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Empirical study on the efficiency analysis of Australian banks

Abstract

To keep pace with the trend of globalization, many countries commence to deregulate the financial industry. However, how to ensure financial safety and market integrity under deregulation is essential work for any country. This paper studies whether the performance of 9 Australian domestically owned commercial banks improves after taking financial supervision into account in 1998 using Data Envelopment Analysis (DEA) and Malmquist productivity indexes (MPI). We find overall technical efficiency fell up to 2000, but recovered gradually thereafter. In comparison with American banks, Australian banks had better average efficiency for the 2001-2004 post-financial reforms period. The results represent the overall technical inefficiency mainly was due to the scale inefficiency. In addition, the mean total factor productivity rose slightly by 0.1 percent per year and this increase could be traced to a positive technological change. On the other hand, we also find return on assets (ROA) is an important financial factor affecting positively the performance of Australian banks.

Keywords: performance, commercial bank, Data Envelopment Analysis (DEA), Malmquist productivity indexes (MPI), efficiency.
JEL Classification:

Introduction

Under the trend of globalization, numerous countries start to implement a series of financial reforms which establish a good financial environment and then further improve the performance of financial institutions.

Banking industry is the leading sector in the financial system because it possesses the majority of financial assets and plays a mediator role by funding from suppliers to demanders. Thus, this paper chooses the banking industry as the study target.

With the wave of globalization, how to ensure financial safety and market integrity under deregulation is essential work for any country. This paper investigates whether the performance of Australian domestically owned commercial banks improves after taking financial supervision into account. Accordingly, we choose the reorganization of Australian financial regulatory structure in 1998 followed the Willis Inquiry Report (1997) as critical point. That is, we examine the efficiency of Australian banks for the period of 1996-1998 as well as the period of 1999-2004.

We analyze the overall technical efficiency, pure technical efficiency, and scale efficiency of 9 Australian domestically owned commercial banks. Efficiency was measured using Data Envelopment Analysis (DEA) and efficiency change was measured using Malmquist Productivity Indexes (MPI). Empirical results indicate overall technical efficiency fell until 2000, but recovered gradually thereafter. The average total factor productivity rose slightly by 0.1 percent per year and this increase could be traced to a positive technological change.

The other goal of this paper is to find which factors affect the efficiency of Australian banks using least square regression. We selected five explanatory variables including return on asset (ROA), total assets, Tier 1 and Tier 2 capital, fixed assets and number of employees. The findings show return on assets (ROA) had a significant positive relationship to efficiency.

1. Literature

1.1. The evolution of financial reforms in Australia. Relating to the process of financial reforms in Australia, financial system had been fully regulated prior to the 1960s, tried to reform in 1970s and entered deregulated era in 1980s. Speaking strictly, Australian government placed restriction on financial industry, banking industry especially, up to the end of 1970s.

Severe regulations limited the competition among Australian banks, so made the efficiency of banks decline. Those regulations included the types of products banks could offer and prices of products banks could charge, interest rate ceilings of deposits, interest rate and terms of financial instruments, credit line and so on. Additionally, foreign banks entry also regulated. Manifold regulations mentioned above restricted the international competitiveness of banks and made domestic financial market not connect with international financial market. In contrast to non-bank financial institutions (NBFIs), they were not regulated heavily and these unequal regulations made NBFIs expand their market power rapidly, for example, 17% in 1960, 20% in 1970, and 30% in 1980. As a result, the proportion of total assets of banks to those of total financial institutions declined, that is, 54% in1960, 46% in 1970 and 42% in 1980 (Kent and Debelle, 1999).

With the trend of financial liberalization in the early 1980s, many countries commenced to remove from regulations for financial industry. Australia experiencing a slow financial development over the 1960s and 1970s decided to implement a series of financial reforms for Australian financial system.

Campbell Committee was established to reform Australian financial system in 1979. The contents of reforms were allowing banks to merger and new banks entry, removal of direct control of banks (including interest rate ceilings, terms of deposit and amount of advances, abolishment of foreign exchange regulations), admitting foreign banks into Australian financial market, as well as reforms in stock market.

Deregulations made banks recover market share and improve competitiveness and efficiency. However, excessive expansion in credit, extreme development of stock market and a large growth of indebtedness caused the stock market bubble in October 1987 and brought about a financial crisis and recession in the early 1990s.

At this time, Australian government was well aware that it had to take financial supervision into account simultaneously under deregulation. As a result, it formed the Wallis Committee to review comprehensively the Australian financial system in May 1996. It had three missions. First, it had to inspect the effect of deregulation on Australian financial system since the early 1980s. Second, it had to analyze the forces behind change, technology particularly. Third, it had to arrange a regulatory structure to promote an efficient, flexible and competitive financial system. Therefore, Wallis Committee advanced extensive financial reforms and made a Wallis Inquiry Report including 115 recommendations in March 1997. Wallis Inquiry Report would rather said to a complement of the Campbell Inquiry than a brand-new reform. It aimed to promote competitiveness of banks and also ensure financial safety and market integrity at the same time.

Ultimately Australian government adopted the Wallis Committee's recommendations and decided to reorganize existing financial regulatory structure in September 1997. Three important independent supervisory authorities which were responsible for different supervisory duties supervised the Australian financial system. The Corporations and Financial Services Commission (CFSC) was responsible for market integrity, consumer protection and regulation of corporations. The Australian Prudential Regulation Authority (APRA), established in July 1998, was responsible for prudential regulation of deposit-taking, insurance and superannuation. Reserve Bank of Australia (RBA) was responsibility for overseeing systemic stability through monetary policy and payments system.

Australian financial system went through a significant change of supervisory system and made banking industry change. First, Australian institutions were encouraged to expand externally, for example, Big Four banks created overseas branches or took over foreign banks. Second, Australian government sold portion of shares of domestic banks in order to promote privatization of banks. Third, development of mergers between financial institutions emerged. Forth, the number of branches and employees declined due to development of electronic finance. Finally, cross-business in financial industry developed clearly, for instance, banking, securities, trust, and insurance crossed through subsidiary or holding shares.

1.2. The relevant literature. In the early 1980s, Australian government decided to implement a series of financial reforms for Australian financial system in order to keep pace with trend of financial liberalization and further improve efficiency and competitiveness of banks. However, excessive expansion in credit, extreme development of stock market and a large growth of indebtedness caused the stock market bubble in October 1987 and brought about a financial crisis and recession in the early 1990s.

Accordingly, numerous studies commenced to review the performance of Australian banks during the post-deregulation period using Data Envelopment Analysis (DEA). Avkiran (1999) examined the operating efficiency, employee productivity, profit performance and average relative efficiency of Australian trading banks during the post-deregulation period (1986-1995). Avkiran found the efficiency of banks declined slightly up to 1991 because bad debts occurred by 1990 in Model A. Next year, Avkiran (2000) analyzed productivity of banks using Malmquist productivity indexes (MPI) during the same period (1986-1995) for 10 Australian banks. Total factor productivity fell from 1988 to 1990 due to unprofitable lending and competition among peers, but rose from 1991 to 1993 because banks recovered from unprofitable lending and market rules of competitive guarantee were identified clearly. In addition, increasing the total productivity was due to technological progress instead of technical efficiency.

Sathye (2001) examined the x-efficiency including technical and allocative efficiency of Australian banks in the year of 1996. The findings showed that allocative efficiency of banks was higher than technical efficiency. This implied that banks need to improve the productivity of inputs such as capital, labor and loanable funds. Sathye (2002) put forward the study of productivity change of banks during the period of 1995-1999 for 17 Australian locally incorporated banks using MPI. Technical efficiency of banks fell by 3.1 percent and total factor productivity fell by 3.5 percent over the study period. The fall in productivity resulted from negative technical progress.

Neal (2004) examined x-efficiency and productivity change of Australian banks for the period of 1995-1999. The findings displayed that overall efficiency had a declining trend until 1997 but rose in 1998 as well as 1999, and allocative efficiency of banks was higher than technical efficiency. Besides, Neal grouped bank types into national banks, regional banks, other retail banks as well as investment banks. Neal found that national banks were on the 'best-practice' frontier, but regional banks were much less efficient (allocative and technical efficiency) than other types. This made regional banks become take-over targets for national banks. On the other hand, Neal measured productivity change of banks using MPI. The results were the opposite of Sathye (2002) for the same period of 1995-1999. Total factor productivity rose by 7.6 percent annually and efficiency of banks improved significantly due to technological change rather than efficiency change. The studies mentioned above confirm the efficiency of Australian banks declined since the late of 1980s.

After undergoing financial crisis and recession in the early 1990s, however, Australian government established the Wallis Committee to review comprehensively the Australian financial system. Wallis Committee made a Wallis Inquiry Report including a series of financial reforms in 1997. Kirkwood and Nahm (2006) investigated cost efficiency of producing banking services (model A) and profit (model B) of Australian banks between 1995 and 2002 for 10 domestically owned retail banks listed on ASX. Their findings were dissimilar to previous studies mentioned above. First, banking-service efficiency (model A) had an increasing trend over the study period and technical efficiency increased gradually from 1998 to 2002. Second, a finding that technical efficiency was superior to allocative efficiency was contrary to Sathye (2001) and Neal (2004). In addition, Kirkwood and Nahm found that major banks had higher efficiency than regional banks and this difference was likely to result from diversification, organizational restructuring, different customer bases as well as globalization. In the study of productivity change of banks, the results revealed that total factor productivity over the period of 1998-2000 grew by 31 percent due to technological change. This paper confirms the efficiency of Australian banks improved after implementing the financial reforms proposed by Wallis Committee.

On the whole, we want to understand efficiency of banks since the end of 1980s. Sturm and Williams (2004) investigated the efficiency of foreign-owned banks and domestic banks in Australia over the post-deregulation period 1988 to 2001 using DEA, MPI, and stochastic frontier analysis. The results indicated that technical efficiency of all banks dropped from 1989 (0.76) to 1991 (0.73), but improved gradually thereafter and reached a peak in 2000 (0.94). Relating to productivity change of banks, the result using MPI displayed productivity improved (in model 1) during the post-deregulation period and technological change was the main source. In addition, they found foreign banks had better scale efficiency than domestic banks and caused superior technical efficiency in foreign banks over the study period. This result is not consistent with Sathye (2002), who found technical efficiency of domestic banks outperformed foreign banks in 1996 because foreign banks lacked a broad branch network. In the case of other country, Havrylchyk (2006) found that foreign banks in Poland displayed superior average cost efficiency compared to domestic banks because foreign banks use their better technology and expertise to balance the unfamiliarity with local market. In Hungarian case, Hasan and Marton (2003) also found cost inefficiency of foreign banks was less than that of domestic ones. Besides, Okeahalam (2004) as well as Jemric and Vujcic (2002) both concluded that foreign banks were more efficient than domestic ones.

In international literature, some authors also demonstrated that deregulation or financial reforms really improved efficiency of banks. Xiaogang, Michael and Kym (2005) analyzed the cost, technical and allocative efficiency of 43 Chinese banks before and after the 1995 deregulation. The findings indicated that overall efficiency increased up to 1996, but declined thereafter due to Asian crisis, global economy slowdown and excessive non-performing loans to state-owned enterprises. They concluded that financial deregulation in 1995 could improve efficiency of Chinese banks in the early deregulation period particularly. Furthermore, Chinese banks had better technical efficiency rather than allocative efficiency, and the result was consistent with Kirkwood and Nahm (2006). This implied that banks had to improve the combination of inputs given cost minimization.

Isik and Hassan (2003) investigated the efficiency of Turkish banks after financial reforms in 1980. They assumed that the financial reforms or deregulation could create more liberal and competitive financial environment and hence improved the performance of banks. Just as expected, their findings confirmed the efficiency of all banks increased under deregulation, 1981-1990. Moreover, they found that private and foreign banks outperformed state ones in the deregulated environment. Subsequently, Turkey experienced the three crises in 1994, 2000 and 2001. Ozkan-Gunay and Tektas (2006) studied the efficiency of Turkish banks in precrisis and crisis periods. They found the number of banks declined gradually because inefficient banks were taken over by Saving Deposit Insurance Fund (SDIF) and mean efficiency of banks had a declining trend between 1990 and 2001.

Ataullan et al. (2004) also found overall technical efficiency of Indian banks and Pakistani banks improved gradually after financial liberalization, 1995-1996 especially. A last literature by Ataullah and Le (2006), who studied the influence of Economic Reforms (ERs), that is, fiscal reforms, financial reforms, as well as private investment liberalization, on efficiency of Indian banks including public banks, private banks and foreign banks showed that there was an improvement in the efficiency of Indian banks, foreign banks particularly, over the post-ERs period (1995-1998). In addition, the authors found public banks had better efficiency than private ones. Nevertheless, the efficiency gap between public and private banks fell after ERs due to removal of restrictions regarding operations and private banks entry. In conclusion, Ataullah and Le described ERs could establish a good financial environment for banks to improve their performance.

Likewise, Casu and Molyneux (2003) analyzed the efficiency of European banks after the Single Internal Market establishment. The creation of the Single Internal Market aimed to make goods and services move freely across Member States and improve economic efficiency. They found that there were low average efficiency levels in European banks. Strictly speaking, the efficiency of European banks improved slightly. The efficiency of Spanish banks improved the most, UK was the second, and France ranked the third one.

To compare the efficiency of banks across different countries, Sathye (2002) found that overall efficiency of Australian banks was lower than that of European banks as well as US banks in 1996. That is to say, it was under the world mean efficiency. This implied that there was still room to improve efficiency of Australian banks so as to accomplish world best practice, and Australian banking system concentrated heavily. In international literature, Maudos and Pastor (2001) provided the comparison of efficiency of European banks, Japanese banks and American banks. They found cost efficiency was more stable than profit efficiency for the three nations. Profit efficiency of American banks improved substantially, while that of Japanese banks displayed a significant decreasing; European banks exhibited more stable profit efficiency. The results given above were similar to pattern of accounting ratio, namely, profit before tax dividing by equity. In other words, the trend of accounting ratio was consistent with process of profit efficiency for all three nations. Lim and Randhawa (2005) compared the efficiency of Hong Kong banks and Singaporean banks. They found that efficiency of Hong Kong banks was better than that of Singaporean banks in the operation of funds and financial intermediation using the intermediation approach because Singaporean banks were restricted by government protection, oligopoly banking market as well as strict banking regulations. From individual country perspective, however, the efficiency of Hong Kong banks declined over the study period because of Asian crisis in 1997. In contrast, the efficiency of Singaporean banks kept stable owing to Singaporean government protection during the Asian crisis period.

2. Methodology

2.1. Model overview. This paper studies the efficiency of banks using DEA. Farrell (1957) first advanced the concept of deterministic non-parametric frontier to measure the relative technical efficiency employing the envelope curve. Measured units which lie on the production frontier are efficient for their combinations of inputs and outputs, whereas others which do not lie on the production frontier are inefficient. Farrell defined that technical efficiency multiplied by allocative efficiency is overall one. Afterward Charnes, Cooper and Farrell (1978) developed Data Envelopment Analysis (DEA) model and extended it from signal input and output to multiple inputs and outputs. DEA is a non-parametric linear programming technique which constructs a linear frontier and evaluates relative efficiency of decision making units (DMUs). Its concept is that the best practice for firms is to lie on the production frontier which results in having an efficiency value of one. In contrast, the firms which are below the production frontier have a less value than one and are said to be less efficient.

DEA method has two advantages. One is allowing us to use a small sample size and this meets the limit of small number (9) of Australian owned banks in our study. Another is we do not suppose a production function and this advantage is helpful to different service type which Australian banks offer. Some banks provide a typical intermediation service, while others allow for various ranges of services (Kirkwood and Nahm, 2006). However, a disadvantage of using DEA is no random error and this causes we do not differentiate the noise or inefficiency from efficiency.

We analyze the relative efficiency of firms compared to the best-practice firms which lie on the production frontier using DEA. However, the relative efficiency changes while levels of inputs and outputs change over time. Thus, we do not know whether the efficiency of firms improves over time. Caves, Christensen and Diewert (1982) advanced the Malmquist Productivity Index (MPI) in terms of absolute efficiency. The MPI can analyze the changes in productivity stemming from changes in technical efficiency or in technology.

2.2. Data Envelopment Analysis – CCR model. In 1978, Charnes, Cooper and Farrell advanced CCR model which further made DEA model more definite and used formally the term of Data Envelopment Analysis (DEA). The CCR model can be classified into input-oriented model which minimizes the input levels given output levels and output-oriented model which maximizes the output levels given input levels. Under the assumption of constant returns to scale which indicates input levels rise proportionally to output levels, the overall technical efficiency value will equal using input-oriented model or output-oriented model.

2.2.1. Input-oriented model. To evaluate the efficiency of the *k*th DMU, we have to minimize the input levels given output levels. In other words, we analyze the "maximization" of output levels given input levels for DMU_k using the following method. The original fractional programming is as follows:

$$Max.h_k = \frac{\sum_{r=1}^{s} \mu_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

$$s.t. \frac{\sum_{r=1}^{s} \mu_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \ , \qquad (1)$$

$j = 1,\dots, n$

$\mu_r \geqq \varepsilon \geqq 0;\ r = 1,\dots, s,$

$v_i \geqq \varepsilon \geqq 0;\ i = 1,\dots, m,$

where h_k is the estimate of relative efficiency for the *k*th DMU_k, x_{ij} is the *i*th level of inputs for the *j*th DMU, y_{rj} is the *r*th level of outputs for the *j*th DMU, v_i is the *i*th weighted level of inputs for the *j*th DMU, μ_r is the *r*th weighted level of inputs for the *j*th DMU, ε is the non-Archimedean constant which ensures v_i and μ_r are positive.

As it is difficult to find solutions using the fractional programming and is likely to calculate infinite solutions, we transform the fractional programming into the linear programming and find solutions using the duality which is in favor of reducing the number of constraints. The linear programming is as follows:

$$Max.h_k = \sum_{r=1}^{s} \mu_r y_{rk}$$

$$s.t \sum_{i=1}^{m} v_i x_{ik} = 1 \ , \qquad (2)$$

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \ ,$$

$j = 1,\dots, n$

$\mu_r \geqq \varepsilon \geqq 0;\ r = 1,\dots, s,$

$v_i \geqq \varepsilon \geqq 0;\ i = 1,\dots, m.$

The duality in linear programming is as follows:

$$Min.h_k = \theta_k$$

$$s.t \sum_{j=1}^{n} y_{rj} \lambda_j \geq y_{rk} \qquad (3)$$

$$\sum_{j=1}^{n} x_{ij} \lambda_j \leq \theta_k x_{ik} \ ,$$

$r = 1,\dots, s,$
$i = 1,\dots, m,$
$j = 1,\dots, n,$

λ_j is the weight; $\lambda_j \geqq 0$ for all j,

$\theta \geqq 0.$

2.2.2. Output-oriented model. The development of Output-oriented model is the same as for Input-oriented one. To evaluate the efficiency of the *k*th DMU, we have to maximize the output levels given input levels using the same method mentioned above in Input-oriented model.

2.2.3. Evaluation of efficiency. No matter which model is chosen. The value of θ which is equal to one indicates that DMU_k is relatively efficient, whereas the value of θ which is less than one indicates that DMU_k is relatively inefficient.

2.3. Data Envelopment Analysis – BCC model. Some firms operate at constant returns to scale, whereas others function at variable returns to scale. The CCR model is not suitable if firms operate at variable returns to scale. In 1984, therefore, Banker, Charnes and Cooper presented the BCC model which applies to the cases of variable returns to scale. BCC model measures pure technical efficiency and calculates scale efficiency using overall technical efficiency in CCR model divided by pure technical efficiency. Hence, we further know inefficiency mainly stems from pure technical inefficiency or scale inefficiency. As the CCR model, the BCC model also can be classified into input-oriented model and output-oriented model.

2.3.1. Input-oriented model. The original fractional programming is as follows:

$$Max.z_k = \frac{\sum_{r=1}^{s} \mu_r y_{rk} - \mu_0}{\sum_{i=1}^{m} v_i x_{ik}}$$

$$s.t. \frac{\sum_{r=1}^{s} \mu_r y_{rj} - \mu_0}{\sum_{i=1}^{m} v_i x_{ij}} \le 1 \;, \qquad (4)$$

$j = 1,\ldots, n$

$\mu_r \geqq \varepsilon \geqq 0;\ r = 1,\ldots, s,$

$v_i \geqq \varepsilon \geqq 0;\ i = 1,\ldots, m,$

$\mu_0 \ni (-\infty,\infty)$

The linear programming is as follows:

$$Max\, z_k = \sum_{r=1}^{s} \mu_r y_{rk} - \mu_0$$

$$s.t \sum_{i=1}^{m} v_i x_{ik} = 1 \;, \qquad (5)$$

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - \mu_0 \le 0 \;,$$

$j = 1,\ldots, n,$

$\mu_r \geqq \varepsilon \geqq 0;\ r = 1,\ldots, s,$

$v_i \geqq \varepsilon \geqq 0;\ i = 1,\ldots, m,$

$\mu_0 \ni (-\infty,\infty).$

The duality in linear programming is as follows:

$$Min.z_k = \theta_k$$

$$s.t \sum_{j=1}^{n} y_{rj}\lambda_j \ge y_{rk} \,,$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j \le \theta_k x_{ik} \,, \qquad (6)$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$r = 1,\ldots, s,$
$i = 1,\ldots, m,$
$j = 1,\ldots, n,$
λ_j is the weight; $\lambda_j \geqq 0$ for all j.

2.3.2. Output-oriented model. The concept of Output-oriented model is the same as for Input-oriented one. To evaluate efficiency of the *k*th DMU, we have to maximize the output levels given input levels using the same method mentioned above in Input-oriented model.

2.3.3. Evaluation of efficiency. Using the either of two models, the value of λ_0 in equation 5, which is equal to zero indicates that the production frontier on which DMU_k lie belongs to constant returns to scale. The value of λ_0 which is less than zero indicates that the production frontier on which DMU_k lies belongs to increasing returns to scale. On the contrary, the value of λ_0 which exceeds zero indicates that the production frontier belongs to decreasing returns to scale.

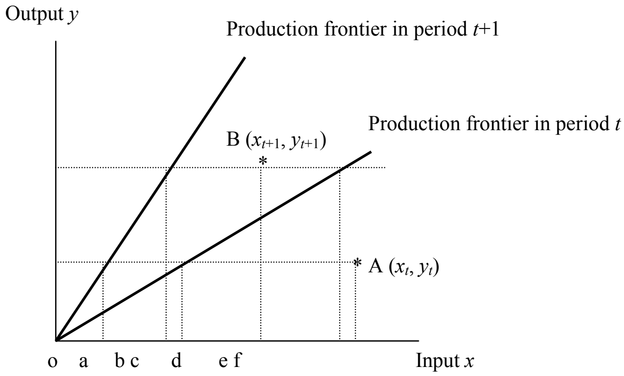

Fig. 1. Input-oriented MPI under constant returns to scale technology

2.4. Malmquist Productivity Index. Malmquist Total Factor Productivity (TFP) index analyzes the change in TFP. We have to use distance functions to calculate the MPI, which is illustrated in Figure 1.

In the signal input and output case, considering a production point A (x_t, y_t) in period t with the period t technology and another one B (x_{t+1}, y_{t+1}) in period $t + 1$ with the period $t + 1$ technology, the formula of the input-oriented MPI is as follows:

$$MPI(x_t, x_{t+1}, y_t, y_{t+1}) = \left[\frac{d_t(x_{t+1}, y_{t+1})}{d_t(x_t, y_t)} \frac{d_{t+1}(x_{t+1}, y_{t+1})}{d_{t+1}(x_t, y_t)}\right]^{\frac{1}{2}}, \qquad (7)$$

where d_{t+1} (x_t, y_t) represents the relative efficiency of a production point A compared to the period $t + 1$ frontier. The value of MPI which exceeds one displays there is a positive total factor productivity change from period t to period $t + 1$, that is, an improvement in productivity, whereas the value which is less than one points at productivity loss.

We further divide the changes in technical efficiency or total factor productivity into changes in technology and changes in technical efficiency. The formulas are as follows:

$$MPI = TC \times TEC, \qquad (8)$$

technology changes (TC) =

$$\left[\frac{d_t(x_{t+1}, y_{t+1})}{d_{t+1}(x_{t+1}, y_{t+1})} \frac{d_t(x_t, y_t)}{d_{t+1}(x_t, y_t)}\right]^{\frac{1}{2}}, \quad (9)$$

technical efficiency changes (TEC) =

$$\frac{d_{t+1}(x_{t+1}, y_{t+1})}{d_t(x_t, y_t)}. \quad (10)$$

The value of TC which is larger than one indicates there is an advance in technology, and the value of TEC which exceeds one points at an improvement in efficiency. On the contrary, the value of TC and TEC which is less than one respectively indicates there is an opposite result. Besides, technical efficiency changes can be divided into pure technical efficiency changes and scale efficiency changes.

2.5. Data. We acquired mainly the data from the Global COMPUSTAT database for 9 Australian banks[1] classified as commercial ones with 6020 SIC code, and checked some non-value data from their annual reports. The small number of Australian domestically owned banks[2] as well as the availability of non-zero and non-negative data restrict sample size we use. Kirkwood and Nahm (2006) also studied the efficiency of Australian banks using a small sample size of 10 domestically owned banks. To measure whether the efficiency of Australian banks can improve in healthier financial system, we examined the efficiency of Australian banks for the periods of 1996-1998 and 1999-2004 due to the reorganization of Australian financial regulatory structure in 1998.

Because the production process is not definite in the banking industry compared to manufacturing and makes it difficult to differentiate between inputs and outputs, we use the intermediation approach to define the classification of inputs and outputs. Intermediation approach regards banks as intermediaries which transfer funds form depositors to borrowers and earn incomes.

Table 1. Descriptive statistics

Variables	Mean	Standard deviation	Maximum	Minimum
Inputs				
Capital	168,567	18,791	72,100	160
Deposit	63,730	69,213	262,796	1,731
Outputs				
Loan	71,268	76,146	271,330	1,604
Fee revenue	1,402	1,428	5,563	21

Note: Unit is millions of Australian dollars.

A small sample size restricts the number of variables we can use. Neal (2004) stated it is important to reduce the number of variables when sample size is limited. Avkiran (1999) stated the sample size should be larger than the product of the number of inputs and outputs. According to the rule of thumb, sample size should be at least twice as large as the sum of the number of inputs and outputs. Accordingly, we choose capital and deposit as inputs, and loan and fee revenue as outputs. Capital represents shareholder's equity and long-term debt. It is a total capital investment compared to partial investment in property, plant and equipment. Deposit is a sum of total deposits from customers and other banks. Loan is a sum of total loans, claims and advances made to other banks, government and customers. On the other hand, numerous banks have expanded their traditional activities to the non-traditional activities in order to increase additional incomes, namely, non-interest incomes, in the more and more competitive environment. Thus, we choose non-interest income as a proxy for non-traditional activities. Non-interest income includes commissions and fee, incomes on trading securities, incomes on investment securities and so on. The detailed statistics measured in millions of Australian dollars are presented in Table 1. Finally, we use DEA software, DEAP Version 2.1, to analyze our data.

2.6. Regression model. After measuring the efficiency of banks, we analyze the factors influencing efficiency using multiple-regression model. Efficiency score of individual bank for each year is regressed on relative explanatory variables. Our regression model is as follows:

$$OTEs = a_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5, \quad (11)$$

$$PTEs = a_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5, \quad (12)$$

$$SEs = a_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5, \quad (13)$$

where *OTEs* is the score of overall technical efficiency, *PTEs* is the score of pure technical efficiency, *SEs* is the score of scale efficiency, a_0 is the intercept, X_1 is the return on assets (ROA), X_2 is the logarithm of total assets, X_3 is the Tier 1 and Tier 2 capital divided by risk-adjusted assets, X_4 is the book value of fixed assets divided by total assets, X_5 is the logarithm of number of employees.

The two indicators of operational performance in banking industry are return on equity (ROE) and return on assets (ROA). The banks which can create higher returns by operating assets for stockholders have better performance, so we expect b_1 will be positive. Australian banking system concentrated

[1] Australian-owned banks in our sample are Adelaide Bank Limited (ADB), Australia and New Zealand Banking Group Limited (ANZ), Bank of Queensland Limited (BOQ), Bendigo Bank Limited (BEN), Commonwealth Bank of Australia (CBA), Macquarie Bank Limited (MAB), National Australia Bank Limited (NAB), St. George Bank Limited (SGB), and Westpac Banking Corporation (WBC).

[2] See the website of APRA, Statistics. There are 14 Australian-owned banks.

heavily in the way of Big Four banks[1]. Because the Big Four banks which hold about two-thirds of total banks assets dominate Australian banking industry, we want to know whether the size of banks affects their performance. As to capital, Basel Agreement motivates banks to handle their capital properly in order to protect them from insolvency risk. The adequate capital raises the safety of banks, so we expect b_2 will be positive. In addition, we want to test the relationship between the performance of banks and scale of production. We use the book value of fixed assets and the number of employees, namely, full time staffs, as the proxies of scale of production. We think instinctively an increase of fixed assets and the number of employees represent the expansion of scale of production.

3. Empirical results

3.1. The efficiency analysis. In July 1998 Australian government created the Australian Prudential Regulation Authority (APRA) in charge of prudential regulation of deposit-taking, insurance and superannuation. Henceforth, APRA, Corporations and Financial Services Commission (CFSC) and Reserve Bank of Australia (RBA) became the three central independent supervisory authorities in Australian financial system. Australian supervisory authorities underwent a significant change which made the financial system of the country more robust. We analyze whether the performances of Australian banks improve in the sounder financial environment.

The results obtained by using DEA model are shown in Table 2. We find the overall technical efficiency scores declined until 2000, but recovered in later years through two adjusting years, 1999 and 2000. On the average, the efficiency of banks during the post-financial reforms period was not superior to one before financial reforms.

In addition, we also find the overall technical inefficiency mainly stemmed from scale inefficiency. This indicated, on the average, the banks did not operate at an optimal scale. The number of banks which did not operate at an optimal scale exceeded a half of total from 1998 to 2002 except 2001 and a bulk of banks experienced decreasing returns to scale (see Table 3). The problem was the injudicious combination of inputs. For the banks experiencing decreasing the returns to scale, they had to reduce the input levels.

Table 2. Efficiency scores of Australian banks (yearly averages)

Year	Overall technical efficiency	Pure technical efficiency	Scale efficiency
1996	0.9927	0.9985	0.9942
1997	0.9846	0.9939	0.9907
1998	0.9777	0.9991	0.9786
mean	0.9850	0.9971	0.9879
1999	0.9595	0.9828	0.9764
2000	0.9496	0.9771	0.9722
2001	0.9733	0.9969	0.9764
2002	0.9655	0.9969	0.9683
2003	0.9792	0.9942	0.9849
2004	0.9737	0.9970	0.9767
Mean	0.9668	0.9908	0.9758

Table 3. The number of Australian banks operating at IRS, DRS and CRS

Year	IRS	DRS	CRS
1996	1	2	6
1997	1	2	6
1998	2	3	4
1999	3	2	4
2000	2	3	4
2001	0	4	5
2002	0	5	4
2003	1	2	6
2004	0	3	6

Notes: IRS is increasing returns to scale, DRS is decreasing returns to scale, and CRS is constant returns to scale.

In contrast to the findings of Kirkwood and Nahm (2006), their results in model A represented the overall technical efficiency scores demonstrated an increasing trend from 1995 (0.869) to 2002 (0.963) except 1997. The difference seemed to result from different inputs and outputs, different assumptions of returns to scale, different samples and different sample sizes.

Table 4. Efficiency scores of American banks (yearly averages)

Year	Overall technical efficiency	Pure technical efficiency	Scale efficiency
1996	0.9740	0.9896	0.9842
1997	0.9809	0.9945	0.9863
1998	0.9812	1.0000	0.9812
Mean	0.9787	0.9947	0.9839
1999	0.9638	0.9875	0.9758
2000	0.9580	0.9881	0.9693
2001	0.9019	0.9502	0.9517

Table 4 (continued). Efficiency scores of American

[1] Big Four banks are Australia and New Zealand Banking Group Limited (ANZ), Commonwealth Bank of Australia (CBA), National Australia Bank Limited (NAB), and Westpac Banking Corporation (WBC).

banks (yearly averages)

Year	Overall technical efficiency	Pure technical efficiency	Scale efficiency
2002	0.9049	0.9733	0.9308
2003	0.9324	0.9612	0.9699
2004	0.9088	0.9696	0.9383
Mean	0.9283	0.9716	0.9560

To know whether the improvement in efficiency of Australian banks after 2001 resulted from the benefit of financial reforms or business prosperity, we compared the efficiency of Australian banks to that of American banks. America is the leader of the global economy and often drives the economic development of other countries, so we choose American banks as comparative targets. First of all, we ranked the American banks according to their total assets, and chose 9 banks[1] out of the top 15 American banks as samples. The inputs and outputs as well as study period were identical to the Australian case. The results of using DEA model are shown in Table 4, and we charted the comparison of the efficiency of Australian and American banks in Figure 2.

We find the efficiency of American banks represented a decreasing trend from 1996 to 2004 and dropped obviously after 2001. On the average, the efficiency of Australian banks surpassed that of American ones for the 2001-2004 period especially. Hence, we think the performance of Australian banks recovered after financial reforms and this gain stemmed from the benefit of financial reforms rather than the business prosperity.

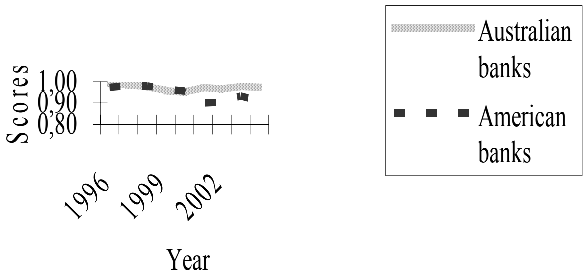

Fig. 2. Comparison of efficiency

3.2. Productivity growth. We use the input-orientated Malmquist Productivity index to analyze the total factor productivity (TFP) change, and the findings are presented in Table 5. We have found out that after the financial reforms, the average total factor productivity for Austrian banks rose slightly by 0.1 percent per year and this increase mainly resulted from an annual average advance of 0.2 percent in technological change exhibiting a shift in the frontier. However, an annual average degeneracy of 0.1 percent in technical efficiency change reveals no improvement in efficiency relative to the frontier. We further look over the average total factor productivity change for each year and find the productivity grew by an annual average of 1.4 percent, 4.5 percent and 3.4 percent in 1999, 2002 and 2003 respectively. These gains mostly determined the growth in technological change by an annual average 3.3 percent, 5.4 percent and 1.9 percent respectively related to the development of electronic finance, e.g., ATMs and EFTPOS (Electronic Funds Transfer Point of Sale) terminals. They provide the communities with greater access to electronic financial services. The number of ATM increased approximately by 20 percent in 2002 and 2003 respectively. In 2003 particularly, technical efficiency change and technological change both increased by an annual average 1.5 percent and 1.9 percent respectively, and this result confirmed that the score of the overall technical efficiency reached the peak (0.9792, see Table 2) during the post-financial reforms period, from 1999 to 2004, and also implied the performance of Australian banks improved best with the simultaneous improvement in technical efficiency change and technological change. Technical efficiency change can be decomposed into the produce of pure technical efficiency change and scale efficiency change. On the average, pure technical efficiency change and scale efficiency change had no change per year during the post-financial reforms period.

Table 5. Malmquist productivity indexes for Australian banks (yearly average)

Year	MPI	TEC	TC	PTEC	SEC
1999	1.014	0.981	1.033	0.983	0.998
2000	0.955	0.989	0.965	0.994	0.995
2001	0.992	1.026	0.967	1.021	1.005
2002	1.045	0.992	1.054	1.000	0.991
2003	1.034	1.015	1.019	0.997	1.017
2004	0.972	0.995	0.977	1.003	0.992
Mean	1.001	0.999	1.002	1.000	1.000

Notes*:* MPI is total factor productivity change, TEC is technical efficiency change, TC is technological change, PTEC is pure technical efficiency change, and SEC is scale efficiency change. MPI is equal to the produce of TEC and TC, and TEC can be decomposed into the produce of PTEC and SEC.

Figure 3 charts the trend of MPI, TEC, TC and OTEs. We find the MPI and TC varied in the same direction and the score of overall technical efficiency (OTEs) and TEC had the similar trend

[1] American banks in the sample are Bank of America Corp. (BAC), J.P. Morgan Chase & Co. (JPM), Wachovia Corp. (WB), Wells Fargo & Co. (WFC), U.S. Bancorp. (USB), Suntrust Banks, Inc. (STI), Bank of New York Co. (BK), Branch BKG&TC Corp. (BBT), National City Corp. (NCC).

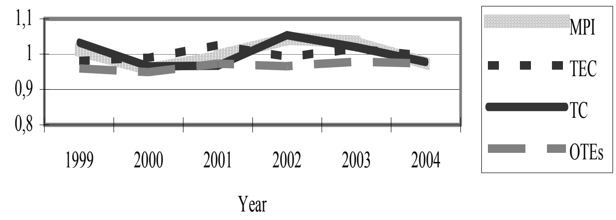

Fig. 3. Productivity changes for Australian banks

3.3. Regression analysis. Table 6 summarizes the results of regression on overall technical efficiency at 5 percent significance level. It is noteworthy that ROA (X_1) has a significant positive relationship to overall technical efficiency. This result supports the Neal's (2004) findings, which confirmed the overall efficiency scores and ROA had a similar story indicating high overall efficiency scores accompanied with high ROA. Total assets (X_2) and overall technical efficiency had a positive relationship displaying big banks had better performance. However, this positive influence is not significant. The findings which indicated that Tier 1 and Tier 2 capital (X_3) had a negative relationship to overall technical efficiency do not meet our positive expectation. Nevertheless, this negative relationship is not significant. In addition, we used the book value of fixed assets (X_4) and the number of employees (X_5) as the proxies of scale of production. The findings indicate the scale of production related negatively to the performance of banks, but only the negative effect of the number of employees (X_5) was significant. It was similar to Sathey (2001) who also found a negative relationship between the number of staff and overall efficiency. We think the development of electronic finance benefiting the performance of banks decreases the number of branches and employees.

Table 6. Empirical results for regression analysis

Dependent variable: OTEs				
	Coefficient	Standard deviation	T-statistic	P-value
Intercept	1.1129	0.0618	18.0172	0.0000
X1	8.2051	2.4512	3.3474	0.0016***
X2	0.0396	0.0426	0.9306	0.3567
X3	-0.1985	0.2208	-0.8990	0.3732
X4	-1.8148	2.0303	-0.8939	0.3758
X5	-0.0946	0.0458	-2.0640	0.0444**
R-sq	0.6392			
Adj. A-sq	0.4086			

Notes: OTEs is the score of overall technical efficiency, X_1 is the return on asset (ROA), X_2 is the logarithm of total assets, X_3 is the Tier 1 and Tier 2 capital divided by risk-adjusted assets, X_4 is the book value of fixed assets divided by total assets, and X_5 is the logarithm of number of employees. *, **, and *** indicate a variable is significant at 10 percent, 5 percent, and 1 percent levels, respectively

Table 7 summarizes the results of regression on pure technical efficiency at 5 percent significance level. The findings are similar to those of Table 5. ROA (X_1) still has a significant positive influence on pure technical efficiency, but a negative relationship between the number of employees (X_5) and pure technical efficiency is not significant.

Table 7. Empirical results for regression analysis

Dependent variable: PTEs				
	Coefficient	Standard deviation	T-statistic	P-value
Intercept	1.0238	0.0382	26.8217	0.0000
X1	3.3547	1.5147	2.2148	0.0316**
X2	0.0220	0.0263	0.8362	0.4072
X3	-0.1459	0.1365	-1.0694	0.2902
X4	-1.5305	1.2546	-1.2199	0.2285
X5	-0.0354	0.0283	-1.2482	0.2180
R-sq	0.3833			
Adj. A-sq	0.1469			

Notes: PTEs is the score of pure technical efficiency, X_1 is the return on assets (ROA), X_2 is the logarithm of total assets, X_3 is the Tier 1 and Tier 2 capital divided by risk-adjusted assets, X_4 is the book value of fixed assets divided by total assets, and X_5 is the logarithm of number of employees. *, **, and *** indicate a variable is significant at 10 percent, 5 percent, and 1 percent levels, respectively.

Table 8 summarizes the results of regression on scale efficiency at 5 percent significance level. The findings are similar to those of Table 6. ROA (X_1) still has a significant positive influence on scale efficiency. Nevertheless, the degree of influence on scale efficiency is stronger than pure technical efficiency by comparing the coefficients 4.8712 to 3.3547. ROA measures whether a firm can use efficiently the invested capital or assets to generate earnings. We think that banks which parlay the assets can further increase their performance by expanding adequately the scale, especially it concerns the banks operating at increasing returns to scale or constant returns.

Table 8. Empirical results for regression analysis

Dependent variable: SEs				
	Coefficient	Standard deviation	T-statistic	P-value
Intercept	1.0889	0.0603	18.0583	0.0000
X1	4.8712	2.3927	2.0358	0.0473**
X2	0.0179	0.0416	0.4296	0.6694

Table 8 (continued). Empirical results for regression analysis

Dependent variable: SEs				
	Coefficient	Standard deviation	T-statistic	P-value
X3	-0.0527	0.2156	-0.2442	0.8081
X4	-0.2732	1.9819	-0.1379	0.8909
X5	-0.0596	0.0448	-1.3311	0.1894
R-sq	0.5576			
Adj. A-sq	0.3110			

Notes: SEs is the score of scale efficiency, X_1 is the return on assets (ROA), X_2 is the logarithm of total assets, X_3 is the Tier 1 and Tier 2 capital divided by risk-adjusted assets, X_4 is the book value of fixed assets divided by total assets, and X_5 is the logarithm of number of employees. *, **, and *** indicate a variable is significant at 10 percent, 5 percent, and 1 percent levels, respectively.

Conclusion

In 1996 the Wallis Inquiry was established to review the Australian financial system again after the Campbell Inquiry (1979) and make a Wallis Inquiry Report (1997). After taking financial supervision into account, Australian financial system became more integral and more robust. This paper measured the efficiency of 9 Australian banks from 1996 to 2004.

The evidence obtained by using DEA model indicates that overall technical efficiency fell up to 2000, but recovered gradually thereafter through the adjusting period in 1999 and 2000. The scale inefficiency was mainly a source of the overall technical inefficiency which indicated the banks did not operate at an optimal scale. We compare the efficiency of Australian banks to that of American banks and find that on the average Australian banks outperformed American ones for the period of 2001-2004 especially. Therefore, we conclude the recovery in performance of Australian banks during the post-financial reforms period stemmed from the benefit of financial reforms rather than the business prosperity.

In the course of the productivity analysis of Malmquist productivity indexes (MPI), we find an average total factor productivity rose slightly by 0.1 percent p.a. However, this increase could be traced to an annual average increase of 0.2 percent in technological change. However, a growth of technical efficiency indicated an improvement in efficiency in 2001 and 2003. In 2003 particularly, technical efficiency change and technological change both increased and suggested that the overall technical efficiency score attained its peak (0.9792, see Table 2) during the post-financial reforms period.

In a regression analysis, it is noteworthy that ROA (X_1) has a significant positive relationship to overall technical efficiency, pure technical efficiency and scale efficiency. The findings display that ROA is an important financial factor affecting positively the performance of banks.

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