of Singapore banks during this period was due to the merger program among domestic banks during the period, which may have resulted to banks to have to absorb extra capacities and incur higher costs associated with branch closures and systems integration.

It is also interesting to note that despite the severity of the Asian Financial Crisis that swept the region in 1997-98, Singapore banks were relatively unscathed. The Singapore government had implemented measures which has successfully deflated the growing property market bubble in 1996, which has stopped Singapore banks from building a large exposure to the property sector and shielded them from the full impact of the 1997/98

Table 3
Window Analysis of Overall Efficiency Scores

Bank	*Window*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*Mean/ Window*	*Mean*	*SD*	*LDY*	*LDP*
	1	74.9	86.2	92.2									**84.4**				
	2		86.2	92.2	95.7								**91.4**				
	3			92.3	95.8	68.9							**85.7**				
	4				100.0	89.6	82.1						**90.6**				
DBS	**5**					81.8	79.0	98.4					**86.4**	**90.1**	**0.084**	**20.7**	**31.1**
	6						78.9	98.4	94.3				**90.5**				
	7							96.8	94.3	94.2			**95.1**				
	8								88.7	84.4	100.0		**91.0**				
	9									88.7	100.0	100.0	**96.2**				
	1	88.6	83.9	80.1									**84.2**				
	2		84.0	80.1	93.6								**85.9**				
	3			80.2	93.6	92.7							**88.8**				
	4				100.0	96.7	100.0						**98.9**				
KEP	**5**					96.3	98.8	100.0					**98.4**	**94.4**	**0.075**	**6.4**	**19.9**
	6						96.5	100.0	100.0				**98.8**				
	7							100.0	100.0				**100.0**				
	8								100.0				**100.0**				
	9																
	1	84.3	82.1	86.6									**84.3**				
	2		82.1	86.6	91.2								**86.6**				
	3			86.6	91.2	97.7							**91.8**				
	4				96.9	100.0	95.6						**97.5**				
OCB	**5**					100.0	95.8	100.0					**98.6**	**95.3**	**0.063**	**5.7**	**17.9**
	6						98.3	100.0	99.9				**99.4**				
	7							100.0	100.0	100.0			**100.0**				
	8								100.0	100.0	100.0		**100.0**				
	9									100.0	97.7	100.0	**99.2**				

Mean = Average score for the ten year period; **SD** = Standard Deviation for the period; **LDY** = Largest difference between scores in the same year; **LDP** = Largest difference between scores across the entire period

Table 3: Continued

Bank	*Window*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*Mean/ Window*	*Mean*	*SD*	*LDY*	*LDP*
	1	90.6	89.0	100.0									**93.2**				
	2		89.0	100.0	100.0								**96.3**				
	3			100.0	100.0	99.3							**99.8**				
	4				100.0	100.0	95.5						**98.5**				
OUB	**5**					100.0	96.8	100.0					**98.9**	**98.3**	**0.038**	**4.5**	**11.0**
	6						100.0	100.0	100.0				**100.0**				
	7							100.0	100.0				**100.0**				
	8								100.0				**100.0**				
	9																
	1	100.0	100.0	99.8									**99.9**				
	2		100.0	99.8	90.5								**96.8**				
	3			100.0	91.8	96.5							**96.1**				
	4				96.8	98.4							**97.6**	**98.1**	**0.034**	**6.3**	**9.5**
TLB	**5**					100.0							**100.0**				
	6																
	7																
	8																
	9																
	1	87.2	93.4	88.5									**89.7**				
	2		95.5	88.6	86.0								**90.0**				
	3			100.0	97.7	86.1							**94.6**				
	4				100.0	94.5	100.0						**98.2**				
UOB	**5**					95.9	100.0	100.0					**98.6**	**95.9**	**0.052**	**14.0**	**14.0**
	6						100.0	100.0	96.3				**98.8**				
	7							100.0	100.0	100.0			**100.0**				
	8								100.0	90.6	100.0		**96.9**				
	9									88.3	100.0	100.0	**96.1**				

Mean = Average score for the ten year period; **SD** = Standard Deviation for the period; **LDY** = Largest difference between scores in the same year; **LDP** = Largest difference between scores across the entire period.

Asian Financial Crisis. In addition, the conservative loan growth strategies as well as high capital reserves, which prior to 1998 included hidden reserves, ensured that Singapore banks were able to ride out of the Crisis. These served the as a buffer to the banks and allowed them to maintain stable average overall efficiency scores throughout the period of our studies.

2. Overall Efficiency

Table 3 decomposes overall average efficiency scores for each bank in each window while clarifying the trends. It is apparent that, Singapore banks have exhibit an average overall efficiency score of 95.4% for the 1993-2003 period, suggesting that the Singapore banking system has performed relatively well in its basic function – transforming deposits to loans and that a minimal input waste of about 4.6% during the period. Our findings are similar to Chu and Lim (1998), which suggest that Singapore banks have exhibits an average efficiency of 95.3% during the period of 1992-1996. Randhawa and Lim (2005) on the other hand have found 19.6% input waste among seven Singapore domestic banks during the period of 1995-1999. It is apparent from Table 3 that OUB the best performers for the period, maintained its position with an average overall efficiency of 98.3% and standard deviations of 0.038.

While OUB is the best bank in terms of minimizing costs to produce the same level of outputs, on the other hand our findings suggest that DBS is the worst performer with 90.1% overall efficiency level and standard deviations of 0.084 during the period. We also find that KEP and OUB exhibits improvements and upward trend in the later parts of the period, while UOB overall efficiency scores seems to deteriorate at the latter part of the period.

Our results suggest that the smaller banking groups with total assets of less than SG$50 billion, exhibited higher efficiencies at 96.9% compared to the large and very large peers overall efficiencies of 95.6% and 90.1% respectively, while the very large bank reports lower overall efficiency level compared to its large counterparts.

The overall efficiency score is a composite of both pure technical and scale efficiency scores, the relative sizes of these indexes provide evidence as to the source of overall inefficiency. An insight into the decomposition of overall efficiency into its pure technical and scale efficiency components suggests that during the period of study, scale inefficiency (output related) dominates pure technical inefficiency (input related) in Singapore banking. In contrast, Randhawa and Lim (2005) have found that pure technical inefficiency dominates scale inefficiency during 1995-1998, while Singapore domestic banks exhibits higher scale efficiency in 1999.

3. Pure Technical Efficiency

Table 4 presents the pure technical efficiency of Singapore banks. In general, it has been concluded by among others Berger *et al*. (1993) that larger banks report higher levels of technical or x-efficiency, than do their smaller counterparts. Accordingly, we also find that large Singapore banks average pure technical efficiency is slightly higher compared to its smaller and very large counterparts.

Our results suggest that the smaller banking groups, KEP, TLB and OUB have reported average pure technical efficiency of 98.6% compared to its larger counterparts with total assets of SG$80 billion to SG$120 billion, OCB and UOB, which exhibits average pure technical

Table 4
Window Analysis of Average Pure Technical Efficiency Scores, 1993-2003

	DBS	*KEP*	*OCB*	*OUB*	*TLB*	*UOB*	*Sample Mean*
93-94-95	91.2	94.7	93.2	95.9	100.0	100.0	**95.8**
94-95-96	95.6	94.0	93.7	97.3	96.9	99.5	**96.2**
95-96-97	98.5	97.1	93.8	100.0	96.8	98.8	**97.5**
96-97-98	99.7	99.0	99.8	99.4	100.0	99.7	**99.6**
97-98-99	95.6	99.9	100.0	99.4	100.0	98.6	**98.9**
98-99-00	100.0	100.0	100.0	100.0		100.0	**100.0**
99-00-01	100.0	100.0	100.0	100.0		100.0	**100.0**
00-01-02	100.0	100.0	100.0	100.0		100.0	**100.0**
01-02-03	100.0		100.0			100.0	**100.0**
Mean	**97.8**	**98.1**	**97.8**	**99.0**	**98.7**	**99.6**	**98.5**

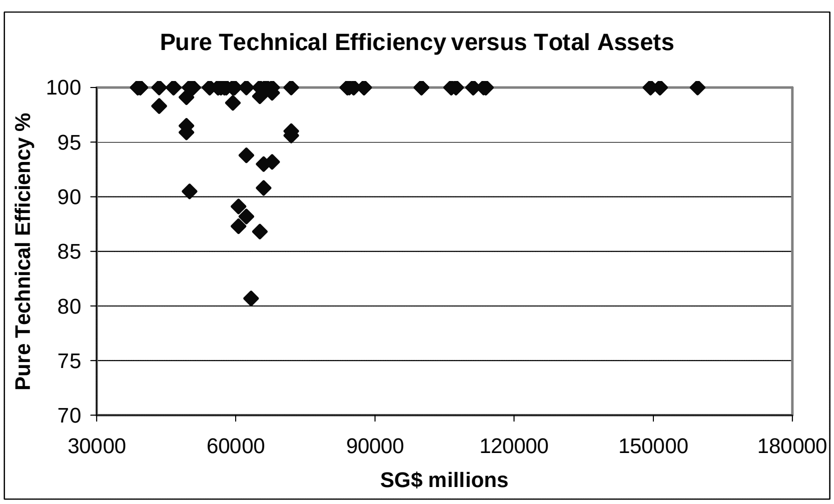
efficiency levels of 98.7%. Surprisingly, DBS, which is the largest bank in our sample in terms of total assets, exhibits the lowest average pure technical efficiency score of 97.8% during the period.

Figure 3 (a) corroborates Berger *et al*. (1993) findings, showing that during the early part of the studies, technical efficiency was low amongst the sample with the majority of banks reporting technical efficiency in average of 97.6%. If at all, anything can be discerned from Figure 3 (a) there seems to be a clustering of efficiency around asset levels of SG$10 billion to SG$29 billion and there seems to be tendency for higher levels of technical inefficiency to be reported around total assets of SG$39 billion to SG$72 billion.

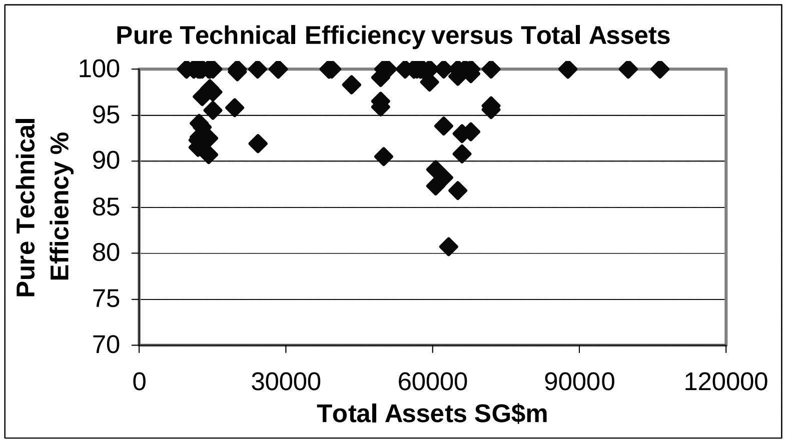
In contrast, the trend during the latter part of period shows higher levels of technical efficiency with technical efficiency reported through all asset sizes (see Figure 3 (b)). As banks expand in size brought about by the consolidation in the domestic banking sector, it could be argued that Singapore banks are more efficient in controlling costs. As pointed by

Figure 3

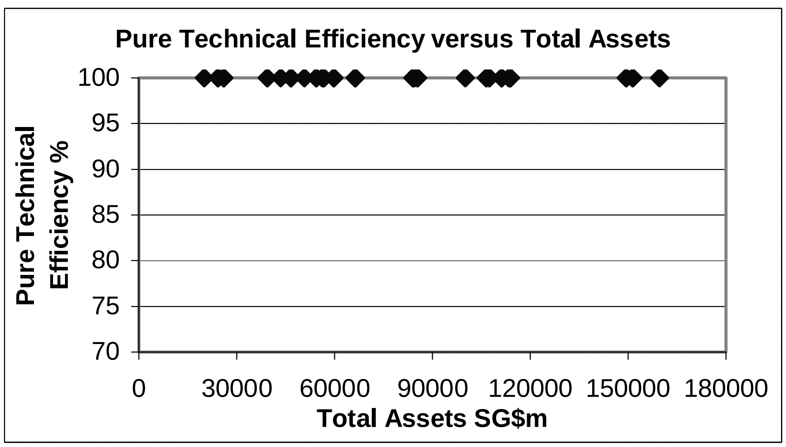
Pure Technical Efficiency versus Total Assets



(a) Window 1-5: 1993-1999



(b) Window 6-9: 1998-2003



Chu and Lim (1998: pp. 163), large banks may have the advantage over its small counterparts as large banks attracts more deposits and loans transactions and that the large banks may command larger interest rate spreads. Furthermore, large banks offers more services and in the process derive substantial non-interest income from commissions, fees and other treasury activities. In addition, Randhawa and Lim (2005) suggest that large banks extensive branch networks and large depositors base attracts cheap source of funds while on the other hand the small banks with smaller depositors base might resort to purchasing funds in the inter-bank market, which is more costly and might explain the lower technical efficiency scores of the small Singapore banks.

It is also interesting to note that despite earlier evidence which suggests that the lack of competition may result in lower technical efficiency, (see Sathye, 2001 and Walker, 1998), it is apparent from Figure 3 (b) that all Singapore banks have reported 100% pure technical efficiency scores during windows 6 onwards, which corresponds to the period of 1998 to 2003. Walker (1998) states that the high degree of concentration in the Australian banking, which were dominated by four major banks, may result in the "quiet life" hypothesis to come into play. The "quiet life" hypothesis predicts a reverse causation, that is, as firms enjoy greater market power and concentration, inefficiency follows not because of non-competitive pricing but more so because of a relaxed environment with no incentives to minimize costs. Hence, the findings suggest that during the period of 1998-2003, the source of inefficiency among Singapore domestic incorporated banks is solely attributed to scale inefficiency.

4. Scale Efficiency

Given the dearth of research on the nature of scale efficiency in Singapore banking, the next section provides some interesting results on the relationship between efficiency and scale (in terms of total assets). Earlier studies on banks efficiency has generally concluded that large banks tend to report lower levels of scale efficiencies (see Webb, 2003, Drake, 2001, and Miller and Noulas, 1996). Figure 4 shows the results for all banks across all windows, indicating a clear grouping of scale efficient banks around asset levels of SG$10 billion to SG$29 billion (excepting the performance of DBS). In contrast to the pure technical efficiency, it is clear from Table 5 that small Singapore commercial banks exhibits the highest average scale efficiency scores compared to its large and very large counterparts and that the very large bank in our sample reported the lowest average scale efficiency score during the period.

Table 5
Window Analysis of Average Scale Efficiency Scores, 1993-2003

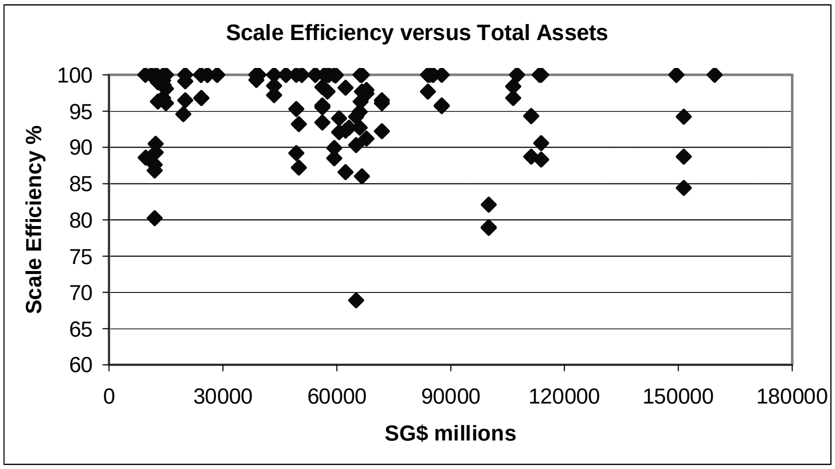
	DBS	*KEP*	*OCB*	*OUB*	*TLB*	*UOB*	*Sample Mean*
93-94-95	92.5	88.9	90.6	97.1	99.9	89.7	**93.1**
94-95-96	95.6	91.4	92.5	98.9	99.9	90.5	**94.8**
95-96-97	87.1	91.8	97.9	99.8	99.3	95.6	**95.3**
96-97-98	90.8	99.9	97.7	99.1	97.6	98.4	**97.3**
97-98-99	90.5	98.5	98.6	99.5	100.0	100.0	**97.9**
98-99-00	90.5	98.8	99.4	100.0		98.8	**97.5**
99-00-01	95.1	100.0	100.0	100.0		100.0	**99.0**
00-01-02	91.0	100.0	100.0	100.0		96.9	**97.6**
01-02-03	96.2		99.2			96.1	**97.2**
Mean	**92.1**	**96.2**	**97.3**	**99.3**	**99.3**	**96.2**	**96.8**

Our results suggest that the smaller banking groups, KEP, TLB and OUB have reported average scale efficiency of 98.3% compared to its larger counterparts, OCB and UOB, which exhibits an average scale efficiency levels of 96.8%. Again, but as expected, DBS which is the largest bank in our sample with total assets of over SG$150 billion, exhibits the lowest average scale efficiency score of 92.1% during the period.

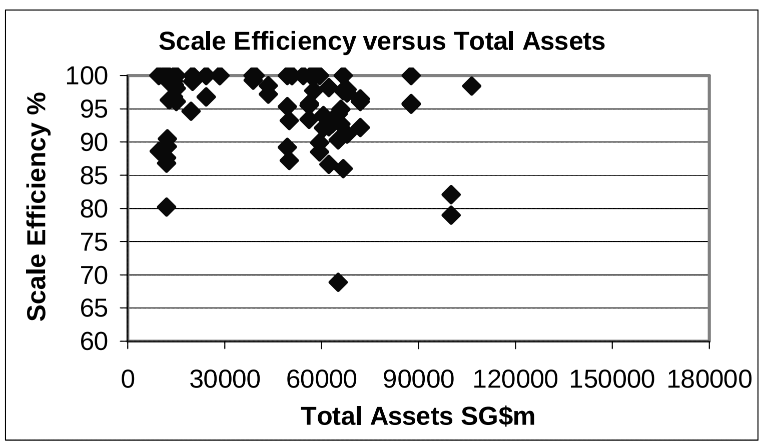
It is clear from Figure 4 (a) that there seems to be a clustering of efficiency around asset levels of SG$10 billion to SG$29 billion and there seems to be tendency for higher levels of

Figure 4

Scale Efficiency versus Total Assets

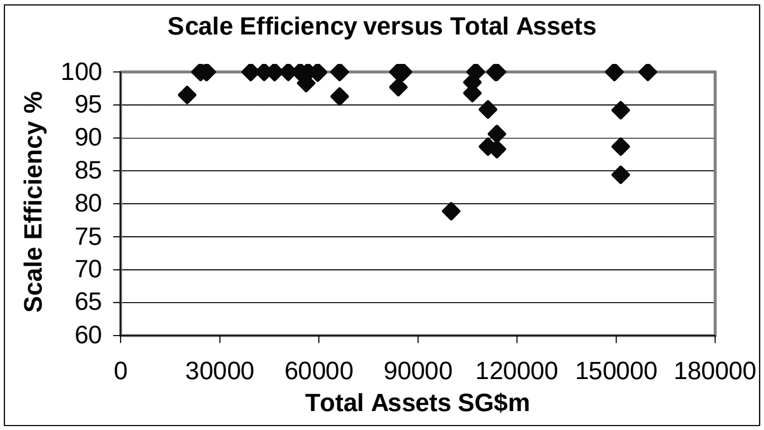


(a) Window 1-5: 1993-1999



scale inefficiency to be reported around total assets of SG$40 billion to SG$106 billion in the early part of the period. The trend during the latter part of period shows lower levels of scale efficiency to be reported at around asset sizes of over SG$100 billion (see Figure 4 (b)). In contrast to the pure technical efficiency, our results suggest that as banks expands in size brought about by the consolidation in the domestic banking sector, it is clear from Figure 4 (b) that Singapore banks has become more inefficient towards its intermediation role. A possible explanation could be due to the large depositor base resulting from government protection, high capital reserve requirement by the MAS and overly conservative loan growth strategies. As pointed by Randhawa and Lim (2005), the small Singapore banks

(b) Window 6-9: 1998-2003



due to its smaller depositors base and thus lesser deposits to transform into loans, have attained higher efficiency levels compared to its larger counterparts.

Although Singapore banks were relatively left unscathed during the 1997/98 Asian Financial Crisis period, the banks may have taken an overly conservative and cautious loan growth strategies as banks attempt to rehabilitate their balance sheets from the rising volume of non-performing loans. This has resulted in low interest income and in turn scale efficiency (output related) during the latter part of the studies.

5. Returns to Scale

As the main source of inefficiency is attributed to scale, it is worth investigating the nature of returns to scale for Singapore banks. Hence, the nature of returns to scale of Singapore banks is considered next. As have been mentioned earlier, a bank can operate at CRS or VRS where CRS signifies than an increase in inputs results in a proportionate increase in outputs and VRS means a rise in inputs results in a disproportionate rise in outputs. Moreover, a bank operating at VRS can be at increasing returns to scale (IRS) or decreasing returns to scale (DRS). Hence, IRS means that and increase in input results in a higher increase in outputs, while DRS indicates that an increase in inputs results in lesser output increases.

To identify the nature of returns to scale, first the CRS scores (obtained with the CCR model) were compared with VRS (using BCC model) scores. For a given bank, if the VRS score equals to its CRS score, the bank is said to be operating at constant returns to scale (CRS). On the other hand, if these scores are not equal, a further step is needed to establish whether the bank is operating at IRS or DRS. To do this, the DEA model is used under non-increasing returns to scale assumptions (NIRS). If the score under VRS equals the NIRS score then the bank is said to be operating at DRS. Alternatively, if the score under VRS is different from the NIRS score, than the bank is said to be operating at IRS (Coelli *et al.*, 1998).

Table 6 reports the nature of returns to scale for each bank in the sample. In general, this table indicates that large banks tend to operate at CRS or DRS, whereas smaller banks tend to operate at CRS or IRS, which is similar to earlier studies by Noulas *et al*. (1990), McAllister and McManus (1993) and Reisman *et al*. (2003). McAllister and McManus (1993) suggest that while small banks have generally exhibit IRS, the large banks on the other hand tend to exhibit DRS and at best CRS.

Table 6
Nature of Returns to Scale of Individual Banks

Bank	*Window*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*
	1	DRTS	DRTS	DRTS								
	2		DRTS	DRTS	DRTS							
	3			DRTS	DRTS	DRTS						
	4				CRTS	DRTS	DRTS					
DBS	**5**					DRTS	DRTS	DRTS				
	6						DRTS	DRTS	DRTS			
	7							DRTS	DRTS	DRTS		
	8								DRTS	DRTS	CRTS	
	9									DRTS	CRTS	CRTS
	1	IRTS	IRTS	IRTS								
	2		IRTS	IRTS	IRTS							
	3			IRTS	IRTS	IRTS						
	4				CRTS	IRTS	CRTS					
KEP	**5**					IRTS	IRTS	CRTS				
	6						IRTS	CRTS	CRTS			
	7							CRTS	CRTS			
	8								CRTS			
	9											
	1	DRTS	DRTS	DRTS								
	2		DRTS	DRTS	DRTS							
	3			DRTS	DRTS	DRTS						
	4				DRTS	CRTS	DRTS					
OCB	**5**					CRTS	DRTS	CRTS				
	6						DRTS	CRTS	DRTS			
	7							CRTS	CRTS	CRTS		
	8								CRTS	CRTS	CRTS	
	9									CRTS	DRTS	CRTS
	1	DRTS	DRTS	CRTS								
	2		DRTS	CRTS	CRTS							
	3			CRTS	CRTS	DRTS						
	4				CRTS	CRTS	DRTS					
OUB	**5**					CRTS	DRTS	CRTS				
	6						CRTS	CRTS	CRTS			
	7							CRTS	CRTS			
	8								CRTS			
	9											
	1	CRTS	CRTS	IRTS								
	2		CRTS	IRTS	IRTS							
	3			CRTS	IRTS	IRTS						
	4				IRTS	IRTS						

contd.

TLB	5											
	6											
	7											
	8											
	9											
	1	DRTS	DRTS	DRTS								
	2		DRTS	DRTS	DRTS							
	3			CRTS	DRTS	DRTS						
	4				CRTS	DRTS	CRTS					
UOB	**5**					DRTS	CRTS	CRTS				
	6						CRTS	CRTS	DRTS			
	7							CRTS	CRTS	CRTS		
	8								CRTS	DRTS	CRTS	
	9									DRTS	CRTS	CRTS

CRTS = Constant Returns to Scale; DRTS = Decreasing Returns to Scale; IRTS = Increasing Returns to Scale

As it appears, the small Singapore banks experience increasing returns to scale (IRS) in their operations in the earlier period of study. One implication is that, for the small Singapore banks, increases in inputs would result in more than proportional increases in outputs. Hence, the banks that operate with IRS could achieve significant cost savings and efficiency gains by increasing the scale of their operations. In other words, substantial gains could be obtained from altering scale via internal growth or further consolidation in the sector. In fact, in a perfectly competitive and contestable market, scale inefficient banks should be absorbed by the efficient banks to exploit cost advantages. Thus, the banks that experience IRS should either eliminate their scale inefficiency or be ready to become a prime target for acquiring banks, which can create value from underperforming banks by streamlining their operations and eliminating their redundancies and inefficiencies (Evanoff and Israelvich, 1991).

VI. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Utilizing the non-parametric Data Envelopment Analysis (DEA) windows analysis method, we attempt to investigate the long-term trend in efficiency change of listed Singapore commercial banks during the period of 1993-2003. Our results suggest that during the period of study, listed Singapore commercial banks have exhibit an average overall efficiency of 95.4% and that the inefficiencies was largely attributed to scale (output related) rather than pure technical (input related). During the period of study, small Singapore commercial banks were found to have outperformed their large and very large peers.

We find that large banks exhibit higher pure technical efficiency scores while the smaller banks outperforms their larger counterparts on scale efficiencies, suggesting that the large Singapore banks inefficiency were largely due to scale rather than pure technical or x-inefficiency. On the other hand, our findings suggest that the large banks exhibits higher pure technical efficiency compared to the small and very large banks during the period of study. Consistent with earlier studies, we also find that while the smaller banking groups tend to operate at CRS and IRS, the large banking groups on the other hand tend to operate at DRS and CRS at best.

Due to the normal limitations, this paper can be extended in a variety of ways. It is suggested that further analysis into the investigation of x-efficiency of Singapore banks to consider risk exposure factors. As to establish overall bank performance, risk exposure factors should be taken into account along with productive efficiency measures. As the best banks may not necessarily be the most efficient producer of loans, but also one, which balances high efficiency with low risk assumptions. Moreover, this paper examined the intermediation functions of banks could be extended by considering the production function at the same time. Investigation of changes in productivity over time as a result of technical change or progress by using the Malmquist Total Factor Productivity Index could be yet another extension.

Notes

1. QFB license permits the bank to carry out the whole range of banking business approved under the Banking Act. All the local commercial banks fit into this category apart from those offshore banks mentioned above.
2. A bank under Restricted Banking license may engage in the same range of activities as a full bank except that they can only have one main branch and cannot accept SGD savings accounts and fixed deposits of less than SG$250,000 from non-bank customers. Banks that comes under this category includes UBS, AG, CSFB, Barclays Bank Plc.
3. An Offshore Banking privilege have the same opportunities as the full and restricted banks in business transacted in their Asian Currency Units (ACUs), their scope of business in the SGD retail market is slightly more limited. In the domestic banking market, offshore banks cannot accept any interest bearing deposits from persons other than approved financial institutions, nor can they open more than one branch. In addition, offshore banks may extend a maximum credit of SG$300 million in total credit facilities to resident non-bank customers in SG$. Commonwealth Bank of Australia, Bank of Montreal, New Zealand and Taiwan belong to this group.
4. Humphrey (1985) presets an extended discussion of the alternative approaches over what a bank produces.
5. See Avkiran (2002) for discussions on the optimal number of inputs and outputs in DEA.

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