Productivity and Efficiency Analysis of Australia Banking Sector under Deregulation

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(Draft)

Abstract:
This paper conducts productivity and efficiency analysis of banks operating in Australia since the deregulation of the Australian financial system in early 1980s. Applying data envelopment analysis (DEA), with a moving window, the Malmquist indices are determined in order to investigate the levels of and the changes in the efficiency of Australian banks over the period from 1983 to 2001. The DEA window analysis is adopted in order to relieve the small sample problem that in previous studies has proved problematic in the study of the Australian banking sector. The particular window used in this case has been carefully designed to ensure the robustness of the efficiencies scores to changes in the window width. A second-stage regression is conducted by using the unconditional bootstrap approach suggested by Xue and Harker (1999) to overcome the dependency and heteroskedasticity of DEA efficiency scores. The empirical results demonstrate the effect of deregulation on the performance of individual banks, banks of different organizational types and the entire Australian banking sector.

Keywords:
Data envelopment analysis, efficiency and productivity, Malmquist index, Moving window technique, unconditional bootstrapping approach
1. Introduction

This paper measures the efficiency and productivity of banks operating in Australia since the deregulation of the Australian financial system in early 1980s. Deregulation is expected to improve the competitiveness and efficiency of the banking sector and the financial system. Within a deregulated environment, some new banks, most likely foreign banks and former building societies, were established and competed intensively with existing banks for market share. As of December 2001, there were fifty authorised banks in Australia, including eleven foreign subsidiary banks and twenty-six branches of foreign banks. The general experience of deregulation for the Australian banking sector has been so far fairly positive. However, the lack of quantitative assessment of banking deregulation underpinning such viewpoint initiates our study.

Using data envelopment analysis (DEA) and Malmquist indices method, the levels of and the changes in the efficiency and productivity of banks are estimated for the sample period of 1983 to 2001. The sampled banks are categorized into five sub-groups; major banks, existing regional banks, newly established regional banks, foreign banks, and specialised banks. Such classification allows for the analysis of the impact of bank deregulation on efficiency and productivity by organizational type. The empirical results show the effect of deregulation on the performance of individual banks, banks of different organizational types and the Australian banking sector as a whole. It also provides valuable information on direction of further development of Australian financial system.

The DEA results show that all the sample banks appeared to be performing reasonably well. The industry managed to achieve annual mean technical efficiency of 73.8%. The major banks are found to be the most inefficient group. Foreign banks performed far superior to existing regional banks and slightly inferior to newly established regional banks, but these three types of banks ended up with similar level of high efficiency in the latter part of sample period. The major source of inefficiency in the industry is scale inefficiency arising from sub-optimal size of operation. Low scale efficiencies of major banks dominate in this case. By reducing their operational size, the major banks could improve their scale efficiency dramatically. The impact of other factors rather than scale on a bank’s efficiency is fairly
small as all types of banks obtained high efficiency under the assumption of variable returns to scale. The DEA results are consistent with findings of previous efficiency studies on Australian banks.

The Malmquist indices measure efficiency and productivity changes for sampled banks during the period under study. The results show that the industry was experiencing small productivity loss over the sample period. Technical efficiency fell slightly as a result of relatively smaller increase in pure technical efficiency combined with relatively larger fall in scale efficiency. Technical progress occurred, but being too small to improve total factor productivity. Productivity fell for all types of banks except for foreign banks over the sample period, indicating foreign banks had superior performance in managing their operation in Australia. The dramatic change in efficiency and productivity from year to year has shown that banks were under intensive pressure to catch up with their industry frontier. The effect of deregulation on Australian banking sector is mixed.

The structure of this paper is given as follows. The next section provides an overview of Australian banking sector during the process of financial deregulation. The third section reviews the methodologies of DEA and the computation of Malmquist Indices in the context of panel data. Moving windows technique is also briefly outlined. The fourth section discusses the data and the model. Empirical results are presented and analysed in section five. Conclusions are drawn in the final section.

2. Background

The financial systems of all developed countries have undergone substantial deregulation in recent years. The implications for the future of financial deregulation and for government policy towards the financial system have recently been reviewed by the governments in Britain, Canada, the United States, Australia and many other countries (see Financial System Inquiry 1997).

Australia has undergone gradual but impressive financial deregulation during recent years. In 1980, the financial system was closely regulated, with tight controls over interest rate, exchange rates and the flow of funds into and out of the country, as well as over bank lending
and competition. Financial sector reform has been undertaken together with microeconomic reforms in other sectors since early 1980s. A series of inquiries into the financial system, including Campbell Inquiry in 1981, Martin Inquiry in 1991 and Wallis Inquiry in 1996, has been conducted by the Government, aiming at deregulating the financial system and enhancing the competitiveness in the financial market. The controls on foreign exchange market, stock exchange and securities market were removed or gradually relaxed in 1980s. Legislation on insurance and superannuation industry was passed or amended, along with industry codes of practice introduced. Selected events during the deregulation process are listed in Appendix 2 (see Financial System Inquiry Final Report 1997, for details).

Up to date, the Australian experience in financial deregulation has been fairly positive. While the on-going deregulatory process delivered many desirable results as expected, such as lower interest margin and more intensive competition, great attention has also been put to prudential supervision of financial institutions to safeguard the financial system and, to the accompanying micro-economic reform to remove the fundamental distortions in the economy.

Deregulation of financial system is not only in the interest of the public, but also that of the private banking sector. As suggested by Ackland and Harper (1992), it was the conjunction of public and private interest in financial deregulation in Australia that explained why the deregulation process was so rapid and complete. Before deregulation, banks had dominated the financial system in a number of aspects. They had direct access to payment system. They were granted privileged access to liquidity support from the Reserve Bank. They were also virtually protected from competition with restrictions on entry into banking in place. However, banks were also more heavily regulated with tight credit and interest rate controls, compared with other types of financial institutions. On the contrary, non-bank financial institutions were subject to less regulation and therefore grew more rapidly than the banks in the decades after the Second World War.

The deregulatory process, aiming at creating a competitive but fair market for all the financial institutions, provided a more equal playground for banks than ever. Many direct controls on banks’ lending, borrowing and pricing policy were abolished step by step. Instead, a market-based prudential supervision approach has been adopted to encourage banks to behave
prudentially. As a result, banks were able to compete more effectively with other financial institutions by increasing the scale and scope of their operations. Their market share as a group began to rise relative to other major groups in the financial sector. The four major banks responded by diversification into non-traditional banking business, continuous product innovation and expansion into the world market. All the previously State-owned Banks were no longer in existence, either taken over by other banks because of their own poor performance or privatised and merged with other banks as long-term strategies.

Restriction on foreign entry was also removed. Sixteen foreign banks were invited to establish fully-capitalised subsidiaries in Australia in February 1985. Fifteen banks started their operations within eighteen months. The first of them, Chase AMP Bank, began business in October 1985. In 1992, additional banks were allowed to operate in Australia and the option of bank branch status was made available. Some existing foreign banks opted to convert to branch operations in viewing of the prospects of more competitive performance when operating under their parents’ names and with less regulatory constraints.

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Source: adapted from table 5 of Edey and Gray (1996) and Australian Banking Statistics;

Table 1: Authorised Foreign Banks in Australia

Another type of new entrants in the banking industry is new domestic banks. The majority of them are former building societies. These previous big players in deposit-taking market saw their opportunity of development rising from competing with established banks more intensively than ever. And this could only be achieved by converting to bank status and then competing equally with other banks. In addition, all the government-owned banks were corporatised and privatised in early 1990s in hope for better performance under mechanism operated by the invisible hand of market.
The 1996 financial system inquiry showed government’s determination to further deregulate the financial system, particularly the banking industry. Wallis Report for the Inquiry contained 115 recommendations, which can be broadly classified into three categories; firstly, the abolition of the six-pillar policy banning mergers among the four major banks and the two largest life insurance companies; secondly, the open-up of the banking system to new entrants such as mutuals and insurance companies and the formation of financial conglomerates; and thirdly, some regulatory changes to safeguard the financial system. While the ban on foreign takeovers of big banks is removed, mergers among the four major banks will not be permitted until the Government is satisfied that there is greater competition in the financial sector, particularly in respect of small business lending.

The Commonwealth Government quickly implemented one of the main recommendations of Wallis Inquiry on the regulatory system. New regulatory structure was established in 1998, where RBA (Reserve bank of Australia) located its primary role in conducting monetary policy, monitoring systemic stability and regulating payment system. It was no longer a supervisory body for financial institutions. Its two successors, APRA (Australian Prudential Regulation Authority), was assigned to prudentially supervise all deposit-taking institutions, insurance companies and superannuation funds, and CFSC (Corporations and Financial Services Commission), to regulate corporation law activities, market integrity and consumer protection in the financial sector.

In a speech to CEDA in 1996, Mr. Stan Wallis, Chairman of Wallis Inquiry Committee, stated that:

“the major questions about the financial system under deregulation are: what lessons are to be learnt from the effects of deregulation, what are the implications of rapid technological change and globalisation, how best to moderate the regulatory framework and how to ensure that our financial system and its regulatory framework will remain internationally competitive” (CEDA, Sydney, 25 June 1996).

In all, the deregulation process is still incomplete and remains highly challenging. At this stage, a quantitative assessment of productivity and efficiency performance of Australian financial institutions over the past two decades may provide some answer to the major questions about the financial system under deregulation. Any conclusion or implications
drawn from the studies conducted here could be useful for the policy-makers to further deregulate or re-regulate the financials sector and to ensure the financial system remain sound, safe and internationally competitive.

3. The methodology

3.1. DEA approach

The DEA method is used in this paper to estimate the efficiency and productivity of banks operating in Australia during the sample period of 1983 to 2001. Data Envelopment Analysis (DEA), pioneered by Farell(1957) and Charnes et al. (1978), is a non-parametric approach for measuring technical efficiency of firms. It involves an application of linear programming (LP) to observed data to form an industry production frontier, against which the efficiency of each firm is measured. The best-practice firms that lie on the production frontier will be given a score of one. All other inefficient firms will be given a score between zero and one. Allocative efficiency can also be estimated if the price information is available.

A simple one-output two-input case is illustrated in Figure 1 for DEA technical efficiency measurement. Let the horizontal and vertical axis be labelled as two inputs \( X_1 \) and \( X_2 \) respectively. And assume that the output quantity is given at a fixed level \( Y^* \). Firms A, B, C, D, E constitute the “Best Practice” production frontier, which is constructed as piece-wise linear convex when DEA is applied to sample data. Firm F is observed to be relatively inefficient in that it produces the same level of output using more of at least one of the inputs. To produce \( Y^* \), it uses the two inputs to the amount of \( x_1^f \) and \( x_2^f \) respectively. To be technically efficient, it could proportionally reduce its usage of \( x_1 \) to \( x_1^e \) and \( x_2 \) to \( x_2^e \), as firm C on the frontier does. The distance CF represents technical inefficiency, which is the amount by which inputs can be decreased to produce the same level of output if the firm is operating efficiently. DEA can give each firm a score bounded by zero and one to indicate the level of technically inefficiency. The score of technical efficiency (TE) is just the ratio of \( OF \) relative to \( OC \), as shown in Figure 2. This technique can also be extended to multiple outputs and multiple inputs case in DEA.
Figure 1: DEA technical efficiency measurement

DEA can incorporate multiple inputs and outputs and be used to calculate technical and scale efficiency as it only requires information on output and input quantities. DEA has the advantage of being a non-parametric technique, and avoids the need to make assumptions regarding the functional form of the best practice frontier. It also avoids the need to make distributional assumptions regarding the residuals in the regression analysis. DEA is especially suitable for measuring the efficiency of firms, which lack competitive prices, as the case for Australian banking industry.

However, DEA has also its own shortcomings. DEA scores only measures efficiency relative to best practice with the sample data. DEA is a deterministic model and therefore the efficiency scores are sensitive to measurement errors. It is important to screen for potential outliers when assembling the data. Despite its limitations, DEA is a useful tool to examine the efficiency of Australian banking industry.

3.2. Malmquist DEA method

One extension with DEA is to apply Malmquist index to panel data to estimate changes in technical efficiency, technological progress and total factor productivity. The method is
discussed in Färe, Grosskopf, Norris and Zhang (1994). In order to determine the changes in total factor productivity of banks in Australia over time, this approach has been used. DEA approach is to use sample data collected for firms to derive the best-practice production frontier, against which to evaluate the technical efficiency of each firm. By allowing the production frontier to shift over time due to technical change, the Malmquist index can then be derived to measure efficiency change for one year relative to the prior year. Correspondingly, total factor productivity change, which is the product of efficiency change and technical change, can also be estimated.

Following Färe et. al. (1990, 1993), we use DEA to construct a Malmquist TPF index between period \( t \) (the base period) and period \( s \) :

\[
M_I (y^s, x^s, y^t, x^t) = \left[ \frac{D_I (y^s, x^s)}{D_I (y^t, x^t)} \times \frac{D_I (y^t, x^t)}{D_I (y^t, x^t)} \right]^{-1/2}
\]

(1)

where \( M_I (\cdot) \) is the input-oriented Malmquist TFP index\(^1\), \( D_I (y^s, x^s) \) is the distance function showing a maximal proportional reduction of the observed period \( s \) inputs under the period \( t \) technology. The distance function is defined as follows:

\[
D_I (y^s, x^t) = \min_{\theta, \lambda} \quad \theta
\]

(2)

\[
y_{is} \leq \lambda Y^t
\]

\[
s.t. \quad \theta x_{is} \geq \lambda X^t
\]

\[
\lambda_i \geq 0, \ i = 1, \ldots, n
\]

where \( \theta \) is a scalar and \( \lambda \) is a vector of constants. Please be noted that \( \theta \) is always between zero and one for intra-period distance function, but can be larger than one for inter-period distance function.

Equally being noted, the TFP change is measured under the assumption of constant returns-to scale production, since Grifell-Tatjé and Lovell (1995) demonstrated that a Malmquist TFP

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\(^1\) The output and input-oriented approach are equivalent only when constant returns to scale exist (Färe and Lovell 1978). Here we only illustrate the input orientation equation since this orientation is used in the basic model in this study.
index might not correctly measure productivity change when variable returns-to-scale is assumed for the technology.

An equivalent way of writing the Malmquist productivity index is:

\[ M_{t}(y^{s},x^{s},y^{t},x^{t}) = \frac{D_{t}^{i}(y^{s},x^{s})}{D_{t}^{i}(y^{t},x^{t})} \left[ \frac{D_{t}^{i}(y^{t},x^{t}) \times D_{t}^{i}(y^{s},x^{s})}{D_{t}^{i}(y^{t},x^{s}) \times D_{t}^{i}(y^{s},x^{t})} \right]^{1/2} \]  

(3)

That is just the product of technical efficiency change (TEC) and technical change (TC) between period t and s, where TEC = \[ \frac{D_{t}^{i}(y^{s},x^{s})}{D_{t}^{i}(y^{t},x^{s})} \] and TC = \[ \left[ \frac{D_{t}^{i}(y^{t},x^{t})}{D_{t}^{i}(y^{s},x^{t})} \times \frac{D_{t}^{i}(y^{s},x^{t})}{D_{t}^{i}(y^{s},x^{s})} \right]^{1/2} \].

Productivity improvement takes place if \( M_{t}(\cdot) > 1 \). Analogously, technical efficiency improvement occurs when \( TEC > 1 \) and technical progress occurs when \( TC > 1 \).

A diagrammatical illustration is given in Figure 2 in terms of a simple one-input and one output model where productivity is measured as the ratio of output \( y \) produced to input \( x \) used. We assume that the production frontier exhibits constant returns to scale and it can shift over time, and two different frontiers for the current \( t \) and for future time period \( s \) are labelled accordingly as \( F_{CRS}^{t} \) and \( F_{CRS}^{s} \). Inefficiency is also assumed to exist, and therefore the productivity change of any firm over time will depend on both its position relative to the corresponding constant returns-to-scale frontier (technical efficiency) and position change of the frontier itself (technical change). Take a representative firm A producing at point \( A^{t}(x^{t},y^{t}) \) in period \( t \) and point \( A^{t}(x^{s},y^{s}) \) in period \( s \) for example. In each period, the firm is operating below the production frontier for that period. Using equations (3), we obtain:

\[ TEC = \frac{x^{s}}{x^{t}} \]  

(4)

\[ TC = \left[ \frac{x^{f}}{x^{s}} \times \frac{x^{b}}{x^{t}} \right]^{1/2} = \left[ \frac{x^{f}}{x^{s}} \times \frac{x^{b}}{x^{c}} \right]^{1/2} \]  

(5)

The technical efficiency change under constant returns-to-scale can be further decomposed into two components: pure technical efficiency change under variable returns-to-scale and scale efficiency change (see Färe et al 1994). The two concepts are illustrated in the figure by
adding two variable returns-to-scale frontiers $F_{vrs}^t$ and $F_{vrs}^s$, representing for period $t$ and $s$ respectively. Pure technical efficiency change of a firm is shown as the change in its position relative to the corresponding variable returns-to-scale frontier between the two periods. For firm A, it is measured as, $PTEC = \frac{x^g / x^s}{x^d / x^t}$. And the residual scale efficiency change captures the inter-period change in the firm’s potential to improve its efficiency by moving from operating along variable return frontier to constant return frontier at the given output level, that is, $SEC = \frac{x^e / x^g}{x^b / x^d}$. Computational difficulties may be confronted since the distance functions may not be always well defined in some inter-period DEA linear programming when variable returns-to-scale technology is assumed.

Figure 3: Malmquist Indices and its decomposition
3.3. The application of DEA window analysis technique

Window analysis was initiated by Charnes et al (1985) for analysing efficiency change over time in a panel data context. Suppose that a set of panel data of size $I \cdot T$ ($I$ firms and $T$ time periods) on input quantity and output quantity is available. And the panel is long enough to be broken into a series of shorter overlapping panel of equal size $I \cdot S$ where time period $S \in \{1,2,\ldots,s; \; s < T\}$. So the pooled sub-panel at time $t$ consists of $I \cdot S$ firms during the time periods $\{t,t+1,\ldots,t+S-1; t \leq T-S+1\}$. And there are a successive series of such sub-panels (window), starting at where $t = 1$ and ending at where $t = T - S + 1$. DEA can then be applied to each pooled sub-panel sequentially. The resultant efficiency score of a firm in a sub-panel is compared with its score in another sub-panel, as well as comparison among firms in the same window. The width of the windows, S, is arbitrarily chosen in most of cases.

The sub-panel sets are not nested, so the best-practice production frontier may shift outward or inward across sub-panels. Efficiency scores within a sub-panel are calculated relative to their own best-practice frontier for the given time period and therefore careful interpretation is needed when compared with efficiency scores from other sub-panels. Nevertheless, window analysis technique allows us to examine the trend of a firm’s efficiency performance over time in addition to comparison among a group of firms at a particular point in time. As noted by Charnes et al. (1985), window analysis could be used to examine some properties of the efficiency measures across as well as within window, such as stability of efficiency scores or outlier diagnosis. The technique can also be used in conjunction with other frontier approaches, by applying these approaches to a series of adjacent subsets of a panel data sequentially.

Window analysis technique can also be used to relieve degrees-of-freedom problem when the number of outputs and inputs is large relative to the number of firms at a certain point of time. It provides a trade-off between the two extreme cases: running separate DEA on each set of cross-sectional data at a single time period and running one DEA on the complete panel dataset. The former has the advantage of allowing the reference technology to change over time, but may lead to degrees-of-freedom problem if $I$ is relatively small. The latter has no
such problem, but explicitly assumes that technology is constant over time, which may be unrealistic if $T$ is relatively long.

The primary reason for adopting window analysis technique in this paper is to relieve the small sample problem inherited in the population under study – banks in Australia. In DEA model where there are too few sampled firms relative to the number of outputs and inputs, the derived efficiency scores can be artificially inflated. Some firms are found to be efficient by default because there is no comparable firm in one of the dimensions of outputs and inputs. The formed best-practice frontier may be well below the true industry frontier due to the limitation of sample data. The resultant efficiency scores, which measure relative efficiency with respect to the best-practice frontier within the sample, are therefore artificially high. To avoid such problem, a three-year time series data are used to form sub-panel sets for running DEA model. The sample size is increased at the expense of one extra assumption of constant technology within three consecutive years. (see appendix 1 for further explanations)

4. The data and model

4.1. Data

The purpose of this paper is to examine the efficiency and productivity performance of commercial banks operating in Australia since deregulation. Ideally, the more banking groups included in the sample the better explanatory power of the DEA model. However, some trade-off has to be made between increasing sample size and maintaining homogeneity of sampled firms. When there are too many organisations with diversified range of business included in the sample, it may no longer be appropriate to compare them directly because of the heterogeneity in the nature of business.

In order to fully capture the banking industry in Australia, I select the bank population under study on the following criteria. Firstly, the sample only includes banks that are incorporated in Australia with full banking licences. Other types of financial institutions without banking authorities, such as building societies, credit unions, merchant banks and finance companies,
are excluded from this study\textsuperscript{2}. Foreign bank branches operating in Australia are also not included in this study since they only hold restricted banking licenses\textsuperscript{3}. Secondly, commercial banks involved in either retail or wholesale markets were selected for study. Domestic banks are composed of four major banks and several regional banks, with a mixture of government and private ownership. Each of them has significant retail presence and has captured certain share in the local retail market within the States. Foreign banks entered into Australian market since deregulation as subsidiaries of their parent banks and have been mainly operated in wholesale banking sector. The exceptions are Citibank, Chase Manhattan Bank, Hongkong Bank of Australia, and Arab Bank, who have exposed to residential lending and retail deposits to various extents. Thirdly, availability of data dictated the selection of banks in the sample to certain degree.

The resulting data set is composed of information from commercial banks operating in Australia for the financial years 1982/83 – 2000/01 inclusive. The year 1983 is taken as the beginning of the deregulation in Australian financial sector in view of the fact that the Martin Committee of Review was formed during the year to assess the Campbell Report. The number of firms examined varies slightly from year to year during the sample period due to merger and acquisition, or entry and exit of the market. This leads to an unbalanced panel data with 527 observations. Appendix 2 presents the breakdown of the number of banks in the sample data set by bank types and year. Altogether, these sample banks account for a large proportion of total assets in the banking sector. To be more specific, banks sampled for the year 2001 account for 89.11 per cent of total banking assets in the year. Moreover, they also provide a good representation of the industry since all sizes of the banks have been included. Total assets of these banks range from A$0.7 billion (Arab Bank) to A$161.4 billion (NAB) in 2001.

\subsection*{4.2. Input and output variables}

\textsuperscript{2} Some newly-licensed banks were converted from building society status. For this group of banks, about five-year data prior to their conversion to bank operation are included in the sample, but excluded from the estimation of reference technologies. The purpose of doing so is to examine the impact of change in status on efficiency and productivity performance.

\textsuperscript{3} Another reason for excluding foreign banks with branch operations from the study is that their income figures are not publicly available. They are not required to file the profit and loss statement to the corresponding regulatory bodies.
In the banking literature, there has been some disagreement on the definition of bank inputs and outputs and how they could be measured. Two main approaches, production approach and intermediate approach, have dominated the literature to measure the input and output variables in financial institutions. The production approach emphasizes the commercial activities taking place at the banks, that is, producing deposit and loan accounts. Output is defined as number of deposit and loan accounts or transactions processed on the accounts. Inputs are considered as labour and physical capital used to perform such transactions and provide other financial services. The intermediation approach views banks’ primary role as financial intermediary that flows financial assets between savers and investors. Variables are measured in monetary units. The value of earning assets, such as loan and investment, consists of the principal outputs. Labour, physical capital and deposits are generally treated as inputs.

As often argued, the production approach neglects banks’ role as financial intermediaries to transfer funds by defining inputs as labour and physical capital only. It does not incorporate interest costs into the model where interest costs represents a large share of total operating cost in any bank. In this regard, the intermediation approach is advantageous since it includes total costs of banking. However, the choice over the approaches often depends on the availability of data. Given the limitation of availability of data for Australian financial institutions, the inputs and outputs employed in this study follow the intermediation approach to modelling banks, which are viewed as financial intermediaries that transfer financial assets between savers and investors.

In this study, the outputs used in the measurement of efficiency are net loans, investment and number of branches. The inputs chosen are labour, physical capital, and loanable funds. Net loans are the amount of loans, advances and bills discounted net of provisions. Investment comprises financial securities, inter-bank deposits and other investments. Securities refer to government securities issued by Federal, State and Local governments and trading securities issued in the money market. Inter-bank deposits and other investments are also part of revenue-earning assets. Number of branches is the number of full-service branches in a bank, excluding those agencies. Labour is defined as the number of full-time equivalent staff employed in the bank. Physical capital represents the book value of premises and fixed assets.
Loanable funds are measured as the value of total liabilities.\textsuperscript{4} The monetary units are measured in thousands of Australian dollars and have been deflated to constant 1982-83 prices by GDP deflator.

The selection of inputs and outputs is in line with the studies on Australian banking sector by Walker (1995) and Sathye (2001). Ideally, a further classification of net loans into different categories as separate outputs like housing loans, commercial loans, consumer loans and other lending, should be considered. This has been commonly used in US banking studies (e.g. Aly et al 1990, Wilson & Wheelock 1995). However, it is implausible for Australian studies due to the lack of such disaggregated data. Therefore, we may not be able to study the effect of specialization of the product mix on productivity as in many U.S studies.

Number of branches is also included as one of the outputs in the estimation of efficiency and productivity (see Grifell –Tatje and Lovell 1996 and 1997, Berg et al. 1993). The more branches operated by a bank, the higher level of service and convenience for its customers. Therefore, the number of branches of a bank can be used as proxy for the quality and convenience of bank services that the bank offers to its customers. Generally, branch operations incur higher operating costs than other available delivery channels for banking products, and make the banks with intensive branch network appear to be relatively inefficient in a model where quality is not an issue to be considered. The paper incorporates number of branches into the model as one of the outputs to estimate quality-adjusted efficiency.

\textbf{4.3. Descriptive statistics of data by bank type}

Descriptive statistics of each output and input variables are present in Table 2. Panel A shows the descriptive summary for the entire sample data, while panel B, C, D, E, F, show the descriptive statistics for the sub-group Major, Existing Regional, Newly-licensed Regional, Foreign and Specialised banks. The major banks have the largest levels of all outputs and inputs. These two types of regional banks have similar size of operation. Foreign banks are

\textsuperscript{4} A more accurate measurement is deposits and borrowings. However, inconsistency persists in the presentation of the liability side of banks’ balance sheet. No separation of deposits and borrowings from other liabilities for earlier data set.
operating at an even smaller range of scale than regional banks. While specialised banks produce much less outputs than other types of banks, they also have the minimum requirements for labour and physical capital. A limitation of this study is the assumption of a common technology adopted by all banks of various sizes with the exception of special banks and building societies (predecessors of some newly-established regional banks). Due to the small sample size, it was not feasible to conduct separate DEA analysis for each sub-group of banks.

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Investment (S'000) 128 1141434.1 1451938.7 74101.0 8489183.4
Branch (S'000) 128 109.9 107.2 1.0 513.0
Total liabilities (S'000) 128 5570747.9 7233677.9 503666.7 34987798.8
Fixed assets (S'000) 128 98042.6 115369.7 1741.2 532415.4
Staff (#) 128 1676.4 1612.3 320.0 7886.0

Panel E: Foreign Banks

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Panel F: Specialised Banks

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Table 2: Descriptive Statistics of Australian Banks (1983 – 2001)

An input orientation was chosen for the model to measure the efficiency of banks in terms of their potential to reduce inputs given the same level of outputs. The reason for the choice of orientation lies in the fact that the majority of the banking sector, including four major banks and former state banks, have experienced downsizing in the past in order to make sure efficient use of resources, while they compete with other banks fiercely for the market share. Restructure of business via centralisation of processing function, increased automation, job cuts and closure of branches has been conducted steadily in the past two decades.

The best-practice frontier of Australian banking industry is unknown, and needs to be estimated from observations of the sample data set using linear programming method DEA. In this study, all the observations except for those of specialised banks and building societies are included in the estimation of reference technology. Those involved in the estimation of reference technology are assumed to share the same representative technology, and their
efficiencies are calculated correspondingly. Specialised banks and building societies are excluded from the formation of the reference technology in the belief that these two types of financial institutions may adopt different kinds of technology due to their unique characteristics of operations. We separate these two types of institutions from the rest of banks, and compare the performance of the former group relative to the best practice frontier formed by observations of the latter group to see which form of operation excels in terms of efficiency and productivity.

5. Empirical results
All the empirical results on DEA scores and Malmquist indices are derived from using the EMS1.30 program (see Scheel 2000). This specialist DEA computer package allows one to select model in terms of structure, distance, orientation, and returns-to-scale. It also allows one to choose which observations should be included in the estimation of reference technology. The application of bootstrapping technique is conducted in SAS8.0 program.

5.1. DEA results
5.1.1. Technical efficiency scores
When input-orientation is chosen, technical efficiency shows the potential to reduce the amounts of inputs used in producing current quantities of outputs under the assumption of constant returns-to-scale technology. Technical efficiency scores range from 0 to 1, where 1 representing full efficiency. The geometric mean of efficiency scores for individual bank at each year estimated against reference technologies in three consecutive sub-panel windows are then calculated. The scores are then regrouped according to the types of bank and annual geometric means of each group (weighted by the ratio of total assets of each bank relative to the group mean) are then calculate. Figure 3 plots the resultant efficiency scores by bank type over the sample period.

---

5 For example, in window analysis, the observation of NAB in 1985 is included in three consecutive sub-panel: (1983 – 1985), (1984 – 1986) and (1985 – 1987). Therefore, three efficiency scores are derived for the observation estimated against three different reference technologies. We calculate geometric mean of these three scores as the final efficiency score for the observation. Please be noted that observations in 1983 and 2001 are only included in one panel while those in 1984 and 2000 are in two panels only. Their final efficiency scores are calculated accordingly.
Figure 3: Technical Efficiency Scores by Bank Type

As shown in the figure, the major banks were the most inefficient group among all types of banks. Their annual-mean efficiencies ranged between 0.6 and 0.8 during the sample period. The existing regional banks started as second inefficient group. Their performance was just marginally superior to the major banks during the first part of sample period (1983 – 1990). They then recovered steady and achieved full efficiency in the end. The newly established regional banks started as the most efficient group with efficiency score of 0.99 and had shown persistently high technical efficiency of above 0.86 all the time. However, their performance in terms of efficiency in the latter period is much less impressive than that in earlier period. The foreign banks set up their operation in Australia in 1986. In their first year of presence, they obtained mean efficiency of 0.917, much better than those domestic banks operating on full commercial basis at the time. However, their performance deteriorated in the following years until it reached historic low of 0.837 in 1989. They then managed to improve their efficiency slowly as efficiency score rose back to 0.923 in 1995 and remained above 0.90 in the rest of years. The two specialised banks, who ran their business on a less commercial basis, were found to be operating at full efficiency for all the years in operation.

5.1.2. Scale efficiency scores
Scale efficiency measures the extent to which a firm can take advantage of returns-to-scale by altering its size towards optimal scale. The impact of existence of economies and diseconomies of scale on efficiency is estimated in four steps. First, the DEA model under the assumption of constant returns-to-scale technology is run. Second, the model allowing for variable returns-to-scale is run. The effect of scale on efficiency is measured by the ratio of the constant returns to variable returns efficiency scores, that is, $SE_{it} = TE^c_{it} / TE^v_{it}$. If $SE_{it}$ is equal to 1, then the firm is operating under constant returns-to-scale. However, a scale efficiency score of less than one indicating the degree of inefficiency due to sub-optimal scale of operation contains no information on whether the firm is operating above or below its optimal size. Therefore, it is necessary to conduct the third step which involves re-running the model assuming non-increasing returns-to-scale. By comparing results from the second and third steps for those not at optimal scale, each firm can be identified to be operating on the range of decreasing or increasing returns-to-scale dependant on whether its variable returns-to-scale efficiency score is equal to the non-increasing returns-to-scale score or not. Lastly, we transform the scale efficiency scores obtained for firms on the range of increasing returns of scale by deducting the original score from 2, while leaving decreasing and constant returns-to-scale scores unchanged. Therefore, the final data set comprises of firms operating on increasing returns-to-scale with derived scores above 1, firms on constant returns-to-scale with scores of one and firms on decreasing returns-to-scale with scores below one. For a detailed explanation of this process, see section 6.4 of Coelli et al (1998) and Sturm and Willams (2002).

The annual mean DEA scale efficiency scores by bank type are plotted in figure 4. The diagram is very similar to what is shown in figure 1 on technical efficiency score. The exceptions are the gap between the major banks and the existing regional banks are widen for the first half of sample period (1983 – 1990) and all groups exhibited less dramatic change from time to time. These are mainly resulted from the existence of pure technical efficiencies and their unique pattern among each group. Another minor contributory factor is that as we convert increasing returns-to-scale scores into values above 1, the mean scale efficiency scores are in fact underestimate the degree of scale inefficiency on average when scores for increasing returns-to-scale and scores for decreasing returns-to-scale cancel out each other.
Figure 4: Scale Efficiency Scores by Bank Type

Interestingly to note, the mean scale efficiencies in each year for each group are all smaller 1, indicating that each bank group on average is operating at diseconomies of scale over the entire sample period. All the four major banks are found to persistently operating at a size far above the range of constant returns-to-scale. Other types of banks, while moving toward the optimal size of operation in the latter sample years, have all shown some tendency of expansion in earlier period. This may reflect that many existing banks used size as a barrier to the industry to prevent new entrant to enter by choosing to operate at above optimal size that led to lower scale efficiency. Some banks also engaged in merger and acquisition activities to maintain their strong position in the market.

5.1.3. Pure technical efficiency scores

Pure technical efficiency resulting from factors other than scale is measured by efficiency score derived from DEA model under the assumption of variable returns-to-scale technology. This efficiency score shows the scope for efficiency improvement at current scale of operation resulting from poor management within the organisation, disadvantageous operating environments and so on.
Figure 5: Pure Technical Efficiency Score by Bank Type

The annual mean pure technical efficiency scores by bank type are presented in figure 5. As illustrated in the diagram, all types of banks have shown relatively high efficiency under variable returns-to-scale. The major banks are found to be consistently the second highest efficient group in terms of pure technical efficiency just behind the specialised banks. The existing regional banks had low efficiency at the beginning, but managed to quickly improve their performance since 1986. They even achieved superior performance in the latter sample period (1996 – 2001). Those building societies were estimated to be fully efficient in the banking industry. However, when they started to convert to banking status, their efficiency fell. After a few years’ adjustment, they gradually recovered and operated at high efficiency similar to that of the major banks since 1993. The foreign banks also deteriorated their efficiency in the late 1980s. They then managed to improve their efficiency slowly in early 90s. Despite on one more drop in 1997, they maintain high efficiency of above 0.95 for most of the latter time period.

5.1.4. DEA results in summary

In all, all the sample banks appear to be performing reasonably well. Annual mean technical efficiency scores of each bank group range from 0.63 (major in 1990) to 1 (existing regional bank in 2001) with industry mean over the sample period achieving 73.8%. It should be
pointed out that the low efficiency levels appear to be recorded at banks that are relatively large in scale. The smaller banks appear to be on, or close to, the best practice frontier.

By further decomposing technical efficiency, we could see that the major source of inefficiency in the industry is scale inefficiency arising from sub-optimal size of operation. On average the industry are operating at diseconomies of scale, achieving merely 74.9% of potential efficiency if they are at optimal size. Low scale efficiencies of major banks dominate in this case. By reducing their operational size, the major banks could improve their scale efficiency dramatically. The gap between the fully efficient group and the least efficient group measured under variable returns-to-scale was fairly small, with mean score of 98.7% and lowest score of 88.3% (existing regional banks in 1985). It implies that the impact of internal of external factors associated with the operation of a bank rather than scale on its efficiency is minimal.

In all, there would still be some scope for further improvement in efficiency at many of the Australian banks. Both scale efficiency and pure technical efficiency can be further improved and should be done so as the market for banking products and services is going to be more competitive under deregulation. For major banks who are currently operating at diseconomies of scale, a reduction of their size to optimal level with lower average cost is deemed necessary as size barrier will be little effective in a competitive market. For other banks, efforts should be devoted to reducing pure technical efficiency resulted from bad management practice.

5.2. Malmquist DEA Indices
The Malmquist total factor productivity (TFP) change indices are calculated using DEA. The indices measure total factor productivity changes for sampled firms in adjacent year during the period of 1983/84 and 2000/01. Its decomposition into technical efficiency change (TEC), technical change (TC), pure technical change (PTEC) and scale efficiency change (SEC) components are also derived. These indices are also aggregated into sub-groups of different bank types using geometric means and the resultant indices are then converted into cumulative indices that are plotted in figure 6 – 10 respectively. Please be noted that these
Malmquist DEA indices begin with year 1986, which are all set as 1. Year 1986 is the year when the first bunch of foreign banks setting up their operation in Australia. In order to compare efficiency and productivity change among all types of banks using cumulative Malmquist DEA indices, we choose year 1986 as the base year when all types of banks were in operation.

5.2.1. Malmquist TEC indices
Cumulative Malmquist TEC indices are calculated when assuming constant returns-to-scale technology in place. In figure 6, we find that both major banks and foreign banks achieved some improvement in technical efficiency while the other types of banks had a fall in their performance in terms of technical efficiency.

![Figure 6: Cumulative Indices of Technical Efficiency Change By Bank Type](image)

The major banks managed to obtain a 7.4% increase in technical efficiencies over the sample period, but the changes from time to time were fairly dramatic. As for foreign banks, they initially experienced some sharp fall in technical efficiency, and recovered slowly since 1989. They ended up with an aggregate 4.2% improvement from the efficiency level achieved in their first year of operation in Australia.
There was some decline in efficiency of around 5% for both existing regional banks and newly established regional banks over the whole sample period, although the trends of movements are quite different. For the existing regional banks, technical efficiency slightly improved in the first year (1986 – 1987), and then started to fall over the next few years (1987 – 1991), moved back into opposite direction until 1998 at 6% rise from the base year. However, there was a sharp decline in efficiency in the following two years. The final year of the sample period has seen a small regain which led to a cumulative 5.5% fall over the sample period. On the contrary, the efficiency movements of newly established banks were often in the opposition direction to their existing counterparts, except for the period of (1991 –1994).
5.2.2. Malmquist TC indices

Cumulative Malmquist TC indices are also calculated under constant returns-to-scale technology. In figure 7, we observe that patterns of technical change for different types of banks were very in line with each other, although the levels of changes differed. All of them had up-turning points in the year of 1993 and 1999 and down-turning points in 1990 and 1996. The three-year interval is coincident with the width of window chosen for running moving-window analysis for the DEA.

![Figure 7: Cumulative Indices of Technical Change by Bank Type](image)

The technical changes experienced by the banking industry between 1986 and 1989 are most likely the initial effect of financial deregulation and entry of foreign banks. Foreign banks made big investment in their first few years of operation and exhibited exceptionally rapid rise in terms of technical change at the time. The domestic banks were under increasing pressure to operate more efficiently and be well equipped with advanced technology in order to compete effectively with foreign banks. The major banks reacted quickly and managed to achieve technical progress since 1987. It took much longer time for regional banks to adjust to the situation and they only showed technical progress in 1989.
The business recession of the early 1990 had severe negative impact on the growth of banking industry as the industry were experiencing technical regress. A number of State-owned banks collapsed or were taken over by other banks. Foreign banks also started to adjust their investment strategies as they consistently failed to achieve above-average profitability of the industry. The magnitude of technical regress of this time was much higher than that of the next round during the period of (1996 – 1999) when Wallis report was produced and initially implemented.

The period of (1993 – 1996) have seen all types of banks moved into the direction of technical progress. Among them, industry frontier faced by the major banks was shifted forward at very high pace. Regional banks also had some technical progress to a smaller extent. Foreign banks only made slight improvement in the technological level as a number of them retreated from the market by converting to branch bank or merchant bank status.

5.2.3. Malmquist PTEC indices

When variable returns-to-scale technology is assumed, changes in technical efficiency appear to be much more smooth than the case for constant returns-to-scale. It is shown in figure 8 that relative changes in pure technical efficiency to that in the base year for all types of banks at any point of time were within the range of $[-9\%, +7\%]$. In the end, regional banks and foreign banks achieved some improvement in efficiency while major banks and specialised banks managed to maintain their initial level of efficiency.
Figure 8: Cumulative Indices of Pure Technical Efficiency Change by Bank Type

For the major banks, they exhibited less dramatic changes over time under the assumption of variable returns-to-scale. The efficiency level fell and rose in consecutive years at fairly small magnitude and was restored finally.

The existing regional banks excelled all other types of banks in performance over the whole period. In spite of some ebb and flow over time, it maintained efficiency above 100% and finally approached cumulative improvement as high as 6.8%. Technical efficiency of newly established regional banks moved very closely with that of their existing counter-parts for most of the period, but at a slightly lower level.

For the foreign banks, the largest drop in efficiency came from the first three years of the sample period. Pure technical efficiency dropped to a low point of 91% in 1989, and then started to recover slowly back to 102.1% in 1996. Its performance deteriorated again to below 100% in 1997. It managed to improve the efficiency and ended up with 2.7% improvement in 2001.
5.2.4. Malmquist SEC indices

Assuming variable return-to-scale, we find that efficiency change depicted in figure 1 could be mainly attributable to changes in scale efficiency. As shown in figure 9, the changes in scale efficiency are quite dramatic for all types of banks and are larger over the last half of the sample period than these in the first half of the period.

![Cumulative Indices of Scale Efficiency Change by Bank Type](image)

Figure 9: Cumulative Indices of Scale Efficiency Change by Bank Type

Scale efficiency of the major banks fell in the first few years. During the business recession period between 1990 and 1993 when bank sizes were shrinking, their scale efficiency improved. Scale efficiency then deteriorated in the following years. During 1996 and 1999 when another round of downsizing in the banking industry took place through branch rationalization and staff cutting, their scale efficiency rose again. The movement in scale efficiency is negatively associated with the expansion and contraction of banking business, indicating this type of bank had been too big to operate efficiently.

Other types of banks also had decreasing scale efficiency in late 1980s as they all attempted to strengthen their market position by expansion in the initial post-deregulation period. Foreign banks and existing banks then moved on to rationalise their operation and therefore obtained
improvements in scale efficiency afterwards. Newly established regional banks also showed similar pattern during the period of (1990 – 1993). However, in fear of being the target of acquisition made by larger and less profitable banks in the market, they later on opted for expansion as their defensive weapons. Their scale efficiency continued to fall until 1997 which saw small recovery in the final period.

5.2.5. Malmquist TFP change indices
When the changes in pure technical efficiency, scale efficiency and technology are combined, we observe some declines in total factor productivity during the sample period for all types of banks except for foreign banks. As shown in figure 10, there were up-and-down movements for all types of banks occurring at different points of time and lasting different periods. The magnitudes of changes in productivity also diverge.

![Cumulative Indices of Total Factor Productivity Change By Bank Type](image)

Figure 10: Cumulative Indices of Total Factor Productivity Change By Bank Type

The major banks experienced some decline in productivity in late 1980s, but managed to improve their performance at steady rate in 90s. A sharp fall in productivity in year 1999 led to a net productivity loss to the group over the sample period. The foreign banks as a group managed to achieve 5.5% rise in productivity during the sample period, with most of the rise occurring over the second half period (1993 – 2001).
Both existing regional banks and newly established regional banks had a decline in productivity by around 15% over the whole sample period; however, their trends of movements are quite different. The newly established regional banks have experienced a fairly steady decline over the period despite of some occasional rises. On the contrary, large decline occurred for the existing regional banks during the first five years (1986 – 1991) and then between year 1998 and 2000. For the middle half of the sample period, these banks were experiencing improvements in productivity at changing rates instead.

The pattern of technical efficiency change certainly dominated productivity change, but the magnitude of change was often broadened or narrowed down by the presence of technical change. The industry, on average, were experiencing productivity loss at an annual rate of 0.4%.

5.2.6. *Malmquist index in summary*

In summary, the above results show that there was a tiny decline in productivity of Australian banking sector over the sample period. Technical efficiency fell slightly as a result of small increase in pure technical efficiency combined with relatively larger fall in scale efficiency. Technical progress and regress occurred in turn about every three years, leading to a net technical advance in the end.

Productivity fell for all types of banks except for foreign banks over the sample period, indicating foreign banks had superior performance in terms of productivity and efficiency to their competitors. The dramatic change in productivity and efficiency from year to year has shown that banks were under intensive pressure to catch up with their industry frontier.

5.3 *Second-stage regression analysis*

In addition to calculate DEA efficiency scores and Malmquist indices, it is also possible to conduct a second-stage regression analysis on the resultant efficiency scores to detect relationship between efficiency and some of its determinants. An ordinary least square (OLS) regression onto a vector of explanatory variables such as specific characteristics of banks and
their operating environments is run in order to explain the variation of the scores derived from the first stage. A concern with running conventional second-stage regression on Malmquist indices is that the indices generated from DEA for different firms may be dependent on each other. To overcome the inherent inter-dependency problem, we follow Xue and Harper (1999) that adopts bootstrap approach to produce consistent regression coefficient estimates. The basic idea is to substitute the inconsistent OLS estimators for standard errors of estimated coefficients with the bootstrap estimators for the standard errors of these estimates. To save space, we refer readers to their original paper for details on the methodology.

The second-stage regression function is specified as follows:

\[
TEC \mid TC \mid TFP = \beta_0 + \beta_1 TA + \beta_{12} TA^2 + \beta_2 TAG + \beta_3 CTA + \beta_4 ROR + \beta_5 MP + \beta_6 MS + \beta_7 DIV + \beta_8 INT + D_{11} FOR + \\
D_{21} PRI + D_{22} PUB + D_{31} P1 + D_{32} P2 + D_{33} P3 + D_{34} P4 + D_{35} P5
\]

where TA denotes size of firm in terms of total assets; TAG is measured as annual growth rate of total assets; TAC is asset composition, calculated by the value of net loans as a share of total assets; ROR is rate of return (pre-tax profits on equity); MP is measured by concentration ratio (HHI) in local deposit market; MS is the market share in the national loan market; DIV stands for diversification of business, which is calculated by the value of non-interest income as a share of total revenue; INT is annual interest rate; FOR, PRI, PUB are dummy variables for the type of bank where For = 1 foreign banks, PRI = 1 for privately-owned banks and PUB = 1 for government-owned banks. P1 to P5 are dummy variables for time period during (1987 – 1990), (1991 – 1993), (1994 – 1996), (1997 – 1999) and (2000 – 01) respectively.

The estimated results are given in table 3 where bootstrapping sample size is 1000. The first two columns of table 3 are the estimated coefficients and standard errors from bootstrap regression for regressing technical efficiency change on the vector of explanatory variables. The test of the null hypothesis that all the slope coefficients are jointly zero is rejected at 0.05 level using a Wald chi-square statistics, indicating the vector of explanatory variables exerts a significant influence on the efficiency performance of banks over the sample period. As shown in the table, efficiency change is related with the bank size in terms of total assets in a
quadratic form. The optimal size of the bank is around 1.6E8, which incur the least inefficiency. In addition, efficiency gain is lower for banks with higher market share in the national loan market, indicating larger firms with sufficient market share may not necessarily operate more efficiently. It should also be noted that two sub-sample periods, (1991 – 1993) and (1997 – 1999), when the Australian economy was in recession, have positive effect on the efficiency change, implying that harsh economic environment can push banks to operate more efficiently than ever in order to survive.

The next two columns of table 3 are the estimated coefficients and standard errors for the regression of technical change on the vector of explanatory variables. The test of the null hypothesis that all the slope coefficients are jointly zero is rejected at 0.05 level, showing the vector of explanatory variables has a significant influence on the efficiency performance of banks over the sample period. In this case, the relationship between technical change and bank size is U-shape. Banks concentrating on traditional banking services (large share of loan as a ratio of total assets), with larger market power and higher market share, have experienced greater technological progress, indicating that they are the one who pay more attention to investing on upgrading technology, such as new delivery channel for banking services and information process system. In addition, foreign banks are found to incur greater technical progress than domestic banks. Both private banks and public banks are superior to financial institutions under mutual ownership in technological improvement as well. All the sub-sample periods since 1986 have some positive impact on technological change, benchmarking against the base period of 1983 – 1986.

The final two columns of table 3 are the estimated coefficients and standard errors for the regression of total factor productivity change on the vector of explanatory variables. A test of the null hypothesis of the joint significance of these explanatory variables is rejected at the 0.01 level. The estimated coefficients on the growth rate of total assets and rate of return are statistically significantly negative while the one on the asset composition is negative. Productivity improvements are generally higher for banks that are profits, size and market driven.
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<th>Total factor productivity</th>
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Table 3: Determinants of efficiency and productivity variation

Note: * Significant at 10% level;

6. Conclusions

The study uses DEA and Malmquist index to measure efficiency and productivity of Australian banking sector under deregulation. The DEA results show that all the sample banks appeared to be performing reasonably well. The major banks and the existing regional banks were found to be the most and the second most inefficient group respectively. On the contrary, market entrants, foreign banks and newly established regional banks, showed superior performance. The major source of inefficiency in the industry is scale inefficiency arising from sub-optimal size of operation, particularly for the major banks in this case. The
major banks and some large regional banks seemed to have adopted some defensive strategy in response to deregulation in the financial sector, using size as a barrier to entry in order to prevent new entrants sharing super profits earned in the industry. Even small profitable banks passively sought for mergers of equal size to avoid being the target of acquisition from larger banks.

The Malmquist indices show that the industry was experiencing small productivity loss over the sample period. Technical efficiency fell slightly as a result of relatively smaller increase in pure technical efficiency combined with relatively larger fall in scale efficiency. Technical progress occurred, but being too small to improve total factor productivity. Productivity fell for all types of banks except for foreign banks over the sample period, indicating foreign banks had superior performance in managing their operation in Australia. The dramatic change in efficiency and productivity from year to year has show that banks were under intensive pressure to catch up with their industry frontier.

The current study provides some modifications to existing studies conducted on the assessment of efficiency and productivity of Australian banking industry using DEA. Given data limitation and time constraint, all the work is done in the current form and may be improved in the development of further models. For future studies, areas in which could be improved include:

1. The striking feature of this study is the estimation of quality-adjusted efficiency and productivity indices by including number of branches as one of the outputs. However, improvements in quality of bank services may be not fully or accurately captured in this variable. Efficiency in banking industry has been sought through branch rationalisation and technology upgrading in recent years. The closure of many branches, as a result of bank mergers, or integration of many functions like customer service and loan processing, has effectively reduced operating costs without any sacrifice to service quality and conveniences. Moreover, driven by technological advances, traditional branch banking no longer plays a key role in delivering banking products and services. The future of banking services will certainly see widespread adoption of new distributional channels, such as ATM, EFTPOS, phone and internet banking. Using number of branches as the only index for quality of services may
underestimate bank efficiency and productivity during the latter part of sample period. Improvements in future studies could be made in the field of measurement of banking outputs if more information on other distributional channels is available.

2. One of the limitations of using DEA is that it will always identify at least one firm as being the best practice within the given sample set. The resultant technical efficiency scores are relative, that is, the technical efficiencies of individual firms relative to what is identified as the best practice firm. It is possible that all firms in a sample are inefficient to some degree by international standard. This is most likely true in this study with the findings that the major banks are operating highly efficiently under variable returns-to-scale. Under variable returns-to-scale DEA, banks of similar size are compared to each other to measure efficiency. Inefficiency of the major banks resulted from market power or other factors cannot be detected. Therefore it is possible that even the best practice bank identified in the model is operating below the optimal level of efficiency.

In order to evaluate the true performance of Australian banks relative to the best-practice frontier in the banking industry, one might consider a DEA model where the banks operating in Australia are benchmarked against banks operating in other countries within similar economic and regulatory environment. In particular, large banks of similar size to that of our major banks should be selected. However, at this stage it is difficult to collect such full data set given the existing discrepancy for data reporting systems among countries.
References:


Appendix 1: Sequential DEA and the chosen window width

In the sequential DEA, each observation is treated as a different firm for each period in the sub-panel (window). There is a problem of choosing the right window width, that is, how many years of observations are included. Instead of making such decision arbitrarily, we examine the sensitivity of DEA scores to the given window width. A relationship between efficiency scores ($\mu$) and number of consecutive years of observations included in reference technology ($\rho$) is drawn in the following diagram:

![Estimated Marginal Means of SCORE](image)

Diagram A3.1: Relationship between $\mu$ and $\rho$

As expected, the relationship between $\mu$ and $\rho$ is negative. The more years of observations included in reference technology, the lower the average efficiency scores. It is also detected that while the mean efficiency score for three-year observations in a sub-panel is significantly lower than these of one- or two- year observations in a sub-panel, it is not significantly different from these of observations for longer period in a sub-panel. Therefore, the width of window is chosen as 3 years.
Appendix 2: Number of Banks by Bank Type and Year in model 1

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