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X-EFFICIENCY AND SHARE PRICES IN THE SINGAPOREAN BANKING SECTOR: A DEA WINDOW ANALYSIS APPROACH[1]

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Abstract

This paper utilizes the non-parametric Data Envelopment Analysis (DEA) window analysis method to investigate the long-term trend in efficiency change of Singapore commercial banks during the period of 1993-2003. We found that Singapore commercial banks listed have exhibited an average overall efficiency of 95.4% thus suggesting input waste of 4.6%. Our results suggest that the small Singapore commercial banks have outperformed their large and very large counterparts. We further established statistical relationship between cost efficiency and share price performance by employing panel regression analysis. The evidence seems to indicate that the changes in stock prices tend to reflect cost efficiency albeit with small degree of reaction. This suggests that stocks of cost efficient banks to some extend outperform cost inefficient banks.

Key words: Banks efficiency, DEA, Window Analysis, Singapore.
JEL Classification: G21.

I. Introduction

The Singapore government's decision to further liberalise the banking sector, which was relatively sheltered from international competition before the financial crisis of 1997-1998, has contributed to the country's growing role as a financial centre for the region and a destination of choice for global investors. The banking sector in Singapore has grown rapidly and operated innovatively in recent years, becoming one of the main engines of growth and sources of employment. Faced with this mounting competition, examination of banks efficiency in Singapore has therefore become an increasingly important issue for public and policy makers (Bhattacharyya *et al*., 1997; and Yeh, 1996).

On the other hand, in a semi-strong, efficient market where most of the information is incorporated into prices, stock value performance is, as it is widely accepted (Brealey and Myers, 1991), the best measure of estimating whether firms are creating value for shareholders or not. Studies on the stock market have found that stock prices do incorporate relevant publicly known information (Ball and Kothari, 1994). It may be expected that efficient firms perform better than inefficient firms and this fact will be reflected in market prices (directly through lower costs or higher output or indirectly, through higher customer satisfaction and higher prices which in turn may improve stock performance).

This paper attempts to combine these two literatures to explain and understand the relationship between estimated banks' efficiencies and its share prices. Specifically, working within the Singapore domestic banking arena, we investigate the influence of X-efficiencies derived from the DEA window analysis technique on the share prices of Singapore commercial banks that are listed on the Stock Exchange of Singapore (SES).

This paper contributes to the literature in several ways. Firstly, there exists the scarce evidence that investigates the efficiency and performance of listed commercial banks in the literature in the context of small open economy. Secondly, there have been only a handful of banks efficiency studies utilising the DEA windows approach to reflect banks relative efficiency and per-

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[1] All findings, interpretations, and conclusions are solely of the authors' opinion and do not necessarily represent the views of the institutions.

formance stability overtime. Finally, it is the first application to further test the relationship between the efficiency scores obtained from a DEA window analysis and to link it with the share performances in the marketplace.

This paper also makes several contributions regarding both data and methodology. In terms of methodology, we present a potentially useful tool in the framework in examining the behaviour of share prices in the marketplace. Given the fact that emerging stock markets are frequently subjected to turbulence i.e. Asian Financial Crisis, 1997-1998, Russian bond default and Long Term Capital Management (LTCM) crisis in 1998, investigations into the relationship between banks' efficiency scores and its share price reaction could be particularly difficult. This paper suggests a potential way to stabilise the excessive volatility in the emerging stock market in investigating the relationship of banks' efficiency and its share prices in the marketplace.

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. Nevertheless, given the small sample size of the Singaporean banking sector, we believe that it is more appropriate to perform banks efficiency studies using the DEA window analysis, which could provide a greater degree of freedom to the sample.

This paper is set out 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 Industry

The development of Singapore as a financial centre 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 centres after New York, London and Tokyo. This is evidenced by presence of a wide network of financial institutions providing a range of services that facilitate domestic, regional and international flows 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 dominate the local banking market.

At present, Singapore is an established financial centre and is one of the key centres 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 capitalised 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 recognised 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 their IT capabilities. Recognising 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 centre 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 intensify 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 liberalisation, 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 Qualifying Full Bank (QFB) privileges[1] 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 Restricted Banking licenses[2] and Offshore Banking licenses privileges[3] 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

[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 come under this category include UBS, AG, CSFB, Barclays Bank Plc.

[3] An Offshore Banking privilege has 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.

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 liberalisation programmes could be regarded as significant milestones in the history of Singapore's financial sector and it is hoped that these initiatives will enable local banks to grow into sound, well-capitalised institutions.

III. Banking Efficiency Studies Utilizing DEA

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 and 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.

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. He found that the major source of overall technical inefficiency is pure technical inefficiency.

Although studies investigating banks efficiency by DEA are voluminous, there are only a few papers, which have utilised 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 of 1986-1995, Avkiran (2004) found that Australian trading banks have exhibited 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) utilises 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 show declining levels of efficiency over the 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 suffer declining returns to scale (DRTS).

Reisman *et al.* (2003) investigate 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.

3.1. Studies on Singaporean commercial banks efficiency

Despite substantial studies performed in regard to the efficiency and productivity of financial institutions in the U.S., Europe and other Asia-Pacific banking industries, the Singaporean banking industry has not followed suite partly due to the lack of available data sources and the small sample of banks. As pointed by Kwan (2003), the reason for the lack of research on the efficiency of Asian banks is due to the lack of publicly available data for non-publicly traded Asian financial institutions.

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 of 1992-1996. They found that during the period the six Singapore banks listed have exhibited higher overall efficiency at 95.3% compared to profit efficiency at 82.6%. More recently, Lim and Randhawa (2005) utilize DEA to investigate the locally incorporated banks in Hong Kong and Singapore x-efficiencies during the period from 1995 to 1999. 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 exhibit higher overall efficiency under the intermediation approach.

IV. Data and Methodology

Following Avkiran (2004), Drake and Hall (2003) and Webb (2003), among others, a non-parametric method, DEA, will be used in measuring the efficiency of the Singaporean commercial banks. The method 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 Singaporean banking system. The small sample size, among other reasons, leads us to DEA as the tool of choice for evaluating X-efficiency of Singapore commercial banks. Further, 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.

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 is best illustrated, for the single output/two input case, in the unit isoquant diagram (Figure 1) where the unit isoquant (*yy'*) shows the various combinations of the two inputs (X_1, X_2) 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,

$$TE = \frac{OQ}{OR}. \tag{1}$$

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,

$$AE = \frac{OP}{OQ}. \tag{2}$$

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 showing how much costs could be reduced if the firm operated in the efficient point *E* instead of point *R*. Hence,

$$OE = \frac{OP}{OR}. \tag{3}$$

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 (X_1 and X_2), compared to the DMU at *Q* in producing the same level of output (*y*).

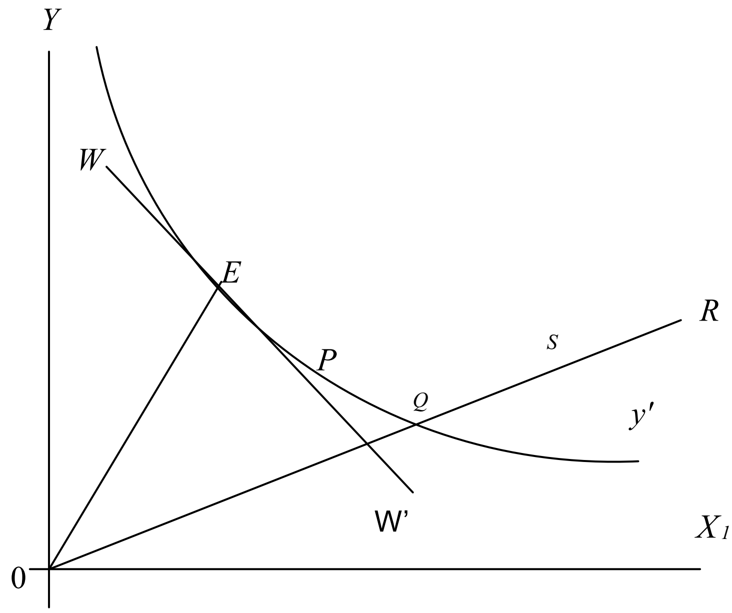

Fig. 1. Farrell Efficiency

The term Data Envelopment Analysis (DEA) was first introduced by Charnes, Cooper and Rhodes (1978), (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 dis-economies 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 assumptions. 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 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.

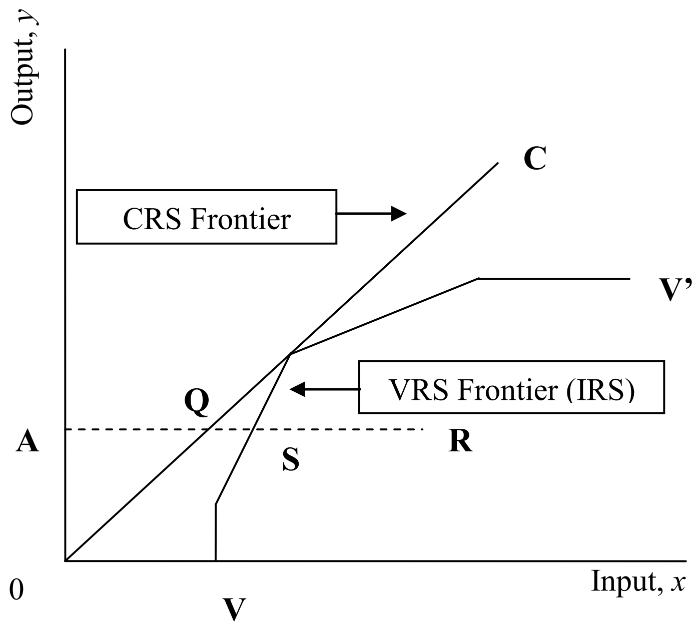

Fig. 2. Scale and Technical Efficiency

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*

$$\min \quad \lambda_0 \theta_0 \tag{4}$$

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

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

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

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

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 (1) is solved under the assumption of variable returns to scale (VRS) to provide

$$\min \quad \lambda_0 \theta_0 \tag{5}$$

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

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

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

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

4.1. 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, 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 utilises a three-year window, which is consistent with the original work by Charnes *et al.* (1985). Furthermore, Avkiran (2004), Webb (2003) and Reisman

(2003) have also utilised a three-year window to investigate banks' efficiency in Australia, U.K. and Tunisia respectively.

To illustrate, from Table 2 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 analyses 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, applying a 9, three-year window, would considerably increase the number of observations of the sample to 189, 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

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

The definition and measurement of inputs and outputs in the banking function remain 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 measure 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 labour and physical capital are defined as inputs. Previous researches that follow 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 input and output definition[1]. 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[2]. 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 modelling bank behaviour.

To recognise 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 3). 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.

4.2. Banks Efficiency and Share Performance

Banks share performance is represented by annual share returns, which were calculated for each bank by adding daily returns for each year in the window. This measure is believed to be a better measure than calculating a point increase with data from the first and the last day of the period under investigation. Daily returns have smaller standard deviations than do annual and monthly returns[3].

The share returns were then transformed into 9 windows by 3-years moving average when given high volatility of banks' annual stock returns. As the window analysis is commonly used sensitivity analysis in DEA to that of external factors that may distort figures for a particular year and a varying group of reference units, the technique could potentially be useful particularly to Singapore where the economy and thus the market are more profound to exogenous shocks given the degree of liberalization and openness. Hence, by transforming the share returns into windows, it would thus help stabilize and smooth the excessive volatility effects in the Singaporean stock market particularly during the 1997/1998 Asian Financial Crisis.

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1 Humphrey (1985) presets an extended discussion of the alternative approaches over what a bank produces.

2 See Avkiran (2002) for discussion on the optimal number of inputs and outputs in DEA.

3 The mean standard deviation of monthly returns for randomly selected securities is about 7.8%, while the corresponding mean standard deviation of daily returns will be approximately 1.8% if daily returns are serially independent (Fama, 1976, p. 123).

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				

Table 3 (continuous)

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.

4.3. Panel data estimation procedures

Estimates obtained by using panel data estimation procedures have a number of advantages over the simply pooled ordinary least squares (OLS) procedures (Hsiao, 1989). Simply pooled OLS estimation procedures cannot adjust for firm specific and time specific (i.e. year specific) effects, which, if correlated with other explanatory variables, would produce omitted variables bias and misspecified models. This problem is serious as it produces flawed estimates.

In the present context, panel data model can be estimated by using a fixed effects estimator or a random effect estimator (feasible GLS). The fixed effect estimator estimates a different constant for each bank. The fixed effects model (FEM) overcomes this problem by adjusting for these effects through the firm specific and time specific intercepts. The firm specific intercepts capture the unobserved and/or unmeasurable firm specific characteristics, while the time specific intercepts capture the unobserved and/or unmeasurable time varying characteristics. Since intercept terms vary across banks, they are indexed by individual bank. Coefficients are computed by running the OLS on transformed data, which are obtained by subtracting the time or "within group" (cross section specific) mean from each variable to eliminate the fixed effects from the regression. Alternatively, the problem of omitting specific effects (both firm- and year-specific) can be similarly overcome by random-effect model (REM), which assumed that the intercept consists of two parts: a constant, which is the same for all cross sectional units and a time-invariant random variable.

Various statistical tests can be used to determine which model (OLS, FEM and REM) produces the most adequate specifications. We estimated all three models and selected the appropriate model based on statistical tests. We initially obtain estimates from all models: simple pooled ordinary least squares regression model (OLS), fixed-effect (FEM) and random-effect models (REM). We run two tests to determine the most appropriate model to use (Hsiao, 1989), namely Likelihood Ratio Test (LR) and Hausman Test. The Likelihood Ratio Test (LR) suggests that FEM outperformed the simple pooled OLS whereas Hausman Test does not suggest that REM model outperformed FEM model. Thus, FEM estimates are reported in the paper.

The relationship between X-efficiency and share performance can be examined by regressing the bank share returns against X-efficiency estimates by employing all the three estimators (OLS, FEM and REM) and we ultimately chose the fixed-effects specification on the basis of Likelihood Ratio Test and Hausman Test results. Accordingly, the estimated model is as follows:

$$SHR\_RET_{jt} = \alpha_0 + \beta_1 EFF_{jt} + \epsilon_{jt}, \qquad (6)$$

where SHR_RET_{jt} is the moving average of bank *j*'s *daily* share returns in window *t;* α_0 is bank *j*'s fixed effects, EFF_{jt} is bank *j*'s mean annual percentage change in X-efficiency in window *t*; β_1 is a parameter excluding the constant; and ϵ_j is a normally distributed error term. The error term is assumed to be free of autocorrelation. Heteroskedasticity is allowed, but corrected in the estimations by using the robust variance covariance matrix.

V. Empirical Results

As has been stated earlier, there is currently no study in the literature that investigates the efficiency of Singapore commercial banks utilizing the 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 are then considered.

The average of all scores, for each bank, is given in the column denoted "Mean". The column labelled "SD" indicates the standard deviation for the score of each bank during the entire period. The column labelled "LDY" indicates the largest difference in a bank's scores in the same year but in different windows. The column labelled "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).

5.1. General Trends

Looking at the average overall efficiency levels for each window in Table 3, it is clear that Singapore banks average efficiency level 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 1997-1998, Singapore banks were relatively unscathed. The Singapore government had implemented measures which have 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 1997-1998 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 as a buffer to the banks and allowed them to maintain stable average overall efficiency scores throughout the period of our studies.

5.2. 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 exhibited 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 exhibited an average efficiency of 95.3% during the period of 1992-1996. Lim and Randhawa (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 exhibit improvements and upward trend in the later parts of the period, while UOB overall efficiency scores seem 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.

As 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. However, as the focus of this study is to examine the relationship between banks' overall efficiency and its share performance in the marketplace, this extension is left for another paper.

6. Efficiency and Singapore Banks' Share Returns

For the purpose of this study, it is necessary to draw attention to the change in efficiency, calculated as the relative change in efficiency scores for every window in the sample of studies.

Table 4

Singapore Banks Summary of DEA Efficiency Scores

Windows	**DBS**	**KEP**	**OCB**	**OUB**	**TLB**	**UOB**
Window 1	84.4	84.2	84.3	93.2	99.9	89.7
Window 2	91.4	85.9	86.6	96.3	96.8	90.0
% Change	8.29	2.02	2.73	3.33	-3.10	0.33
Window 2	91.4	85.9	86.6	96.3	96.8	90
Window 3	85.7	88.8	91.8	99.8	96.1	94.6
% Change	-6.24	3.38	6.00	3.63	-0.72	5.11
Window 3	85.7	88.8	91.8	99.8	96.1	94.6
Window 4	90.6	98.9	97.5	98.5	97.6	98.2
% Change	5.72	11.37	6.21	-1.30	1.56	3.81
Window 4	90.6	98.9	97.5	98.5	97.6	98.2
Window 5	86.4	98.4	98.6	98.9	100	98.6
% Change	-4.64	-0.51	1.13	0.41	2.46	0.41
Window 5	86.4	98.4	98.6	98.9	100	98.6
Window 6	90.5	98.8	99.4	100		98.8
% Change	4.75	0.41	0.81	1.11		0.20
Window 6	90.5	98.8	99.4	100		98.8
Window 7	95.1	100	100	100		100
% Change	5.08	1.21	0.60	0.00		1.21
Window 7	95.1	100	100	100		100
Window 8	91	100	100	100		96.9
% Change	-4.31	0.00	0.00	0.00		-3.10
Window 8	91	100	100	100		96.9
Window 9	96.2		99.2			96.1
% Change	5.71		-0.80			-0.83
Mean Efficiency	90.14	94.38	95.27	98.34	98.08	95.88

It is clear from Table 4 that all percentage changes indicate improvements in X-efficiency among listed Singapore commercial banks ranging from 0.2% to 17.88%. Overall, our results are in contrast to the findings by Chu and Lim (1998) on Singapore listed banks, which suggest that the large Singapore listed banks are on average more X-efficient compared to their smaller peers.

6.1. Results of Panel Regression Analysis

Share performance may be expected to be the ultimate measure of efficiency. If bank share prices reflect almost all the information about the past, present, and expected future performance of firms, then this measure would be the more reliable indicator of bank efficiency. However, even if the choice of measures is correct, the previously described measures of efficiency may only be related to share performance in the long term. Short-term variations may not be explained by efficiency measures. In this case, individual bank effects may explain the majority of total variations in share performance. As mentioned previously, for the purpose of this study, we believe that it is necessary to smooth the share returns by transforming a 3-year moving average share returns into a single window.

Table 5

Window Analysis of Annual Stock Returns

	W1	W2	W3	W4	W5	W6	W7	W8	W9	mean
DBS	-9.41	1.25	2.34	52.48	38.83	28.78	-23.51	-3.86	9.04	10.66
KEP	2.88	-19.12	-14.78	-8.28	2.51	-2.73	4.78	30.35	42.97	4.29
OCBC	-13.06	-0.87	-3.87	33.24	27.54	26.69	2.75	2.46	9.74	9.40
OUB	-4.41	-2.86	-8.17	29.87	28.02	40.75	5.10	20.65	-	13.62
TLB	-7.26	-11.69	-37.01	-51.02	-81.24	-	-	-	-	-37.64
UOB	-1.14	-1.43	-5.56	28.32	26.59	31.70	-0.57	5.62	6.32	9.98

Looking at the average annual stock return for Singapore listed banks in Table 5, all banks except for TLB have posted positive share returns over the years. In term of share price performance over the years, OUB and DBS have the highest annual stock return of 13.62% and 10.66% respectively whereas TLB has the lowest average annual stock return of –37.64 percent over the sample years. Looking at the trends, it is apparent that the bank's share price was bashed down during windows 3 onwards, which corresponds to the years 1995 to 1999. A possible cause could be attributed to investors concern over the banks exposure to troubled companies in Indonesia brought about the Asian Financial Crisis of 1997-1998. Investors concern about the Singapore smallest bank's exposure in Indonesia got even worse when the Indonesian Rupiah declined to record lows against the U.S. Dollars, which makes it even more expensive for Indonesian companies to pay for their foreign-currency denominated debts.

Table 6

Results of Panel Regression Analysis

	Stock Return
Constant	7.76* (1.31)
Cost Efficiency	0.51** (0.06)
R^2	0.57
Adjusted R^2	0.47
F-statistic	5.37
No. of observations	5.37

Note: * and ** indicate significance at 5% and 10% level respectively.
Numbers in parénthesis indicate standard error.

To examine whether statistical relationship exists between X-efficiency scores derived from DEA and listed Singapore banks share performance, equation (6) is performed, by having banks' X-efficiency scores as independent variables against share return as dependent variable. It is expected that the efficiency scores to be positively correlated with share prices.

Even though the regression results display some shortcoming due to the relatively small sample which are only 189 number of observations, it would appear that our explanatory variable do posses some power. Table 6 presents the result of estimating the model by fixed-effect estimators. The coefficient of the X-efficiency score is significantly positive as expected at 10 percent level and the variation in stock return is 57 percent (adjusted variation is 47%) explained by variation in X-efficiency. These suggest that improvement in bank's cost efficiency tends to explain the share price performance in long run, which is also consistent with the findings by Chu and Lim (1998).

To further test this relationship, the reaction of changes in different X-efficiency on share returns is examined through the magnitudes of the coefficient that is derived from the panel regression. The magnitude of the coefficient of X-efficient banks is 0.51, which indicates that a 1 percent improvement in cost efficiency will lead to 0.51 percent improvement in the share prices of Singapore banks. Thus, share prices to some extend reacted towards the improvement in cost efficiency albeit with a low impact.

7. Conclusions

Utilizing the non-parametric Data Envelopment Analysis (DEA) window 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 exhibited an average overall efficiency of 95.4% thus suggesting input waste of 4.6%. During the period of study, small Singapore commercial banks were found to have outperformed their large and very large peers.

In this paper, we further employed panel regression analysis by combining the capital market research in accounting and banks efficiency literature to test the relationship between share performance and banks efficiency. The results appear to suggest that cost efficiency does explain the share prices performance of Singapore banks in the long run. Similar to the findings by Beccalli *et al.* (2005) and Chu and Lim (1998), our result therefore suggests that improvement in cost efficiency to some extent reflects improvement of Singapore banks share performance in the marketplace albeit with a low impact.

Due to its limitations, this paper can be extended in a variety of ways. It is suggested that further analysis into the investigation of x-efficiency of Singaporean banks is needed 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.

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