2011-19: A comparative technical, cost and profit efficiency analysis of Australian, Canadian and UK banks: Feasible efficiency improvements in the context of controllable and uncontrollable factors (Working paper)

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Published

2011

ISSN 1836-8123

Griffith Business School

Discussion Papers | Finance

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No. 2011-19

Series Editor: Dr. Alexandr Akimov

A comparative technical, cost and profit efficiency analysis of Australian, Canadian and UK banks: Feasible efficiency improvements in the context of controllable and uncontrollable factors

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Abstract

This paper employs a mixed two-stage approach to estimate and explain differences in the cross-country efficiency of ten Australian, five UK and eight Canadian banks over the period 1988 to 2008 using stochastic distance, cost and profit frontiers. The variables specified in the stochastic frontiers used to estimate efficiency include the amount and prices of labour, physical capital and deposits, along with the level of non-interest income, profits and total costs. The country and firm-specific variables specified as explanatory factors include per capita national income, capital adequacy, deposit density, the industry concentration ratio, the level of intangible assets, and ratios of provisions for loan losses-to-total loans, loans-to-deposits, debt-to-equity, loans-to-total assets and long-term debt-to-total capital, among many others. In line with the experience of the banking sector during the recent global finance crisis, the evidence indicates that Australian banks exhibit superior efficiency compared with their Canadian and UK counterparts. Key factors found to affect efficiency positively include the level of intangible assets and the loans-to-deposits and loans-to-assets ratios. In contrast, key factors found to affect efficiency negatively include bank size and the ratios of loan loss provisions-to-total loans and the debt-to-equity ratio.

JEL codes: C23, D24, G21.

Keywords: Stochastic frontier analysis, technical, cost and profit efficiency, banks.

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1. Introduction

The banking sector has received considerable attention from academics, practitioners, and regulators alike because of its key contribution to financial system stability and economic growth. Given the stability of the banking system itself depends on the efficiency of banks (Schaeck et al., 2006), a substantial literature has also investigated bank efficiency, typically measured by a bank's ability to operate close to its theoretical or empirical best-practice frontier. In recent years, the measurement of bank efficiency is granted additional emphasis in light of financial and banking crises, especially the global financial crisis (GFC). This builds on existing empirical findings that banks that are more efficient are less likely to fail (Wheelock and Wilson 2000). Moreover, during a crisis, individuals and companies may attempt to leave weaker banks and deposit their funds in stronger banks; in response, banks may attempt to reallocate their asset portfolios and reorganise their operation and in doing so attempt to improve their efficiency (Demirguc-Kunt et al., 2006). The GFC especially showed that liquidity risk stemming from collective reactions by market participants could exacerbate financial instability through the channel of the risk of insolvency, and thence systemic risk (Van den End and Tabbae, 2011).

However, despite an already sizeable literature concerning bank efficiency, there is still no consensus on the sources of variation in measured efficiency. Arguably, three reasons for this variation in results are: (i) differences in efficiency concepts, (ii) variation in measurement methods, and (iii) divergence in the potential correlates of efficiency (Berger and Mester, 1997). Foremost among these are the different efficiency concepts discussed in the banking literature, including technical efficiency, cost efficiency, and profit efficiency. The second two types of efficiency are also commonly termed economic efficiency. The obvious advantage of the economic efficiency over the technical efficiency lies in the inclusion of price information, which better in corresponds to conventional bank performance measurement, such as the return on equity (ROE) and return on assets (ROA), and in closely corresponding to the ability of banks to withstand financial crises. However, technical efficiency has its advantages, as it can be very informative as to how well a bank undertakes operations.

By comparison, the main disadvantage of the notion of economic efficiency compared with technical efficiency is that economic efficiency measurement explicitly relies on bank objectives. In actuality, the estimation of economic efficiency relies on the imposition of a behavioural objective for a bank, which can be inappropriate under the certain circumstances (Kumbhakar and Lovell, 2004). In addition, the assumption that a bank is unconstrained in its ability to adjust freely its use of inputs or outputs is rather unrealistic, especially under the circumstances of highly intensive competition. In response to these longstanding concerns, we address all three efficiency concepts in this paper at our attempt to examine bank performance in a complementary fashion.

Since seminal work by Aigner, Lovell, and Schmidt (1977) and Charnes Cooper, and Rhodes (1978), stochastic frontier analysis (SFA) and data envelopment analysis (DEA) have become two of the most widely used techniques in frontier efficiency analysis. Of these, DEA is a linear programming technique where the set of best-practice observations form a frontier under a convex production possibilities set. Consequently, DEA does not specify the explicit specification of the form of the underlying production relationship, and thereby omits any possibility of random fluctuation in efficiency. In contrast, SFA attributes at least part of the deviation from the best-practice frontier to inefficiency and assumes a distribution of inefficiency effect by specifying a particular form of production, cost or profit function. In addition, SFA has arguable superiority in estimating economic efficiency over DEA, largely because the latter typically ignores price information, even where available (Berger and Mester, 1997).

Once the conceptual and measurement issues have been controlled for, it is important for the purposes of public policy, managerial performance, and research to explain the remaining the remaining variations in efficiency across banks. Research on the determinants of bank efficiency has typically focused on three types of factors, bank-specific factors, industry specific factors, and country specific or macroeconomic factors (e.g. Koutsomanoli-Filippaki Mamatzakis, and Staikouras, 2009; Pasiouras, Tanna, and Zopounidis, 2009; Maudos and Guevara, 2007; Berger, Hasan, and Klapper, 2004; Dietsch and Lozano-Vivas, 2000). However, there is an issue arising from the classification of the factors when the discretion of a bank as to improvement on bank performance is under consideration. As discussed, for a bank, there is a real need for a consistent improvement on efficiency regarding either to a normally performance benchmark or to the ability to be resilient during the financial recessions. As a result, we can classify the factors that affect bank efficiency into two broad categories: (i) environmental (or macro) factors that are beyond

the control of bank management, and (ii) determining factors associated with bank operations, that is, the determinants of efficiency at the firm level. For example, country-specific and macroeconomic factors, such as GDP, interest rates, labour union power, unemployment rates and government regulations, belong to the former category, while some firm-level factors, such as size, financial leverage, asset structure, loan provisions and mortgage loans are part of the latter. Surprisingly, to the authors' best knowledge, no previous studies have differentiated between these factors in a single study. Accordingly, the central purpose of this paper is to: (i) investigate how to improve bank efficiency, (ii) examine environmental factors that can explain variations in efficiency scores, and (iii) check the consistency between three key efficiency concepts.

To achieve these objectives, we employ a mixed two-step approach to examine efficiency and the determinants of efficiency using a panel of data from three countries. In the first stage, we define a common efficiency frontier for banks in three countries, namely, Australia, Canada and the UK, including environmental factors. We then investigate the firm-level determinants of efficiency by specifying efficiencies as regressands and firm-specific factors as regressors. Of course, a number of alternative approaches are available for incorporating factors influencing efficiency scores. These include augmented parametric frontier models directly incorporating environmental factors into efficiency models (e.g. Dietsch and Lozano-Vivas 2000; Barros, Ferreira, and Williams 2007), Battese and Coelli's (1995) single-stage SFA model, and the more commonplace two-step method where efficiency scores are regressed on firm-, industry- and market-specific variables (See Grigorian and Manole, 2006; Casu and Molyneux, 2003). However, the principal shortfall of these studies is that more or less controllable firm-specific factors mix with uncontrollable macro factors (Berger et al., 1997).

Moreover, a common problem typically arises when a study attempts to consider the efficiency of banks across countries, thereby reflecting cross-country differences in institutional, regulatory and market conditions, among others (Berger, 2007). As a rule, countries differ so greatly in terms of economic environments that it seems unlikely that any set of environmental controls or methodological improvements can rule out the possibility that any substantial differences in measured efficiency found arise from the market as a whole rather than firm-level differences. Most past studies avoid this apparent problem by focusing on banks in a single country (e.g. Jonghe and Vennet, 2008; Kasman and Yildirim, 2006; Williams and Nguyen, 2005; Perera et al., 2007). Unfortunately, this limits our knowledge of cross-country efficiency differences and the natural focus this would then place on institutional, regulatory and market conditions in different countries. This is particularly pertinent for the banks in our sample, which while from different countries (Australia, Canada and UK) nonetheless share a common 'Anglo–Saxon' inheritance in the operations, structure and regulation of their financial systems.

The remainder of the paper is structured as follows. Section 2 discusses the methods used for estimating and explaining bank efficiency. Section 3 provides details of the data. Sections 4 and 5 include discussion of the efficiency estimates and the findings concerning the impact of environmental factors and other determinants of efficiency. Finally, Section 5 summarises the paper and details some likely implications for industry practice and regulatory practice.

2. Methods for estimating and explaining efficiency

2.1. Efficiency models

Using panel data over the period 1988 to 2008, we apply a mixed two-stage efficiency methodology to 23 banks in Australia, Canada and the UK. In the first stage, we obtain estimates of cross-country technical, cost, and profit efficiency in these banks using SFA after making allowance for the influence of uncontrollable environmental factors. In the second stage, we investigate the impact on efficiency on controllable firm-level factors using a panel regression model.

Technical efficiency

For the estimation of technical efficiency, we specify an input-oriented translog distance function of the following form:

$$
\begin{aligned}
\ln d_{it} = \alpha &+ \sum_{n=1}^{3}\beta_n \ln x_{nit} + \sum_{r=1}^{2}\chi_r \ln y_{rit} + \frac{1}{2}\sum_{n=1}^{3}\sum_{m=1}^{3}\delta_{nm}\ln x_{nit}\ln x_{mit} + \frac{1}{2}\sum_{r=1}^{2}\sum_{s=1}^{2}\xi_{rs}\ln y_{rit}\ln y_{sit} \\
&+ \sum_{n=1}^{3}\sum_{r=1}^{2}\phi_{ns}\ln x_{nit}\ln y_{rit} + \tau t + \frac{1}{2}\kappa t^2 + \sum_{n=1}^{3}\psi_n t\ln x_{nit} + \sum_{r=1}^{2}\theta_m t\ln y_{rit} + v_{it}
\end{aligned}
\tag{1}
$$

where dit denotes the input distance, ln are natural logarithms, β, χ, δ, ξ, ϕ, τ, ψ, and θ are parameters to be estimated, xnit and yrit are respectively the n-th inputs and the r-th outputs of the i-th bank at time t, and v is a random variable to account for approximation errors and other sources of statistical noise in dit. Based on the intermediation approach to bank efficiency estimation, the inputs are the amount of labour (STF) and the dollar values of deposits and other borrowings (DEP), and physical capital (PHC). The outputs are loans (LOA) (including loans, advances, and other receivables) and non-interest income (NII). vit. Denoting uit as the inefficiency component, technical efficiency (TE) can be defined as $TE_{it} = \exp(-u_{it})$. Since $TE_{it} = d_{it}^{-1}$ the inefficiency component can be expressed as $u_{it} = \ln d_{it}$ a. This function is non-decreasing, linearly homogeneous, and concave in inputs. Setting $\beta_n \geq 0$, $\ln d_{it} = u_{it}$ and $\beta_1 + \beta_2 + \beta_3 = 1$ we transform equation (1) into:

$$
\begin{aligned}
-\ln x_{1it} = {} & \alpha + \sum_{n=1}^{2} \beta_n \ln(x_{nit} / x_{1it}) + \sum_{r=1}^{2} \chi_r \ln y_{rit} + \frac{1}{2}\sum_{n=1}^{2}\sum_{m=1}^{2} \delta_{nm} (\ln x_{nit} / x_{1it}) \ln(x_{mit} / x_{1it}) \\
& + \frac{1}{2}\sum_{r=1}^{2}\sum_{s=1}^{2} \xi_{rs} \ln y_{rit} \ln y_{sit} + \sum_{n=1}^{2}\sum_{r=R}^{2} \phi_{nr} (\ln x_{nit} / x_{1it}) \ln y_{rit} + \tau t + \frac{1}{2}\kappa t^2 \qquad (2) \\
& + \sum_{n=1}^{2} \psi_n t \ln(x_{nit} / x_{1it}) + \sum_{r=1}^{2} \theta_m t \ln y_{rit} + v_{it} - u_{it}
\end{aligned}
$$

The term, uit in Equation (2) is dependent on the environmental factors. Given environmental factors, which are beyond the control of bank management, can affect the shape of the the efficiency frontier, the inefficiency term is assumed to have an independent normal distribution with mean m and variance δ2, that is N(m, δ2). The inefficiency effect, μ, can be obtained through a truncation at zero of the normal distribution N(m, δ2). The mean of the distribution m is defined as z'δ, where z is a m×1 vector of country-specific environmental variables that are allowed to vary over time, and δ is an m×1 vector of unknown coefficients for the country -specific environmental variables. Thus, the inefficiency effect, μ, is:

$$\mu_{it} = z_{it}'\delta + \omega_{it} \qquad \textbf{(3)}$$

where ω is defined by the truncation of the normal distribution with zero mean and variance σ2, z is the environmental variable and δ is a parameter. Thus the truncation point is $z_{it}'\delta$. The efficiency scores are estimated using simultaneous estimation of Equations 2 and 3 (Battese and Coelli, 1995).

The environmental variables, Z, include per capita income (*PCI*), capital adequacy ratio (*CAR*), the four-bank concentration ratio (*CNR*), deposit density (*DED*) and the average profit margin for the banking sector (*APM*). Countries with a higher *PCI* are assumed to have a mature banking sector, which thus results in interest rates that are more competitive. Therefore, we expect *PCI* to have a positive effect on bank efficiency. The second environmental variable is the capital adequacy ratio (*CAR*) as a measure of regulatory conditions. There are various competing arguments concerning the effect of *CAR* on bank efficiency. For instance, Kasman and Yildirim (2006) and Berger and DeYoung (1997) argue that banks with better solvency and greater prudential requirements are less likely to incur loan losses, and thus less compelled to spend additional expenses to recover these loans. They will therefore appear more efficient. Conversely, Lozano-Vivas, Pastor, and Pastor (2002) argue that a low *CAR* can indicate moral hazard behaviour. Thus, banks with a low *CAR* may prefer high risk–return activities. Thus, the bank may appear very efficient in the short term, but could subsequently suffer a positional loss because of risky investments in the longer term.

The four-bank concentration ratio (*CNR*) represents the share of the largest four banks in the banking industry. Unfortunately, it is difficult to hypothesise the impact of CNR on firm-level efficiency. For example, a high *CNR* could result from the exercise of market power allowing large banks especially to operate under non-optimal conditions. However, higher concentration may also be associated with lower costs if the market concentration results from superior management (Demsetz, 1973), and economies of scale (Grigorian and Manole 2006).Thus, the effect of *CNR* on firm level efficiency is a priori indeterminate. . Next, average profit margin (*APM*) measured by individual bank's operating income divided by total revenues, is used as an indicator of the competitiveness in each country's banking sector. APM is assumed to have a positive effect on efficiency. The last environmental variable is deposit density (*DED*) measured by total deposits per inhabitant. The relationship between *DED* and the inefficiencies is expected to be negative (Lozano-Vivas et al., 2002).

Then, the effects on the technical efficiency frontier of time trend are assessed by differentiating distance function with respect to time trend (t),

$$EF_d = \frac{\partial d_i}{\partial t} = \tau + \frac{1}{2}\kappa t + \sum_{n=1}^{3}\psi_n x_{nit} + \sum_{r=1}^{2}\theta_m y_{rit} \tag{4}$$

Since $\ln d_i = -\ln TE$, Equation 2 can be converted to,

$$EF_{TE} = \frac{\partial TE}{\partial t} = -\frac{\partial d_i}{\partial t} = -(\tau + \frac{1}{2}\kappa t + \sum_{n=1}^{3}\psi_n x_{nit} + \sum_{r=1}^{2}\theta_m y_{rit}) \tag{5}$$

where d_i is input-oriented distance function in natural logarithm; *TE* is technical efficiency in logarithm; EF_d and EF_{TE} denote the effect of time trend on distance function and technical efficiency respectively.

Cost efficiency

Following the work of Berger and Mester (1997), we estimate cost efficiency also using a translog cost function as follows:

$$\ln TC_{it} = \alpha + \sum_{n=1}^{3}\beta_n \ln w_{nit} + \sum_{r=1}^{2}\chi_r \ln y_{rjt} + \frac{1}{2}\sum_{n=1}^{3}\sum_{m=1}^{3}\delta_{nm} \ln w_{nit} \ln w_{mit} + \frac{1}{2}\sum_{r=1}^{2}\sum_{s=1}^{2}\xi_{rs} \ln y_{rit} \ln y_{sit}$$
$$+ \sum_{n=1}^{3}\sum_{r=1}^{2}\phi_{nr} \ln w_{nit} \ln y_{rit} + \tau t + \frac{1}{2}\kappa t^2 + \sum_{n=1}^{3}\psi_n t \ln w_{nit} + \sum_{r=1}^{2}\theta_r t \ln y_{rit} + v_{it} + u_{it} \quad (6)$$

This function must satisfy the properties of homogeneity of degree one in inputs and symmetry of the cross effects:

$$\sum_{n=1}^{3}\beta_n = 1, \sum_{n=1}^{3}\delta_{nm} = 0, \ \sum_{n=1}^{3}\phi_{nr} = 0, \ \delta_{nm} = \delta_{mn}, \xi_{rs} = \xi_{sr} \quad (7)$$

where CST_{it} is = total cost, comprised of operating costs and interest expenses of the *i*-th bank at time *t*; w_{it} and y_{it} are vectors of input prices and outputs for the *i*-th bank, respectively; and $\exp(-u_{it})$ provides cost efficiency score of bank *i* in year *t*. The input prices are proxied by labour expenses divided by the number of staff (*PLB*), interest expenses divided by total deposits (*PDP*), and operating expenses less labour expenses divided by fixed assets (*PPC*). The outputs are the same as the technical efficiency model. To satisfy linear homogeneity in input prices, total cost are normalized by the deposit price and to control for potential scale biases in estimation, equity capital (*EQC*) is also used as a normalizing variable, which is measured by the bank's common equity..

Profit efficiency

In a similar vein, the profit efficiency scores are calculated from the 'alternative profit frontier' model in Berger and Mester (1997). The alternative profit frontier model uses the same translog specification and independent variables as the cost frontier model. The dependent variable in the translog profit function is $\ln(P_{it} + \theta)$, where P_{it} is the observed pre-tax profit of the *i*-th bank at time *t*. The use of pre-tax profit as a performance measure eliminates any apparent efficiency gain resulting from a bank's ability to manage its tax affairs. The term θ refers to the absolute value of the minimum level of profits over all the banks in a given year plus 1, |Pmin|+1. The term θ is added to each bank's profit to ensure that all dependent variables are positive so that the natural log of profit can be taken (see Yildirim and Philippatos, 2007). The dependent variable $\ln(P_{it} + \theta)$ is normalized by equity capital.

2.2 Firm-specific determinants of efficiency

Zero and one bound the above efficiency scores. Thus, a Tobit model is used to explain cross-sectional and time variation in efficiency in terms of firm-specific variables (see Coelli et al., 2005; Hsiao et al., 2010). The firm-specific variables are: size (*AST*), intangible assets (*IAS*), provisions for loan losses-to-loans ratio (*PLL*), the ratio of loans-to-deposits (*LND*), the debt-to-equity ratio (*DEQ*), cash and dues from banks-to-assets ratio (*CSH*), the loans-to-assets ratio (*LAT*), the net margin (*NTM*), the long-term debts-to-total capital ratio (*DBC*), and investments-to-loans ratio (*INV*).

We can consider bank size, as measured by the logarithm of total assets, as a control variable rather than a determinant of efficiency, The effect of this factor is likely to be positive for the reasons that are similar to those for the concentration ratio or market power. In comparison, a larger bank may take advantage of technology that is more advanced and superior managements as well as the benefits of economies of scale. In addition, the large bank can benefit from the premiums of being too-big-to-fail. In this paper, we treat IAS, measured as logarithm of assets not having a physical existence, from an accounting viewpoint as an indicator of future growth opportunities (Ozkan, 2001). This is because the values of these assets (including goodwill, patents, copyrights, trademarks, formulae, franchises of no specific duration, capitalized software development, organizational costs, customer lists, licenses of no specific duration, capitalized advertising costs, capitalized servicing rights, and purchased servicing rights) depend on their expected future return. A bank with substantial intangible investment can be expected to adopt more advanced technology, be better managed and, thus, be more efficient. Though a number of studies examine the value relevance of intangible assets (Oliveira, Rodrigues, and Craig, 2010; Dahmash, Durand, and Watson, 2009; Goodwin and Ahmed, 2006), the role of intangible assets as a determinant of bank efficiency has not been previously researched.

We use the next set of variables to investigate the effects of risk-taking and capital structure on bank efficiency. The variable most closely related to these agency costs is financial leverage, as measured by the debt to equity ratio (*DEQ*). A higher DEG may reduce agency costs through pressure to generate cash flow to pay interest expenses and also through the threat of liquidation, which can cause personal losses to the managers of salaries, reputations, and perquisites, etc. In this respect, *DEQ* may positively affect bank efficiency. Conversely, further increases in *DEQ* may incur significant agency costs, because a relatively high *DEQ* makes bankruptcy or financial distress more likely because of risk shifting or a reduced effort to control risk (Berger and Patti, 2006). In this case, *DEQ* has a negative effect on bank efficiency.

Another three measures of liquidity risk are the ratio of cash and dues from banks to assets (*CSH*), the ratio of loans to deposit (*LND*), and the ratio of long-term debt to total capital (*DBC*). *CSH* is expected to negatively affect bank efficiency due to opportunity cost of holding liquid assets (Kwan, 2003). *LND* reflects a bank's ability to covert deposits to loans (Dietsch and Lozano-Vivas, 2000), thus Exerts a postive influence on efficiency. The last liquidity indicator is the ratio of long-term debt to total capital (*DBC*). Long-term debt represents all interest bearing financial obligations excluding amounts due within one year. In comparison, long-term debt can be viewed as a stable source of funds for lending, and may positively affect the efficiency of a bank.

The effect of *PLL,* the ratio of loan provision to total loans, is non-monotonic. If a bank spends more resources on credit underwriting and loan monitoring, the bank will have less problem loans at the expense of higher operating costs (Mester, 1996). From this perspective, the relationship between *PLL* and efficiency is positive. On the other hand, the loan provisions can be proportionally associated with problem loans. Thus, the effect of *PLL* on efficiency can be negative (Berger and DeYoung, 1997).

Over the past few decades, banks have been more and more involved in non-loan services, such as fund managements, financial planning andinsurance services. For the most part, loans are now more costly than other financial products as a source of bank funds. In this sense, the ratio of loans to assets (*LAT*) is expected to have a negative relationship with efficiency (Kwan, 2003). On the other hand, more loans can generate more revenue; thus, a positive relationship between *LAT* and efficiency can also be possible (Casu and Girardone, 2006). In a similar vein, the ratio of net interest income to total revenues (*NTM*) can positively affect bank efficiency. In addition, the ratio of investments to loans (*INV*) is hypothesized to be positively associated with efficiency, because investments securities are less costly than loans.

3. Data sources and descriptive analysis

This paper investigates banks in three countries, Australia, Canada and the UK, over the period 1988 to 2008. The relatively long sample period allows for looking at the time variation in banks during the deregulatory and post-deregulatory period. The sample including ten Australian banks, five UK banks and eight Canadian banks are used to construct a cross-country efficiency frontier. The data is collected from DataStream, the Aspect Financial Analysis database, the annual reports of financial firms, the KPMG Financial

Institution Performance Surveys, and individual bank annual reports.

Table 1. Efficiency variable definitions and summary statistics

Variable	Definition	Australia				Canada				UK			
		Mean	Min.	Max.	Std. dev.	Mean	Min.	Max.	Std. dev.	Mean	Min.	Max.	Std. dev.
STF	Number of staff (n)	19961	664	51879	17898.47	29295	159	73323	19551.76	92217	2959	315520	67645.75
PHC	Physical capital ($ mil.)	663.06	7.39	2771.64	701.10	893.66	4.11	3821.54	729.75	6505.66	480.16	30048.22	6831.53
DEP	Deposits ($ mil.)	43276.23	502.26	273988.80	54666.08	87161.50	243.93	437263.31	83532.16	268668.33	30465.83	1520205.21	290608.84
PLB	Labour price ($ thous.)	56.8	20.49	288.25	46.84	50.75	19.42	106.93	20.37	58.53	24.94	277.10	37.39
PPC	Physical capital price ($ thous.)	3.4	0.45	26.94	4.19	2.05	0.93	5.75	0.98	1.59	0.31	5.15	0.99
PDP	Deposit price (%)	0.08	0.03	0.37	0.05	0.05	0.02	0.11	0.02	0.06	0.02	0.12	0.02
LOA	Loans ($ mil.)	56530.97	495.75	344896.01	73569.02	72500.23	217.33	320037.79	62136.48	329949.70	24840.24	2057044.67	384764.47
NII	Non-interest income ($ mil.)	1512.30	8.34	12231.29	2051.17	2150.87	–1145.56	14274.13	2574.67	10397.97	559.34	53135.30	12157.77
PRF	Profits ($ mil.)	1036.68	–1485.66	6057.58	1354.26	1149.97	–4247.26	5987.04	1336.57	3929.79	–80919.22	22186.33	9639.53
CST	Total costs ($ mil.)	1803.30	78.48	10899.32	2368.24	7323.72	32.14	31466.61	6177.57	27754.93	3270.74	132486.87	27907.25

Table 1 provides the data summary for the input and output variables in the efficiency models over the period from 1988 to 2008. All variables, except prices and staff numbers, are in US dollar millions. As shown, UK banks are generally much larger than Australian and Canadian banks as measured by total assets throughout the full sample period. The largest bank in the sample is Royal Bank of Scotland Group in 2008 at an asset value of $4,765 billion; the smallest bank is Canadian Western Bank in 2008 with assets of $10.6 billion. For the most part, UK banks have a slightly higher labour price when compared with Australian banks with the labour price of Canadian banks being lower. However, the differences between the labour prices of these three countries are much smaller than the differences in their loans and non-interest income. For example, the mean non-interest income of UK banks is six times larger than that in Australian banks and four times larger than in Canadian banks. In addition, UK banks appear to have the lowest price for physical capital compared with both Australian and Canadian banks. Consequently, UK banks could have taken advantage of economic efficiency rather than technical efficiency.

Table 2. Country and firm-specific variables, definitions and summary statistics

Variable	Definition	Australia Mean	Min.	Max.	Std. dev.	Canada Mean	Min.	Max.	Std. dev.	UK Mean	Min.	Max.	Std. dev.
PCI	Per capita	24.	14.	50.7	9.2	24.7	17.	47.5	8.16	26.3	14.	47.99	10.0
CAR	Capital ratio	6.1	5.2	6.77	0.3	4.50	3.9	5.16	0.30	4.53	2.9	5.56	0.59
OPM	Operating	13.	5.6	18.0	3.4	12.4	5.5	19.4	3.88	15.3	3.3	24.15	6.51
DED	Deposit	50.	24.	122.	23.	63.7	35.	128.	31.5	75.6	32.	167.6	37.7
CNR	Concentratio	57.	45.	78.7	9.8	48.1	34.	65.9	9.68	44.6	14.	92.86	25.3
AST	Total assets	71.	0.6	461.	90.	119.	0.2	548.	109.	535.	36.	4047.	730.
IAS	Intangible	0.9	0.0	10.8	1.7	1.09	0.0	13.6	1.99	7.75	0.0	81.96	12.9
PLL	Provisions	0.3	–	3.64	0.4	0.49	–	2.30	0.40	0.74	0.1	5.01	0.63
LND	Loans/depos	1.2	0.5	4.25	0.4	0.91	0.6	1.27	0.12	1.14	0.7	1.66	0.22
DEQ	Debt/equity	3.2	0.0	22.1	2.8	2.24	0.0	7.04	1.75	5.11	0.3	18.06	3.91
CSH	Cash and	3.0	0.2	14.2	2.9	0.89	0.0	2.57	0.53	3.72	0.5	29.32	5.21
LAT	Loans/total	70.	24.	95.2	14.	67.9	40.	89.9	14.0	66.0	24.	90.11	11.0
NTM	Net margin	9.6	–	23.7	4.3	8.55	–	20.5	4.58	10.0	–	21.01	7.16
DBC	Long-term	52.	0.0	94.3	22.	26.4	0.0	78.1	12.4	50.3	22.	83.84	12.0
INV	Investments	24.	2.4	224.	32.	39.5	7.5	128.	30.3	38.4	3.5	291.8	43.8

As also shown, the UK has a slightly higher value of *PCI* than the UK and Canada. However, Australia had the strongest annual growth of *PCI* at a growth rate of 2.9%, and we expect this will positively affect bank efficiency throughout the sample period. In addition, Australian banks had the highest value of capital adequacy ratio among the three countries. This could be a reflection of the different prudential regulation regime introduced in 1989 in Australian financial sector. On average, the Australia banking sector was highly concentrated compared with the other two countries, notwithstanding the highest value of *PCI* of the UK banking sector in 2008. In terms of deposit density (*DED*) and average profit margin (*OPM*), on the one hand, UK banks had the highest average values of *DED* and *OPM*, but with a great deal of volatility. In terms of the variances in *DED* and *OPM,* Australian banks experienced the more stable market conditions compared to UK and Canadian banks.

In Table 2, UK banks appear to have taken advantage of the larger values of intangible assets (*IAS*), higher leverage (*DEQ*), and greater net interest margin (*NTM*). The highest value of the ratio of provisions for loan to total loans (*PLL*) can be a reflection of either bad loan quality or the prudential strategy of the banking sector in UK. In comparison, Canadian banks had a low loan to deposit ratio (*LND*), but a moderate level of the ratio of loans to total assets (*LAT*). This indicates that the funding sources of Canadian banks relied relatively more on deposits, which also can be proven by the lowest ratio of long-term debt to total capital (*DBC*). The lowest level of the ratio of cash and dues from banks to total assets (*CSH*) and the highest level of the ratio of investments to loans (*INV*) may positively affect the efficiencies of Canadian banks.

In comparison, Australian banks appear to have adhered to traditional bank services such as loans, as indicated by the high loan-to-deposit ratio (*LND*), the loan-to-asset ratio (*LAT)*, the low investment-to-loan ratio (*INV*) and long term debt-to-capital ratio (*DBC*). In addition, the lowest level of the ratio of provision for loan to loan (*PLL*), the moderate levels of debt-equity ratio (*DEQ*), and the ratio of cash and dues from banks to total assets (*CSH*), gave rise to the prudential control of credit and liquidity risk-taking of Australian banks.

4. Efficiency estimates

Table 3 reports the estimates of the common frontier models. For the most part, the cost efficiency (CE) model appears to provide better fit than the two other models in terms of the significance of individual coefficients. In evidence, of the 22 estimated coefficients in each model, 19 are statistically significant at the 10% level in for the CE model, 17 in the technical efficiency (TE) model, and 12 in the profit efficiency (PE) model. The value of γ, which represents the proportion of the inefficiency component in total noise, is 97.6% for the CE model, 36% in the TE model, and 97.2% in the PE model. Nonetheless, there is substantial consistency between all models with 85% of the estimated coefficients displaying the same sign in the TE and PE models and 80% in the CE model.

Table 3. Estimation results for technical, cost and profit efficiency cross-country models

	Distance production function		Cost function		Alternative profit function	
Dependent variable	Ln(d)		Ln(CST/(PDP × EQC))		Ln(PRF/(PDP× EQC))	
Independent variables	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
CONS.	8.363	8.115***	6.402	6.158***	0.465	0.629
Ln(PHC)	–0.731	–2.788**	–	–	–	–
Ln(PLB)	–		–0.084	–1.747*	0.181	1.047
Ln(DEP)	–0.622	–1.429	–	–	–	–
Ln(PPC)			0.455	2.84**	0.060	0.828
Ln(LOA)	0.877	3.252***	1.901	4.428***	–0.272	–1.835*
Ln(NII)	–1.836	–6.449***	–0.558	–1.976*	–0.272	–1.835*
½Ln(PHC)²	0.010	0.164	–	–	–	–
½Ln(PLB)²	–	–	1.463	5.89***	0.035	1.310
½Ln(DEP)²	–0.031	–0.336	–	–	–	–
½Ln(PPC)²			0.043	1.414	0.047	2.693**
½Ln(PHC)×Ln(DEP)	–0.200	–3.099***	–	–	–	–
½Ln(PLB) ×Ln(PPC)	–	–	–0.062	–1.939*	–0.047	–0.964
½Ln(LOA)²	0.164	3.174***	0.226	2.300**	–0.033	–2.130**
½Ln(NII)²	0.133	14.199***	–0.072	–2.541**	0.003	0.216
½Ln(LOA) ×Ln(NII)	–0.118	–2.599**	0.087	2.399**	–0.129	–3.959***
Ln(PHC) ×Ln(LOA)	–0.060	–1.926*	–	–	–	–
Ln(PHC) ×Ln(NII)	0.055	2.348**	–	–	–	–
Ln(DEP) ×Ln(LOA)	–0.317	–6.416***	–	–	–	–
Ln(DEP) ×Ln(NII)	0.325	8.762***	–	–	–	–

Ln(PLB) ×Ln(LOA)	–	–	–0.269	–4.170***	0.104	5.508***
Ln(PLB) ×Ln(NII)	–	–	0.028	0.600	0.003	0.124
Ln(PPC) ×Ln(LOA)	–	–	–0.015	–0.395	–0.071	–3.362***
Ln(PPC) ×Ln(NII)	–	–	0.063	2.835**	–0.007	–0.556
t	0.182	5.968***	–0.248	–8.284***	–0.033	–1.877*
½t^2	0.002	2.183*	–0.008	–8.777***	–0.001	–1.389
t×Ln(PHC)	–0.002	–0.492	–	–	–	–
t×Ln(PLB)	–	–	0.035	6.982***	0.002	0.680
t×Ln(DEP)	–0.023	–3.176***	–	–	–	–
t×Ln(PPC)	–	–	0.010	2.344**	–0.005	–1.832*
t×Ln(LOA)	–0.002	–1.088	0.015	2.288**	0.015	4.229***
t×Ln(NII)	0.002	0.440	–0.006	–1.192	0.007	0.027
σ^2	0.020	5.030***	0.018	15.360***	0.065	11.386***
γ	0.360	1.862*	0.976	15.350***	0.972	21.440***

Notes: (d) is the input-oriented distance production function. *, ** and *** indicate significance at the .10, .05 and .01 level, respectively.

On average, the time trend, commonly interpreted as the effect of technological change on technical efficiency, it is about 0.46% annually. That is, the common TE frontier across the three countries shifts downwards on average by 0.46%. The shift in the TE frontier for Australian banks is slightly negative at –0.063%. However, since 2004, Australian banks have caught up with the other two countries, and have shown an increasingly positive trend in the TE frontier (see Figure 1). Interestingly, UK banks exhibit a sharp fall in the effect of time trend on the TE frontier during the period of 1992 and 1993. In comparison, Canadian banks had a stable improvement in the effect of time trend on the TE frontier over the period and had the highest average value at 0.8%. Similarly, the effect of time trend on the shifts of total costs and profits of the banks over the sample period were calculated by differentiating cost and profit function with respect to time trend, t.

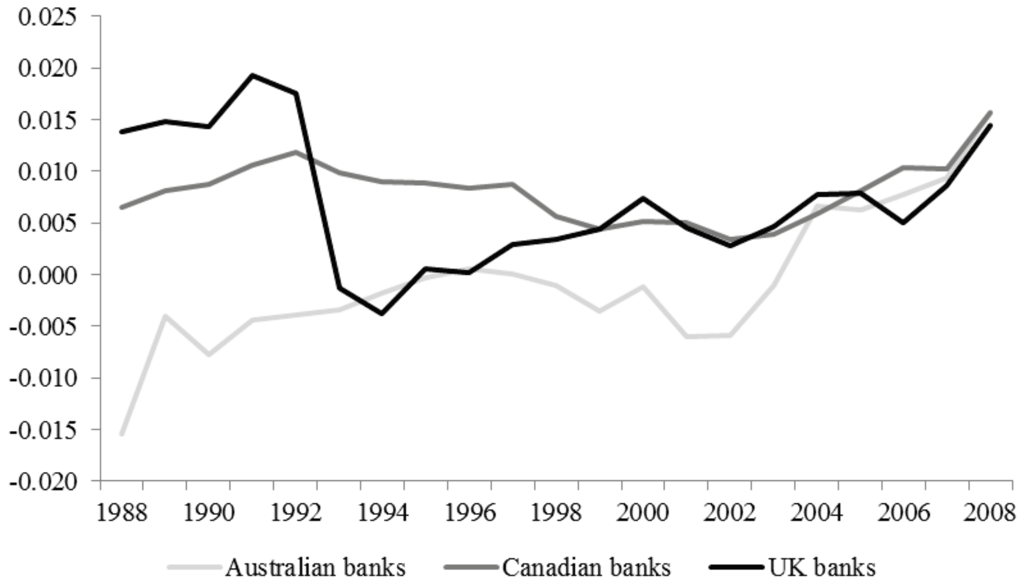

Figure 1. Time effect on technical efficiency frontier

Over the sample period, 1998–2008, the average effects of time on total costs and profits is about 1.75% and 0.03% respectively. Therefore, total costs underwent the largest changes over the period among the three countries, compared to TE and PE. Canadian banks had the largest increase in total costs by a yearly average of 2.97%; UK banks had an increase of 2.31% annually. In comparison, the total costs of Australian banks remained relatively stable over the period with a yearly increase of 0.056%. In combination with the effect of time trend on the TE in Figure 1, it appears that Canadian and UK banks invested more in bank facilities and technology, thus getting more improvements in the TE compared with Australian banks. Consequently, the improvements in profits averaged about 0.325% and 0.148% per year for Canadian and UK banks. Australian banks experienced a slight decline in profits over the period 1988–2008, at an annual average rate of 0.138%. However, the time trend in profits was declining over the period. After 2000, the effect turned out to be negative for all the three countries. We can largely interpret this as the diminishing effect of technology on profits associated with increasingly intense banking competition during this period.

Table 4. Mean efficiency scores for Australian, Canadian and UK banks

	Australian banks			Canadian banks			UK banks		
Year	Technical efficiency	Cost efficiency	Profit efficiency	Technical efficiency	Cost efficiency	Profit efficiency	Technical efficiency	Cost efficiency	Profit efficiency
1988	0.80	0.537	0.973	0.70	0.532	0.974	0.602	0.490	0.95
1989	0.81	0.636	0.952	0.75	0.565	0.902	0.554	0.492	0.78
1990	0.80	0.582	0.924	0.74	0.594	0.942	0.567	0.517	0.86
1991	0.80	0.576	0.920	0.75	0.578	0.945	0.620	0.494	0.85
1992	0.80	0.591	0.800	0.72	0.511	0.872	0.653	0.461	0.84
1993	0.81	0.579	0.923	0.72	0.520	0.922	0.695	0.557	0.94
1994	0.84	0.583	0.967	0.74	0.540	0.954	0.741	0.621	0.98
1995	0.86	0.631	0.959	0.73	0.572	0.955	0.749	0.659	0.97
1996	0.88	0.637	0.959	0.74	0.613	0.961	0.762	0.666	0.98
1997	0.90	0.651	0.946	0.76	0.630	0.966	0.758	0.666	0.97
1998	0.87	0.640	0.947	0.74	0.599	0.942	0.769	0.608	0.96
1999	0.85	0.644	0.962	0.78	0.590	0.937	0.791	0.613	0.96
2000	0.87	0.646	0.961	0.85	0.588	0.938	0.829	0.676	0.95
2001	0.86	0.593	0.961	0.72	0.551	0.918	0.813	0.644	0.94
2002	0.85	0.621	0.966	0.65	0.521	0.855	0.806	0.620	0.97
2003	0.91	0.659	0.966	0.70	0.547	0.950	0.885	0.654	0.97
200	0.98	0.700	0.956	0.78	0.581	0.964	0.907	0.702	0.97
2005	0.98	0.756	0.964	0.81	0.598	0.931	0.879	0.660	0.96
2006	0.98	0.787	0.962	0.83	0.586	0.959	0.864	0.623	0.95
2007	0.98	0.732	0.959	0.87	0.518	0.949	0.871	0.648	0.93
2008	0.99	0.688	0.926	0.98	0.569	0.907	0.773	0.656	0.66
Mean	0.88	0.641	0.945	0.77	0.567	0.935	0.757	0.606	0.92
Mean	0.00	0.008	–	0.01	0.002	–	0.009	0.008	–

Table 4 presents the scores of the technical, cost and profit efficiency of Australian, Canadian, and UK banks over the period 1988–2008. On average, the three countries showed a high level of profit efficiency, a moderate level of technical efficiency, but a low level of the cost efficiency at an average value of 94%, 81.9%, and 61.1% respectively. Thus, the banks of the three countries could have reduced the inputs and costs by 18.1% and 38.9%, and improved their profits by 6%. Specifically, Australian banks turned out to be the best performer in all three efficiencies. Comparatively, Canadian banks had the lowest levels of the CE; UK banks had the worst TE and PE, though the PE score was high at 92.5%. On average, Canadian banks experienced a greater improvement in technical efficiency, with an annual growth rate of 1.4%. Australian and UK banks had a high increase in cost efficiency at the annual growth of 0.8%. All banks of the three countries had relatively stable profit efficiency. The large decline in PE for UK banks was mainly due to two severe episodes of abnormal losses in 1989 and 2008 at –17.2% and –26.9%, respectively.

Canadian and UK banks had a similar level of technical efficiency over the period, which had an average TE score of 77% and 75.7% respectively. The scores fell within the range of TE scores found in recent studies on UK and Canadian banks, although none of them employed the SFA approach. Compared to the studies on the cost and profit efficiency, there are a very limited number of studies using the SFA approach to estimate TE, especially no SFA studies on the TE has been found for UK and Canadian banks. A number of the DEA studies find that the technical efficiency of UK banks ranges from 58.65% to 78.16% (see Casu and Molyneux, 2003; Lozano-Vivas, Pastor, and Pastor, 2002). A study by Asmild et al., (2004) finds that the average TE of Canadian banks are about 68%. To my knowledge, only one study (Koutsomanoli-Filippaki et al.,2009) uses the input-oriented distance function and SFA techniques to estimate TE for the banks of Central and Eastern European (CEE) countries. The average technical efficiency (TE) score of the banks of CEE countries is 36%.

The TE score of Australian banks is slightly higher by 3.7% than the score reported in the study without including environmental factors (forthcoming), where the average technical efficiency score of Australian banks is 84.5%. The comparison between the efficiency scores from an efficiency model with environmental factors included and those from an efficiency model, disregarding the effects of environmental factors, are also presented in the earlier literature. Dietsch and Lozano-Vivas (2000) argue that, if the country-specific variables are important factors in explaining efficiency differences, then the efficiency model neglecting these factors would generate too much inefficiency. They find that the average efficiency scores of Spanish and French banks improved when the environmental factors were included. However, an improvement in efficiency is not assumed to be the only consequence of the incorporation of environmental factors into the efficiency models. Bos and Schmiedel (2007) find a decline in efficiency scores while comparing the scores from a pooled frontier model with those from a Meta frontier model. In this study, cost efficiency scores were also found to decline when the environmental factors are included, which will be further discussed in the next sub-section.

The average CE score of the sample is low at 61.1%. All the banks of the three countries have a large amount of room to improve CE by up to 38.9%. The Canadian banks show the lowest score of CE at 58.6%, and have the lowest rate of increase in CE over the sample period from 1988 to 2008 with an average growth rate of 1.2% per year. The CE score of Canadian banks is lower than that of Allen and Liu (2007). They report an average score of cost inefficiency at 10% using a parametric cost model without environmental factors. In comparison, the average CE of UK banks have a slightly higher score and growth at 60.6% and 0.8% respectively. A number of studies report CE scores for UK banks ranging from 44.3% to 86.3% (e.g., Valverde et al., 2007; Bos and Schmiedel, 2007). Our result is clearly within this range.

Again, Australian banks have the best performance in terms of cost efficiency (CE) with an average CE score of 64.1%. However, this score is lower than that of models without environmental factors (forthcoming) by 27.1%. The difference is statistically significant at the 1% level. This reflects the extent to which the environmental factors determine the CE scores. The impact of environmental factors on CE is much larger than that on TE and PE.

Figure 2. Trends in allocative efficiency

Allocative efficiency (AE) can be derived by dividing CE by TE. The average AE score of the whole sample is 76.1%. Figure 2 gives the trends of allocative efficiency of the banks of the three countries over the sample period from 1988 to 2008. In comparison with Australian banks, UK and Canadian banks have superior AE scores at 80% and 73.6%, respectively. The superior performance in AE of UK banks can be attributed to the advantage of being close to the international finance centre − London. Similarly, the advantage of Canadian banks is that they are geographically close to the United States, which is the largest financial market in the world. Comparatively, Australian banks are geographically isolated from those major financial markets in the world, which may give rise to an inferior performance in AE. This influence is clearly reflected in Figure 2. In 2007, the AE of Canadian banks declined sharply; Australian banks had a slight dent; however, UK banks experienced a jump in AE. This ripple may be due to the international capital market turmoil at the onset of the US Subprime Mortgage Crisis.

In comparison, the average profit efficiency (PE) of the sample banks is high at 94%. In brief, the average PE score is 94.5% for Australian banks, 93.5% for Canadian banks, and 92.5% for UK banks over the sample period 1988–2008. The estimated PE score is higher than that of previous studies (e.g., Pasiouras, et al., 2009). The higher PE score can be attributed to differences in the selection of sample and specification of variables, and the effects of environmental factor. Lozano-Vivas et al. (2001) suggest that use of environmental factors as control variables improves efficiency scores and the less favourable the factors, the greater the improvement in efficiency scores. Although the average PE score of Australian banks increases by 3.4% after controlling for environmental factors, the difference in the means of PE is not statistically significant even at the 10% level (see Table 5).

5. Impact of environmental factors and firm-level efficiency determinants

Table 5 gives the estimates for the effects of the environmental factors. All environmental factors have a significant effect on efficiency except for the concentration ratio (CNR) in the cost and profit functions. As expected, per capita income (PCI) has a significant effect on all of three inefficiencies; that is, technical, cost and profit inefficiencies. Banks in higher per capital income countries can be more efficient due to advantages, such as attracting more deposits and generating stronger cash flows, than banks in low income countries (Grigorian and Manole, 2006). The results are also consistent with the findings of Pasiouras et al. (2009) and Koutsomanoli-Filippaki et al. (2009). In contrast, Dietsch and Lozano-Vivas (2000) argue that the more developed economy may give rise to the higher operating and financial costs of banks, and thus impact on the banks' efficiency. However, the results in this study apparently do not support the negative effects of higher per capita income on efficiency.

Table 5. Estimates for environmental variables

Variables	Definitions	Technical inefficiency effect			Cost inefficiency effect			Profit inefficiency effect		
		Coef.	Std. err	t-statistic	Coef.	Std. err	t-statistic	Coef.	Std. err	t-statistic
PCI	Per capita income	–0.681	0.087	–7.792***	–0.310	0.048	–4.810***	–2.081	0.073	–8.811***
CNR	Concentration ratio	–0.024	0.043	–0.548	–0.032	0.064	–0.812	1.130	0.118	10.687***
DED	Deposit density	0.326	0.053	6.129***	0.181	0.039	3.461***	1.289	0.105	7.825***
CAR	Capital ratio	–0.316	0.038	–8.298***	–0.175	0.052	–3.593***	0.334	0.117	2.815**
OPM	Profit margin	–0.047	0.019	–2.417**	–0.109	0.025	–4.250***	–1.127	0.104	–9.605***

The indicator of regulation, i.e. capital ratio (*CAR*), has a significant positive effect on technical and cost efficiency, but a negative effect on profit efficiency. This means that higher capital requirements can improve on the technical and cost efficiency, but diminish the profit efficiency. The finding is consistent with the notion that a bank with a higher *CAR* can improve its efficiency through being stable. The benefits of stability can result either from being less likely to incur loans losses (Kasman and Yildirim, 2006), or from attracting more deposits (Grigorian and Manole, 2006). The divergent effects of *CAR* on cost and profit efficiency are in line with the findings of Pasiouras et al. (2009) who suggest that, in addition to the benefits of lowering the probability of financial distress and thus reducing risk premiums on otherwise potentially costly risk management activities, higher capital requirements increase the cost of raising bank capital. However, this may be offset by the fact that equity capital does not bear interest payments. The interpretation of the reduction in the profit efficiency is that a well-managed bank with higher *CAR* may substitute loans with other forms of financial assets to meet the requirements of risk-control (VanHoose, 2007). Since the bank would switch less-risky assets, the profit efficiency could then drop (Pasiouras et al., 2009). Thus, banks that show the highest inefficiencies and incur the highest costs might be able to generate greater profits than more cost-efficient banks (Casu and Girardone, 2006).

The four-bank concentration ratio (*CNR*) has a significant negative influence on profit efficiency, suggesting that higher *CNR* reduces profit efficiency. The significant negative effect of *CNR* on the profit efficiency suggests that the higher concentration of banks is associated with the increasing market power, instead of market selection and consolidation through the survival of the most efficient banks (Koutsomanoli-Filippaki et al., 2009). Thus, less concentrated markets are associated with increased profit efficiency (Pasiouras, 2008). In addition, De Nicolo, et al. (2004) find that highly concentrated banking systems exhibited levels of systemic risk potential higher than less concentrated systems during the period from 1993 to 2000, and that this relationship strengthened during the 1997–2003. On the other hand, Koutsomanoli-Filippaki et al. (2009) argue that the markets can remain contestable and competitive in spite of increased concentration, reflecting market selection and consolidation through the survival of the most efficient banks. Moreover, larger banks can benefit from economies of scale and scope, which can exert a positive effect on cost efficiency. However, the positive effect of *CNR* on technical and cost efficiency do not appear to be statistically significant.

The significant and positive effect of average profit margin (OPM) on the technical, cost and profit efficiencies indicates that banks can improve their efficiencies in the more lucrative markets. This is in line with previous studies (e.g., Casu and Molyneux, 2003; Perera et al., 2007). Contrary to a priori expectations, the coefficients of deposit density in three models have a significant positive sign. More deposits per people apparently contribute to an increase in banking costs instead of the expected decrease in cost. One reason can be found in the characteristics of banking competition. More deposit density may imply more intense competition in the markets, because banks need to provide advanced facilities and services in order to attract big customers. On the other hand, the advanced facilities and services may arise from more supplies of deposits. Berger and Mester (2003) suggest that banks try to maximize profits by raising revenues, as well as by reducing costs. Over time, banks could offer a wider variety of financial services and provided additional convenience.

Table 6. Firm-specific variable correlations

	CSH	DBC	DEQ	IAS	LAT	LND	NTM	PLL	INV	AST
CSH	1.000									
DBC	0.112	1.000								
DEQ	–0.098	0.557	1.000							
IAS	–0.280	–0.002	0.120	1.000						
LAT	0.012	–0.077	–0.349	–0.264	1.000					
LND	–0.014	0.552	0.537	0.033	–0.068	1.000				
NTM	–0.065	0.095	0.031	0.172	–0.158	0.093	1.000			
PLL	0.120	–0.025	0.024	–0.005	–0.095	–0.090	–0.441	1.000		
INV	–0.149	0.023	0.392	0.206	–0.750	0.090	0.064	0.027	1.000	
AST	–0.051	0.214	0.451	0.543	–0.574	0.101	0.207	0.261	0.385	1.000

Table 6 demonstrates that the firm-specific variables are not highly correlated. The highest value of correlation coefficient is 0.75 between LAS and INV. Then, two separate models with one of the two variables were run. The results show that either the signs or coefficient values of relevant variables are not significantly affected. Thus, the problem of co linearity can be ruled out in this model. The results of the three Tobit models are presented in Table 7. In total, 23 out of 30 variables are statistically significant at a p-value lower than 10%.

Table 7. Second-stage model estimates

Variables	Definition	Technical efficiency			Cost efficiency			Profit efficiency		
		Coef.	Std. err	Z-statistic	Coef.	Std. err	Z-statistic	Coef.	Std. err	Z-statistic
CONS.	Constant	0.713	0.085	8.361^{***}	0.024	0.091	0.269	0.936	0.047	19.847^{***}
AST	Total assets in logarithms	–0.009	0.003	-2.701^{***}	0.011	0.004	2.889^{***}	–0.007	0.002	-3.865^{***}
IAS	Intangible assets in logarithms	0.006	0.001	7.026^{***}	0.001	0.001	1.564	–0.001	0.000	-2.606^{***}
PLL	Provisions for loan/total loans	–5.991	1.045	-5.732^{***}	–4.361	1.120	-3.895^{***}	–0.863	0.580	–1.488
LND	Loans/deposits	0.044	0.013	3.368^{***}	0.122	0.014	8.626^{***}	–0.003	0.007	–0.359
DEQ	Debt/equity	–0.006	0.002	-3.641^{***}	0.003	0.002	1.440	0.004	0.001	3.852^{***}
CSH	Cash and dues from banks/total	–0.218	0.114	-1.906^{*}	0.033	0.124	0.269	0.000	0.064	–0.002
LAT	Loans/total assets (%)	0.131	0.056	2.322^{**}	0.232	0.060	3.867^{***}	0.080	0.031	2.556
NTM	Net margin	0.193	0.084	2.315^{**}	0.376	0.089	4.217^{***}	1.108	0.046	23.981^{***}
DBC	Long-term debt/total capital	0.221	0.024	9.037^{***}	0.104	0.026	3.968^{***}	–0.039	0.014	-2.872^{***}
INV	Investments/total loans	0.060	0.019	3.091^{***}	0.042	0.021	2.035^{**}	–0.014	0.011	–1.301
	Adjusted R-squared		0.504			0.559			0.763	
	Sum squared residual		1.460			1.648			0.367	
	Log likelihood		478.396			451.690			686.179	
	Sample size		359			356			356	

The relationship between size and efficiency varies across the three efficiency models. In brief, size has a positive effect on cost efficiency, but a negative effect on technical and profit efficiency. The positive effect on cost efficiency and the negative effect on technical efficiency fit well with the results of the Australian SFA models, where the big-four banks show an inferior performance in technical efficiency, but a superior performance in cost efficiency compared with their regional counterparts. Perera et al. (2007) also find a positive influence of size on cost efficiency using a sample of south Asian banks.

They suggest that a larger size allows wider penetration of markets and increase in revenue at a relatively low cost. Kasman and Yildirim (2006), as well as Carvallo and Kasman (2005), suggest that relatively large banks, that is, banks with assets between €4 bn and €$5 bn in European banks amd $5 bn to $10 bn in Latin American banks, are more cost efficient than the banks in other size groups. Their findings are consistent with the results of the Australian SFA models, namely that the large banks could have inferior technical efficiency arising from scale inefficiency, because the large banks operate under a decreasing returns to scale. In this sense, size can exert a negative effect on technical efficiency. In addition, the negative effect on technical efficiency of size can reflect the loss of control resulting from inefficient hierarchical structure in the management of the bank (Margaritis and Psillaki, 2007). The significantly negative effect of size on the profit efficiency shows that the big banks cannot exploit additional profits by relying on their market power, because of intense competition in the markets.

As expected, the significant and positive effect of intangible assets (*IAS*) on technical efficiency demonstrates that banks with substantial intangible investment opportunities may adopt a better technology, be better managed and, thereby, be more efficient (Margaritis and Psillaki, 2007). However, the influence of *IAS* on cost efficiency is not significant. Again, the improvement in technical efficiency cannot be transferred into increased profits. The negative effect of *IAS* on profit efficiency reflects the fact that the investment in potential growth in the future can incur some losses in the profits at present.

The important indicator, financial leverage (*DEQ*) in the agency costs theory, appears to have a non-monotonic effect on efficiencies: *DEQ* is significantly and negatively associated with the technical efficiency, but positively associated with the cost and profit efficiency, although the effect on the cost efficiency is not statistically significant at the 10% level. The negative effect on the technical efficiency of *DEQ* is consistent with the effect of capital adequacy ratio (CAR), which has a positive effect on the technical efficiency. However, this is not aligned with the hypothesis of the agency costs, which implicitly indicates a positive relationship between *DEQ* and efficiency (Margaritis and Psillaki, 2007). As mentioned by Berger and Patti (2006), a relatively high *DEQ* makes bankruptcy or financial distress more likely due to risk shifting or reduced effort to control risk. In addition, the goal of a bank is to maximize profits; thus, the bank can adjust its capital structure by balancing the costs of adjustment with the benefits of operating at or near their leverage level (Barclay and Smith, 2001). The positive effect on the cost and profit efficiency of LE demonstrates the fact that a higher level of *DEQ* can ease the problem of the agency costs and improve the performance of the bank in terms of the cost and profit efficiency.

As expected, the loan-deposit ratio (*LND*) exerts a significant positive effect on the technical and cost efficiency. That is, the ability to convert deposits into loans is in line with improved efficiency level of a bank (see Carvallo and Kasman, 2005; Dietsch and Lozano-Vivas, 2000). No significant relationship is found between *LND* and the profit efficiency. However, the ratio of loans to assets (*LAT*) exhibits a significant and positive influence on all sorts of efficiencies, i.e. technical, cost and profit efficiency. This result is consistent with a number of studies (e.g., Barros, Ferreira and Williams, 2007; Valverde et al., 2007). This indicates that the banks can still rely on lending services to achieve a significant improvement on technical, cost and profit efficiency, despite the fact that loans can be viewed as being costly compared with securities. The ratio of investment to loans (*INV*) gives complementary evidence of the role of loans in a bank's activities. SL is significantly and positively associated with the technical and cost efficiency, but does not have a significant effect on the profit efficiency.

As an indicator of liquidity risk, the ratio of cash and dues from banks to assets (*CSH*) exhibits a negative effect on technical efficiency, because liquid assets may be more costly to handle owing to additional transportation costs, storage and protection costs, and labour costs. However, *CSH* does not have a significant effect on the cost and profit efficiency. The effects on the technical and cost efficiency of the ratio of long-term debt to total capital (*DBC*) are positive, which are aligned with the expected. However, *DBC* has a negative effect on the profit efficiency. The significant negative effect on the technical and cost efficiency of the ratio of loan provision to loan (*PLL*) is consistent with the finding of Berger and DeYoung (1997), suggesting that inefficient banks with higher operating costs will also have more problem loans. And finally, as expected, the ratio of net interest income to total revenues (*NTM*) has a significant and positive effect on technical, cost and profit efficiency, which is consistent with the literature (e.g., Perera et al., 2007; Carvallo and Kasman, 2005).

6. Concluding remarks

By conducting a comparative study of efficiency of Australian, Canadian, and UK banks, this paper has investigated the factors that can affect the technical, cost, and profit efficiency of a bank. The macro factors refer to the environments under which the banks are operating, and which are thus beyond the control of the banks. In contrast, the micro factors are the firm-level factors with which the banks can play to achieve a high level of efficiency and, thus, are the determinants of efficiency.

Australian banks show superior performance in terms of the technical, cost and profit efficiency, compared to the Canadian and UK banks. This good performance can be attributed to a stable growth of per capita income and a relatively high level of the capital adequacy ratio, which may be due to the prudential regulation regime. In comparison, the UK and Canadian banks have a higher allocative efficiency, arising from the vantage locations of the two countries. Consequently, Australian banks demonstrated resilience to external shocks, such as the Asian financial crisis and the GFC, which is aligned with the good performance of the Australian banks, measured by all technical, cost and profit efficiency concepts.

As expected, the significant and positive effects of per capita income (*PCI*) and average profit margin (*OPM*) on all of three efficiencies, that is technical, cost and profit efficiencies indicate that banks can improve their efficiencies in the more lucrative markets. The significant negative effect of the four-bank concentration ratio (*CNR*) on the profit efficiency suggests that a higher concentration of banks is associated with the increasing market power, instead of market selection and consolidation through the survival of the most efficient banks. The significant and positive effect of the capital adequacy ratio (*CAR*) on technical and cost efficiency suggests that this maintains the balance between the objective of promoting financial safety and the need to minimize adverse effects on efficiency and competition. Banks with higher solvency and prudence are less likely to incur loan losses; it is thus less necessary to spend additional expenses to recover these loans. They will therefore appear more efficient. In addition, the imposition of capital adequacy requirements and other prudential constraints on risk-taking appears to strengthen the incentive for efficiency improvements (Koutsomanoli-Filippaki et al., 2009).

All the firm-specific factors are found to have a significant effect on the firm level efficiency. The factors such as intangible assets (IAS), loans to deposits ratio (LND), loans to assets ratio (LAT), net margin (NTM), long-term debts to total capital ratio (DBC), and investments to loans ratio (INV) exert a positive effect on technical efficiency. In contrast, size (AST), provisions for loan to loans ratio (PLL), debts to equity ratio (DEQ), and cash and dues from banks to assets ratio (CSH) are negatively associated with technical efficiency. With respect to the determinants of economic efficiency, all the factors except CSH are the significant influential factors. However, IAS and DEQ have an opposite sign compared to the TE model. In addition, the effects of AST and DBC on cost and profit efficiency are not consistent. They have a positive effect on cost efficiency, but a negative effect on profit efficiency.

From the perspective of a bank manager, there are several ways of tuning up the capital structure and asset structure to boost efficiency within a given operating environment. First, the ratio of debt to equity is found to have a mixed effect on efficiency. A high ratio of debt to equity gives rise to good performance in terms of profit efficiency, but leads to a negative effect on technical efficiency. Therefore, the decision on capital structure largely depends on the goal of the bank management. With respect to the debt structure, long-term debt appears to be positively associated with technical and cost efficiency, but it negatively influences profit efficiency. Risk management is an important factor for bank performance. As discussed above, the capital adequacy ratio as an indicator of the good risk management practices can have diverse effects on efficiency. Another indicator of good risk management practices is the ratio of cash and dues from banks to total assets (*CSH*). A high *CSH* can keep a bank safe from being insolvent, but at the cost of technical efficiency. A high loan-to-deposit ratio helps improve bank efficiency but increases risk exposure. However, a high level of risk-taking can lead to low efficiency, which is reflected by the negative effect of the loan loss provision ratio (*PLL*) on efficiency. Loans are regarded as costly as marketable securities, but they are still an important contributor to an improvement of technical, cost, and profit efficiency.

Two notes need to be taken when interpreting the results from this paper. Firstly, as discussed, the SFA models are based on the distributional assumptions on error terms. In this paper, it is assumed to be a truncated normal distribution. This is an arbitrary judgment. Furthermore, the results may be biased by an unbalanced panel dataset in this paper. Because of these issues, the rankings of bank efficiency rather than actual efficiency scores in this paper are more informative. Secondly, in the second-stage analysis, there are the assumptions that the effects of the factors are time-invarying, and there are no endogeneity issues. Again, the assumptions are a little arbitrary.

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