

## Cost Efficiency of Asian Banks during the Post-Crisis Era: A Comparison of Frontier Techniques

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### บทคัดย่อ

บทความนี้ได้ทำการศึกษาประสิทธิภาพด้านต้นทุนของธนาคารในเอเชีย และความสัมพันธ์ของรูปแบบขององค์กรที่มีต่อประสิทธิภาพด้านต้นทุนของธนาคารในช่วงเวลาภายหลังวิกฤตการณ์ทางการเงิน โดยการได้ทำการศึกษาตั้งแต่ปี พ.ศ. 2540 ถึง 2551 การศึกษาในครั้งนี้ได้ทำการเปรียบเทียบการประมาณค่าประสิทธิภาพด้านต้นทุนของธนาคารโดยใช้เครื่องมือเส้นพรมแดนประสิทธิภาพ 2 ชนิดที่เรียกว่า Data Envelopment Analysis และ Stochastic Frontier Analysis วิธีการศึกษาเริ่มต้นจากการสร้างเส้นพรมแดนประสิทธิภาพด้านต้นทุนของธนาคารใน 5 ประเทศ ตลอดระยะเวลา 12 ปี จากนั้นจึงทำการเปรียบเทียบประสิทธิภาพด้านต้นทุนของธนาคารต่างๆ กับธนาคารที่มีประสิทธิภาพสูงสุด และทำการทดสอบความสัมพันธ์ของประสิทธิภาพกับรูปแบบขององค์กร ผลการศึกษาพบว่าแม้ว่าเครื่องมือทั้งสองชนิดให้ผลการประมาณการประสิทธิภาพแตกต่างกัน แต่ผลจากเครื่องมือทั้งสองให้ความเชื่อมั่นทางสถิติว่า รูปแบบขององค์กรมีความสัมพันธ์ต่อประสิทธิภาพด้านต้นทุนของธนาคารทั้งในด้านบวก



และลบ โดยธนาคารที่ถูกควรรวมมีประสิทธิภาพด้านต้นทุนสูงกว่าธนาคารที่ไม่ได้ควรรวม ในขณะที่ธนาคารที่ถูกควรรวมโดยธนาคารต่างประเทศ และธนาคารที่ถูกรัฐเข้าควบคุม จะมีประสิทธิภาพน้อยกว่าธนาคารที่ไม่ได้ถูกควบคุม นอกจากนี้ผลการวิจัยยังพบความสัมพันธ์ระหว่างเครื่องมือวัดประสิทธิภาพเชิงเส้นพรมแดนกับอัตราส่วนทางการเงินที่ใช้ในการวัดประสิทธิภาพกันโดยทั่วไป

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## Abstract

This paper investigates cost efficiency of Asian banks and its relationship with forms of ownership during 1997 to 2008 using the frontier techniques called Data Envelopment Analysis, and Stochastic Frontier Analysis. A common cost frontier across five countries and twelve years is constructed and measure how a bank performs during the period of study. The results indicate that, overall, changes in ownership do not necessarily lead to more cost efficient banks.

Domestic-merged bank, locally-owned, and non-intervened banks appear to perform better than foreign-owned and state-intervened banks. Although the different frontier approaches provide quantitatively different results, they provide some consistent rankings. Both non-parametric and parametric frontier efficiency scores are statistically associated with traditional non-frontier measures of performance.

**Keywords :** Cost efficiency, Commercial banks, Banking crisis, Merger and acquisition



## 1. Introduction

This paper examines cost efficiency of commercial banks in five Asian countries over the 1997 to 2008 period. This period allows us to analyse effects of post-crisis restructuring on bank cost efficiency following the Asian banking crisis of 1997. Specifically, we attempt to answer the questions, whether: (i) cost efficiencies of banks in 2008 are higher than the efficiencies measured at the start of the crisis in 1997; (ii) different types of bank ownership affect cost efficiency of banks; (iii) different frontier methods provide consistent measures of cost efficiency on Asian banking samples; and (iv) results from the frontier methods are related to traditional non-frontier measures of performance. Bank cost efficiencies are estimated using the non-parametric and parametric frontier techniques, Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), respectively. We focus on bank ownerships related to restructuring measures during the crisis period, namely, domestic mergers, foreign takeover, and state intervention.

In literature, change in bank ownership has been used as a measure during a financial crisis. During the 1997 Asian Financial Crisis, the bank regulators in Asian countries implemented measures to enhance viability of their banking systems. These include encouraging or even forcing troubled banks to merge as a way to reduce failure risk and inefficiency. Full foreign ownership of commercial banks was allowed to attract foreign investors and their technologies to reduce operating costs. Yet, the effectiveness of these policies is hardly

investigated for these Asian countries. Therefore, a significant question raised in this paper is whether changes in bank ownerships as a part of restructuring programs lead to more cost efficient banks as expected by the regulators.

Even though it is tempting to adopt the evidence that previously worked for the western countries as principal guidelines for Asian countries, such an approach is likely to become problematic. Due to the banking industry's distinct local markets (for example, in the U.S.) which are not concentrated (Berger & Humphrey, 1997), such evidence cannot be used as an appropriate benchmark for the expected policy outcomes in Asian countries which have concentrated banking sectors. Also motivations and constraints for mergers and foreign bank entry conditions as evidenced in the literature on the western developed economies are quite different from those in Asian countries (Claessens, Demirguc-Kunt, & Huizinga, 2000). So the results of mergers and foreign bank entries are inevitably diverse. In addition, regulatory environments in the Asian developing countries are different from those in developed countries (Barth, Capiro, & Levine, 2001). These observations provide us with the opportunity to explore such gaps in research.

Another reason for focusing on cost efficiency of Asian banks is because a claimed has been made that bank inefficiency is a cause of banking crisis in 1997. However, efficiency study for the Asian countries is lag far behind those that focus on the U.S. market. In addition, most of the cross-country cost efficiency studies in literature have been

conducted in Europe, and cross-country comparisons of bank efficiency in Asian countries were missing from the comprehensive survey by Berger and Humphrey (1997). Although there have been an increasing number of efficiency studies on Asian banking systems in recent years, most of them are conducted in a single-country setting, where either parametric or non-parametric approaches have been used. Since non-parametric and parametric frontier approaches have advantages as well as disadvantages, it is useful to conduct a comparative cost efficiency study using both approaches to provide evidence on the consistency of the efficiency estimates. Such a study would allow us to measure the valid effects of changes in bank ownership during the crisis period.

To the best of author's knowledge, this paper is the first cross-country efficiency study which applies both parametric and non-parametric approaches to the Asian banking system. Furthermore, consistency among efficiency estimated from the frontier techniques and traditional non-frontier measures of performance can add more confidence to the measured efficiencies that they are accurate indicators of actual accomplishment and not artefacts of the assumptions of different efficiency approaches (Bauer, Berger, Ferrier, & Humphrey, 1998).

The paper is organised as follows. Section 2 provides an overview of bank cost efficiency in Asian countries around the 1997 banking crisis. In section 3, we review changes in bank ownership after the Asian banking crisis. Section 4 discusses

frontier approaches in cost efficiency studies. Section 5 details methodology and data. Section 6 presents an analysis of the results, and section 7 concludes.

## 2. Overview of Bank Cost Efficiency in Asian Countries

Cost efficiency study in recent years has ignored to measure bank cost efficiency around banking crisis although there is a claim that bank inefficiency is a cause of banking crisis in Asian countries. Only a handful of research has focus on Asian banking efficiency during the crisis period. For example, Kwan (2003) investigates the banking industry's per unit operating costs in seven East Asian economies (Hong Kong, Indonesia, Malaysia, Philippines, Singapore, South Korea, and Thailand) using multiple regressions. The author find that prior to the 1997 crisis period, bank operating costs among these Asian countries were declining, indicating that banks, on average, were improving their operating performance over time. Laeven (1999), however, argues in different way. The author suggests that, on average, the enhance in estimated efficiency prior to the East Asian banking crisis in 1997 was due to massive risk-taking rather than a true increase in efficiency. The author also indicates that foreign-owned banks took little risk relative to other banks in the East Asian region, and family-owned banks were among the most risky banks.

Nonetheless, evidence for cost efficiency of banking industries in Indonesia, Malaysia, Philippines, and Thailand prior to the crisis in 1997, reports opposite results from the aforementioned

study. Karim (2001), who uses SFA to assess bank performance, shows that cost inefficiencies in South East Asian banks tend to increase over the year preceding the crisis, and suggests that the problem of bank failures may have been related to inefficiency.

During the post-crisis period, evidence shows that Asian banks were increasing additional costs in dealing with their problem loans while bank outputs were simultaneously declining (Kwan, 2003). Moreover, the proportion of labour costs to total costs is found to decline significantly between 1997 and 1999. The author suggests that banks were adjusting their inputs such as human resources upon falling demand, but were less flexible in reducing physical capital input.

Unfortunately, the aforementioned are based on parametric approaches only, and they do not reveal a clear relationship between banking crisis and bank cost efficiency in Asian countries. In addition, they do not consider the effect of measures implemented during and after the crisis period on bank efficiency. An exception is Thoraneenitiyan and Avkiran (2009), who recently investigated the relationship between bank technical efficiency and bank restructuring for East Asian countries from 1997 to 2001. However, due to the short period in their study implication may be limited. The next section highlights the bank restructuring measures implemented following the 1997 banking crisis.

### 3. Changes in Bank Ownership after the 1997 Asian Banking Crisis

A significant goal of bank restructuring in 1997 was to restore efficient banking services on a sustainable basis (Garcia, 1997). Lingren et al. (1999) provide a comprehensive review of restructuring programs adopted in Asia. However, the focus of this paper is on the forms of ownership and individual bank cost efficiency; therefore, this section discusses only the measures used in bank restructuring that relate to changes in bank ownership.

#### 3.1 Domestic Mergers

Governments in the crisis affected countries intensified their efforts to promote bank mergers as a part of banking sector recovery. Regulators in the crisis affected countries encouraged a large bank to take over a troubled small bank. For instance, Bank Indonesia (BI), the central bank of Indonesia, encouraged distressed banks to merge rather than let them fail (Khambata, 2001). This policy was similar to South Korea where 11 Korean banks were merged after implementation of the amended ‘Act concerning the Structural Improvement of the Financial Industry’ in 1998 (Bank of Korea, 1998). Hawkins and Turner (1999) suggest that domestic mergers and takeovers often constitute the least costly way of restructuring the banking system. Mergers alone can fix isolated problems in small banks. For example, a large well-capitalised bank can readily absorb nonperforming loans of a target

bank and the quality of management can be improved. Berger et al. (1999) insert that mergers may also enhance efficiency if greater diversification improves the risk - return tradeoffs. They suggest that regulators may act to encourage consolidation in periods of financial crisis.

Although merging the insolvent bank with a solvent bank is an option usually implemented in the U.S., this may not be practical in many developing economies (Daniel, 1997). Empirical evidence from bank mergers in Asian countries is inconclusive regarding of improvement of efficiency. Hawkins and Turner (1999) and Shih (2003) point out that it is questionable whether merging two weak banks can create a strong bank. While there may be cost reductions from eliminating overlapping branches, the immediate practical difficulties in merging cultures, linking computer systems, and dismissing excess staff can be formidable. For example, Lin (2002) suggests that bank mergers did not significantly improve cost efficiency of Taiwanese banks. It may therefore be unrealistic to expect mergers to produce the quick cost reductions needed in a crisis. On the other hand, improvement in productivity during the post-merger of Malaysian banks have been documented by Krishnasamy et al. (2004). Also, cost efficiency enhancement has been found in Taiwan (Peng & Wang, 2004).

### 3.2 Foreign Bank Takeovers

Barrier rules have been relaxed and foreign banks have been allowed to increase their presence in most Asian economies after the crisis in 1997.

Majority foreign ownership is permitted in Indonesia, while foreign banks may take a majority stake in domestic banks in Thailand for only up to ten years (Bank of Thailand, 2000). In contrast, a 30 percent ceiling on foreign ownership of banks has been retained in Malaysia, whereas a 60 percent interest in an existing domestic bank has been allowed in the Philippines (Unite & Sullivan, 2003).

During a banking crisis, the difficulty of finding enough large and healthy domestic banks has led governments to invite foreign banks to take over domestic banks. Foreign banks may have faster and cheaper access to international capital markets and liquid funds. Okuda and Rungsomboon (2006) indicate that foreign-owned banks have put emphasis on cutting operating expenses. Meantime, credit extension facilities were moved from branches to head offices. These changes not only have impacted on banks that have taken on foreign partners, but also on the remaining domestic banks. Therefore, to maintain their competitiveness and market shares in the new market environment, domestic banks have introduced new financial products and services with lower costs, concentrating more on consumer and retail markets. Claessens et al.(2001) suggest that increasing foreign ownership in banking system of emerging markets is expected to enhance bank efficiency, productivity and technology due to superior management and technology of the new comers. For example, Leightner and Lovel (1998) insert that foreign banks were more productive than local banks in Thailand, while Kim and Lee (2004) illustrate that foreign bank penetration has increased

competition in the Korea banking system, and then forced local banks to reduce their costs.

### 3.3 State Intervention

Another mechanism for the authorities to support bank restructuring is temporarily taking control of banks in trouble. This regularly involves recapitalisation. Governments can directly improve banks' viability by purchasing new shares or by rolling over long-term debts of the troubled banks (Daniel, 1997). Under Indonesia's joint recapitalisation program, owners had to provide 20 percent of the capital shortfall, and the remaining 80 percent was provided by the government (Fane & McLeod, 2002). Korean government purchased nonperforming loans, subordinated debt, or subscribed new capital, to assist private banks' recapitalisation efforts (Jeon & Miller, 2004).

During the crisis, state banks appear to be relatively safer, making them more attractive to depositors and borrowers in a risky environment (Isik & Hassan, 2003). Hence, their funding costs are lower than that of private banks, which are riskier from the investors' perspective. In addition, superior information on state-owned banks may lead to loans to specific projects which are guaranteed by government. Thus, the production of bank loans and other bank services during a crisis will cost public banks less than it would private banks.

Nevertheless, state-owned banks' operations may be inefficient by its nature. Although they are typically backed by the full resources of the government, politically motivated loans may cause

problems. In some cases, supervisory standards have been less stringent for state-owned banks (Hawkins & Turner, 1999). Most research in literature suggest that large concentrations of state bank ownership have some unfavourable economic consequences, such as reduced overall access to financing, or diminished financial system development (see, for example, Clarke & Cull, 2002; La Porta, Lopez-de-Silanes, & Shleifer, 2002).

## 4. Comparing Frontier Approaches in Cost Efficiency Studies

Generally, bank efficiency is usually measured by fundamental analysis, which primarily relies on examining its financial statements. However, a major problem when a bank's efficiency is assessed by using the financial statements is that the bank is essentially isolated from its industry group and the market as a whole. Any follow up comparison of a company's ratios against similar firms or industry averages evidently fails to capture the benefits of a simultaneous multi-dimensional benchmarking relative to its peers (Avkiran & Morita, 2008). Thus, given that no bank operates in isolation, ratio analysis is an improvised evaluation of a bank's performance. DeYong (1997) also suggests that comparing the financial ratios of different banks is not appropriate unless the banks are nearly identical in terms of product mix, bank size, market conditions, and other characteristics that can affect the costs of the banks. Frontier efficiency measures, on the other hand, use programming or statistical techniques to try to remove the effects of differences

in input prices and other exogenous market factors affecting the standard performance ratios in order to obtain better estimates of the underlying performance of the managers.

In addition, frontier efficiency has been used extensively in regulatory analysis to measure the effects of mergers and acquisitions, capital regulations, deregulation of deposit rates, on financial institution performance (Bauer et al., 1998). The key advantage of frontier efficiency over other indicators of performance is that it is an objectively determined quantitative measure that removes the effects of market prices and other exogenous factors that influence observed performance. This allows the researcher to focus on the quantitative effects on costs, input use.

In frontier efficiency literature, various types of parametric and non-parametric frontier approaches have been used to analyse bank cost performance. Certainly, both approaches have advantages as well as disadvantages over each other. Although the parametric approaches are more common and have the advantage of separating noise from inefficiencies, they have a major drawback in requiring an explicit functional form for the technology and specific distributional assumptions for the error term. Since the true production technologies are essentially unknown, the problem of model specification might cause confusion in isolating the inefficiency. On the other hand, non-parametric approaches do not require a specific functional form for the cost function, but they have a major disadvantage in that they do not capture random errors, in which

case the inefficiency estimated might be overstated.

Bauer et al. (1998) suggest that to make informed policy decisions regarding financial institutions, regulators need to have fairly accurate information about the likely effects of their decisions on the performance of the institutions they regulate. They specify a set of six consistency conditions that frontier efficiency approaches to measuring the performance of financial institutions. These include the efficiency estimates derived from the different approaches should be consistent in their efficiency levels, rankings, and identification of best and worst firms, consistent over time and with competitive conditions in the market, and consistent with standard non-frontier measures of performance. To date, however, studies that use non-parametric and parametric approaches to check for the robustness of cost efficiency estimates are dominated by those conducted in the U.S. and European settings.

The decisive work was authored by Ferrier and Lovell (1990), who apply SFA and DEA on the U.S. banks to estimate cost efficiency. Although the same conclusions on average cost efficiency have been drawn by both techniques, different conclusions on decomposition of cost inefficiencies into technical and allocative inefficiencies have been reported. Furthermore, the rank-order correlation is particularly weak between SFA and DEA.

Bauer et al. (1998) apply three parametric approaches and a non-parametric approach to



U.S. bank data to estimate cost efficiency, and then compare the results on the basis of several consistency conditions. Distributional characteristics of the efficiency scores are quite similar across parametric approaches with comparable values for means and standard deviations, whereas the distribution of DEA scores has a lower mean and a larger standard deviation. It is found that the rank-order correlation is high and positive across parametric approaches, but negative between DEA and parametric approaches. Moreover, the identification of best and worst banks leads again to very weak correspondence between DEA and parametric approaches. Finally, they show that parametric approaches provide efficiency measures that are consistent with traditional measures of performance such as financial ratios, while DEA does not.

However, some evidence comparing parametric and non-parametric approaches on European banking data suggest different results regarding the consistency of frontier measures. Drake and Weyman-Jones (1996) apply SFA and DEA to estimate cost efficiency of British building societies. They observe different mean efficiency scores, but nonetheless a very high positive rank correlation. Consistency of efficiency scores between DEA and SFA have also been found for Italian banks (Resti, 1997), but not for the Swiss banking system (Sheldon, 1994). Weill (2004) indicates that the frontier techniques do not provide comparable average efficiency scores in all five European countries. However, the efficiency scores

are positively correlated between parametric approaches for all countries, while there is no positive relationship between any parametric and non-parametric approaches.

In summary, there is a consensus regarding the robustness of scores provided by parametric approaches, but disagreement on the differences between mean efficiency scores provided by parametric and non-parametric approaches. Furthermore, in contrast to the U.S. evidence, European evidence shows a positive rank correlation between SFA and DEA rankings. An equally interesting point here is that these conclusions are drawn from the studies based on the industrialised countries which have unique market structures, and none of the above-mentioned studies were undertaken during a crisis period which might further confound such insight.

## 5. Methodology and Data

### 5.1 A Non-Parametric Approach: Data Envelopment Analysis

The linear programming technique Data Envelopment Analysis (DEA) introduced by Charnes et al. (1978) is used to construct a set of best-practice or frontier observations. The DEA frontier represents the set of efficient observations for which no other decision making unit (DMU) or linear combination of units has as much or more of every output or as little or less of every input. DEA does not require the explicit specification of the form of the underlying production relationship.

To estimate cost efficiency for each bank, we first construct an efficient frontier by solving the following linear program:

$$\min_{\lambda, x_i} \hat{w}'_i x_i^* \tag{Equation 1}$$

subject to

$$y_i + Y\lambda \geq 0, x_i^* - X\lambda \geq 0, \mathbf{1}'\lambda = 1, \lambda \geq 0,$$

where  $x_i$  is an input vector used by bank  $i$ ,  $w_i$  is a vector of unit cost of the input for bank  $i$ , and  $w_i^*$  is the calculated cost-minimising vector of input quantities for bank  $i$ , given cost of input  $w_i$  and output quantities  $y_i$ . The term  $X = [x_1, \dots, x_I]$  is an  $N \times I$  matrix of input vectors,  $Y = [y_1, \dots, y_I]$  is an  $M \times I$  matrix of output vectors, and  $\lambda = [\lambda_1, \dots, \lambda_I]$  is an  $I \times 1$  vector of peer weights. The convexity constraint for the variable returns to scale assumption (VRS),  $\mathbf{1} = [1, \dots, 1]$  is an  $I \times 1$  vector. The variable returns to scale assumption is preferred because the imperfect operating environments in Asian countries may cause a bank not to operate at an optimal scale; hence assuming constant returns to scale (CRS) or optimal scale may provide inaccurate inferences.

Once the linear program is solved, the individual cost efficiency scores are given as the ratio of minimum input cost observed in the sample ( $\hat{w}'_i x_i^*$ ) to the input cost of the evaluated bank ( $\hat{w}'_i x_i^0$ ).

$$CE_{VRS_i} = \frac{\hat{w}'_i x_i^*}{\hat{w}'_i x_i^0} \tag{Equation 2}$$

By definition, the cost efficiency ratio lies between 0 and 1, with the most efficient bank receiving a score of 1. For example, a bank with an efficiency score of 1 means that the estimated cost for the bank ( $\hat{w}'_i x_i^0$ ) is equal to the minimum cost observed in the sample ( $\hat{w}'_i x_i^*$ ). However, if a bank has an efficiency score of 0.9, it means that the bank is 90% efficient relative to the best practice banks. In other words, the evaluated bank utilise input cost greater than the minimum point.

### 5.2 A Parametric Approach: Stochastic Frontier Analysis

In the second part of our analysis, cost inefficiency is estimated using the Stochastic Frontier Analysis (SFA) developed by Aigner et al. (1977). An advantage of SFA is that it can capture inefficiency by separating it from statistical noise, such as measurement error. The current study estimates a panel cross-border efficient frontier across five countries during the twelve-year period from 1997 to 2008. The SFA cost function can be written as:

$$C_i = f(w_i, y_i) + \varepsilon_i, \text{ and } \varepsilon_i = u_i + v_i \tag{Equation 3}$$

where  $C_i$  is the observed cost of production for bank  $i$ ,  $f$  is a suitable functional form,  $w_i$  is the vector of input market prices,  $y_i$  is the vector of output levels for bank  $i$ , and  $\varepsilon_i$  is composite error term. The term  $u_i$  represents managerial inefficiency, and  $v_i$  represents random error such as statistical noise, that may temporarily give banks high or low costs.

The often used standard translog specification is specified in the current study. It has advantages over the Cobb-Douglas functional form of being a flexible form (Kumbhakar & Lovell, 2000). Although there is evidence that the Fourier flexible form is more flexible than the translog (see Mitchell & Onvural, 1996), it is unsuitable for this study

due to the sample size issue. Also, Berger and Mester (1997) found that the translog and the Fourier flexible form yield a small difference in average efficiencies, and very little difference in efficiency dispersion or rank of the individual banks. Therefore, the following translog stochastic cost frontier is constructed:

$$\begin{aligned} \ln C_{ijt} &= \alpha_0 + \sum_m^n \alpha_m \ln y_{m,ijt} + \sum_s^t \beta_s \ln w_{s,ijt} + \tau_1 T \\ &+ \frac{I}{2} \left[ \sum_m^n \sum_n^m \alpha_{m,n} \ln y_{m,ijt} \ln y_{n,ijt} + \sum_s^t \sum_t^s \beta_{s,t} \ln w_{s,ijt} \ln w_{t,ijt} + \tau_{11} T^2 \right] \\ &+ \sum_m^n \sum_s^t \phi_{m,s} \ln y_{m,ijt} \ln w_{s,ijt} + \varepsilon_{ijt} \end{aligned} \tag{Equation 4}$$

subject to:

$$\alpha_{m,n} = \alpha_{n,m}; \beta_{s,t} = \beta_{t,s}; \sum_s^t \beta_s = 1; \text{ and } \sum_s^t \beta_{s,t} = \sum_t^s \beta_{t,s} = \sum_m^n \phi_{m,s} = 0$$

where  $\ln C_{ijt}$  is natural log of observed total costs of bank  $i$  in country  $j$  in period  $t$ ,  $\ln w_s$  and  $\ln w_t$  are natural log of  $s$ th and  $t$ th input prices, and  $\ln y_m$  and  $\ln y_n$  are natural log of  $m$ th and  $n$ th output quantities. The term  $T$  is a time-trend variable representing technical change. We initially include cross products of time trend and other variables. However the parameters are insignificant; and hence are omitted to preserve degrees of freedom. The terms  $\alpha$ ,  $\beta$ ,  $\tau$ , and  $\phi$  are the unknown parameters, which can be estimated using the maximum likelihood method (Olson, Schmidt, & Waldman, 1980), and  $\varepsilon_{ijt}$  is composite error term which comprises managerial inefficiency ( $u_{ijt}$ ), and random error ( $v_{ijt}$ ). Linear homogeneity in input price is

imposed by normalising the total costs and other variables by the price of physical capital ( $w_3$ ) before taking logarithms (Berger & Mester, 1997). In addition, various restrictions are applied to the parameters of the cost function in Equation 4. This is because the duality theorem requires that the cost function is linearly homogeneous in input prices and that the second-order parameters are symmetric.

After the cost frontier is constructed, the estimation of cost efficiency for each bank in the sample is determined. The Jondrow et al. (1982) method is applied to obtain  $u_{ijt}$ , managerial inefficiency for bank  $i$  in country  $j$  at time  $t$ . Jondrow et al. (1982) shows that the bank-level measures of inefficiency are given by the mean and mode of

the conditional distribution of inefficiency term ( $u_{ijt}$ ) given the composite error term ( $\varepsilon_{ijt}$ ). Therefore, the bank managerial inefficiency can be derived from:

$$E(u_{ijt} | \varepsilon_{ijt}) = \frac{\sigma\lambda}{(1+\lambda^2)} \left[ \frac{\phi(\varepsilon_{ijt}\lambda/\sigma)}{1-\Phi(\varepsilon_{ijt}\lambda/\sigma)} - \frac{\varepsilon_{ijt}\lambda}{\sigma} \right], \tag{Equation 5}$$

where,  $\lambda = \sigma_u / \sigma_v$ ,  $\Phi$  is the standard normal density function and  $\phi$  is the standard normal cumulative distribution function.  $E(u_{ijt} | \varepsilon_{ijt})$  is an unbiased, but inconsistent estimator of  $u_{ijt}$ , an estimate of inefficiency for each bank in the sample (Greene, 1993, pp. 80-82).

Then, cost efficiency (CE) of bank  $i$  is defined as the ratio between the estimated minimum costs ( $\hat{C}_{min}$ ), given by a bank on the frontier, and the estimated costs incurred by bank  $i$  in country  $j$  at time  $t$  ( $\hat{C}_{ijt}$ ), given the same exogenous variables ( $w, y$ ).

$$CE_{ijt} = \frac{\hat{C}_{min}}{\hat{C}_{ijt}} = \frac{\exp[\hat{f}(w_i, y_i)] \times \exp[\ln \hat{u}_{min}]}{\exp[\hat{f}(w_i, y_i)] \times \exp[\ln \hat{u}_{ijt}]} = \frac{\hat{u}_{min}}{\hat{u}_{ijt}}, \tag{Equation 6}$$

where  $\hat{u}_{min}$  is the estimated minimum value of managerial inefficiency for all banks in the sample,  $\hat{u}_{ijt}$  is the estimated managerial inefficiency for bank  $i$  in country  $j$  at time  $t$ . By definition, the cost efficiency ratio ranges between 0 and 1, with the most efficient bank receiving a score of 1. For example, a bank with an efficiency score of 0.80 means that the bank is 80% efficient relative to the best practice banks.

### 5.3 Determinants of cost inefficiency

To test research hypotheses, banks in the

sample are categorised into two main groups: (1) a group of banks without change in the form of ownership, which is the control group; and (2) a group of banks implementing restructuring measures and change the form of ownership, which is the treatment group. Further, Figure 1 also shows that the second group is categorised into three sub-groups according to the form of ownership undertaken. This includes banks subjected to mergers, foreign takeovers, and state intervention between 1997 and 2008. It should be noted that the members in each groups are vary across time.

**Figure 1 Category of Banks for the Entire Sample**

<b>Control Group</b> Domestic private banks without merger, foreign takeover and state intervention	<b>Treatment Group (1)</b> Domestic merged banks
<b>Treatment Group (2)</b> Foreign takeover banks	<b>Treatment Group (3)</b> Domestic banks under state intervention

In order to investigate the relationship between cost efficiency and forms of bank ownership stated in section 3, the DEA *cost inefficiency*<sup>1</sup> is regressed

on sets of factors detailed in Table 1 using Tobit regression.

**Table 1 Description of environmental variables**

<i>Variables</i>	<i>Description</i>
<i>Bank Ownerships</i>	
<i>MER</i>	a dummy variable which equals 1 for a bank that underwent a domestic merger.
<i>FOR</i>	a dummy variable which equals 1 for a bank subjected to a foreign takeover.
<i>SI</i>	a dummy variable which equals 1 for a bank subjected to a government intervention.
<i>Country-Specific Variables</i>	
<i>MC</i>	market concentration, which is the proportion of sum of three largest bank's assets to total bank industry assets
<i>INT</i>	inter-bank interest rates at the end of each year
<i>IR</i>	intermediation ratio of the banking sector, measured as the ratio of loans to deposits
<i>PGDP</i>	per capita GDP (gross domestic product), defined as the ratio of nominal GDP to population as a proxy for level of overall economic development
<i>Individual Bank Control Variable</i>	
<i>SIZE</i>	natural logarithm of total assets, a control variable for bank size

<sup>1</sup> For reporting and comparison purposes, the initial DEA efficiency scores are transformed to inefficiency index (*1-DEA efficiency scores*).

The four country-specific variables are adapted from Thoraneenitiyan and Avkiran (2009) which suggest that macro-economic factors have a significant impact of bank efficiency during the post-crisis period. The bank market concentration index (*MC*), defined as the proportion of the three largest banks to total banking system assets (Beck, Demircuc-Kunt, & Levine, 2006), measures the market power utilised by large banks in that sector. Dietsch and Lozano-Vivas (Dietsch & Lozano-Vivas, 2000) suggest that a higher concentration may be associated with either higher or lower costs. Rising interest rates (*INT*) may increase interest costs of banks and also tend to adversely affect the risk management and credit screening through higher risk (Fries & Taci, 2005). Intermediation ratio (*IR*), which is represented by a proportion of total loans to total deposits of banking sector, reflects differences among the banking sectors in terms of the extent to which they convert deposits into loans. A higher intermediation ratio reflects greater efficiency in financial service provision (Carvalho & Kasman, 2005); therefore, a negative relationship with bank inefficiency is anticipated. Per capita GDP (*PGDP*) serves as a proxy for the overall level of economic development, particularly in comparison to other nations. Countries with a higher per capita GDP have a banking system that operates in a mature environment resulting in more competitive interest rates and lower profit margins (Dietsch & Lozano-Vivas, 2000).

For SFA analysis, the so-called one-step procedure of Battese and Coelli (1995) is applied, where bank inefficiencies are estimated from the

functional form and regressed against a vector of predictor variables. In particular, the estimation procedure allows for bank inefficiencies to have a truncated-normal distribution that is independently but not identically distributed over different banks. The inefficiency of bank *i* ( $u_i$ ) is assumed to be a function of a set of explanatory variables ( $Z_i$ ), which are shown in Table 1, and a vector of coefficients to be estimated ( $\partial$ ).

$$u_i = z_i \partial + w_i \quad \text{Equation 7}$$

#### 5.4 Data

The study sample comprises banks from five countries heavily hit by the 1997 banking crisis and implemented bank restructuring programs (Indonesia, Malaysia, Philippines, South Korea, and Thailand). Our final sample consists of 110 banks and 1,320 observations across 1997 to 2008 for empirical analysis. The average percentages of sample coverage by assets vary between 74.8 and 90.2 in the selected Asian countries.

Unconsolidated annual financial data of commercial banks are mainly obtained from the BankScope database. The use of unconsolidated data allows us to focus specifically on banking operations. Additional data are obtained from the official publications of bank's regulators, the International Financial Statistics (IFS), and World Bank. To ensure that data across countries are comparable, values in local currencies are converted into U.S. dollars by BankScope.

Three inputs and four outputs are specified in the cost efficiency models. All variables are

measured in millions of U.S. dollars. Assuming that the main role of a bank is to mobilise funds between depositors and borrowers at the lowest cost: deposits, labour capital, and physical capital are employed as the input variables. These variables have been widely used in the bank efficiency literature (Casu, Girardone, & Molyneux, 2004; Gilbert & Wilson, 1998; Hasan & Marton, 2003; Isik & Hassan, 2002; Karim, 2001; Williams & Nguyen, 2005).

Banks are regarded as intermediaries in raising funds in the form of deposits and purchased funds. The amount of deposits ( $x_1$ ), defined as the sum of demand deposits, saving deposits, and time deposits, is proposed as the first input in the analysis. The second input, labour capital ( $x_2$ ), is measured by the value of personnel expenses as a proxy for the numbers of full-time equivalent staff. Full-time equivalent staff is commonly used in bank studies implementing the intermediation approach and address the different mix of full-time and part-time staff. However, they are not available for all the banks in the sample; therefore the labour capital is the best available input in this study. Finally, operating expense ( $x_3$ ) is the third input, as a proxy for physical capital.

Cost of deposits is computed by dividing interest expenses by the total amount of deposits ( $w_1$ ). As data on the numbers of employees or branches are not available, the labour price ( $w_2$ ) is obtained by dividing personnel expenses by the total assets as the best available proxy measure, following Hasan and Marton (2003), and Dietsch

and Weill (2000). The price of physical capital ( $w_3$ ) is obtained by dividing operating expenses net of personnel expenses by fixed assets net of depreciations. Finally, total costs are calculated as the sum of interest expenses, personnel expenses and other operating expenses.

Four bank outputs capture both traditional bank lending activity and non-traditional bank activity: customer loans ( $y_1$ ), investment and other earning assets ( $y_2$ ), fee income ( $y_3$ ), and off-balance sheet items ( $y_4$ ). To compare all banks on the same level playing field in terms of loan quality, total amount of loans is adjusted for nonperforming loans (Grigorian & Manole, 2002; Havrylchyk, 2006). While investments and other earning assets (such as treasury bills, government bonds, and other securities) measure the performance of bank portfolio management, non-interest income or fee income captures the extent of bank services.

Contingent liabilities in off-balance sheet items, such as guarantees, acceptances, and letters of credit, are specified in the fourth output in the analysis. These items are measured at face value, as risk weighted values were incomplete for the sample period. As suggested in the literature, non-traditional bank functions such as off-balance sheet activities are becoming more important (Casu et al., 2004; Isik & Hassan, 2003; Lozano-Vivas, Pastor, & Pastor, 2002). Therefore, exclusion of these items might bias the performance measurement of banks (Berger & Mester, 1997; Jagtiani & Khanthavit, 1996).

The input and output variables are first screened for missing data, normality, and univariate outliers, before the non-parametric frontier analysis is conducted.

## 6. Analysis of results

### 6.1 The cost efficiency scores estimated against a *Non-parametric frontier*

Single efficient frontier comprised of 1,320 observations across twelve years and five countries, referred to as an ‘intertemporal production set’ by Tullkens and Eeckaut (1995). We believe that during the post crisis period the bank technology in the sample countries were similar. For example, after 1997, commercial banks in Thailand, and Malaysia, as well as South Korea were pushed to expand their electronic banking services, instead of relying on branch-based services (Bank Negara Malaysia, 2001; Bank of Thailand, 2000). Therefore, the use of a common frontier is appropriate and enables an efficiency comparison across five countries. Importantly, to compare bank efficiency scores over time, the choice is limited to measuring efficiency relative to a common frontier; otherwise it would be inappropriate to compare efficiency estimates from separate annual frontiers because groups have their own benchmarks in each year (Dietsch & Lozano-Vivas, 2000).

The summary results of cost efficiency for the sample can be found in Table 2. The sample average cost efficiency score of 77.96% in the year

1997 decreases to 60.53% in 1998, and then, starts to rebound to 69.93% and 74.40% in 1999 and 2000, respectively. However, the mean cost efficiency declines again in 2001 and moves sideways until 2004 where an upward trend starts. The figures in Table 2 reveal that the mean efficiency score in 2008, when the effects of changes in bank structure have flowed through the system, is slightly greater than that in 1997 when the crisis emerged.

### 6.2 Parametric results

For brevity the maximum likelihood estimates of the translog cost function are not reported here but are available upon request. The likelihood-ratio test indicates presence of bank inefficiency related deviations from the estimated cost frontier. The estimated coefficients suggest that most of the outputs and input price variables are positively correlated with total costs. The positive coefficient of time trend variable also suggests that bank total costs appear to be increasing over time.

Instead of replicate a table, the result from SFA estimate is shown in comparison mode in Figure 2. The arithmetic mean efficiency scores from the DEA and SFA cost efficiency models shown in the figure suggest that SFA estimates are higher than DEA estimates. An interesting point here is that although the level of efficiency is different, the movement of mean efficiency estimates in SFA and DEA appear to be similar. Bauer et al. (1998) explain that the low efficiency scores estimated by DEA may reflect the confounding effect



**Table 2 Mean DEA cost efficiency categorised by country and year**

	<b>Indonesia</b>	<b>Malaysia</b>	<b>Philippines</b>	<b>South Korea</b>	<b>Thailand</b>	<b>Sample Average</b>
<b>1997</b>	0.7842 (0.1678)	0.8250 (0.0709)	0.8135 (0.0808)	0.7203 (0.1397)	0.7550 (0.1171)	<b>0.7796</b> (0.1153)
<b>1998</b>	0.4543 (0.0671)	0.7529 (0.0195)	0.6398 (0.0878)	0.5971 (0.1702)	0.5822 (0.1580)	<b>0.6053</b> (0.1005)
<b>1999</b>	0.6411 (0.2295)	0.8113 (0.0558)	0.7471 (0.1066)	0.6049 (0.1177)	0.6922 (0.1382)	<b>0.6993</b> (0.1296)
<b>2000</b>	0.7389 (0.0465)	0.8109 (0.0127)	0.7538 (0.0289)	0.6740 (0.0353)	0.7424 (0.0179)	<b>0.7440</b> (0.0283)
<b>2001</b>	0.6522 (0.1511)	0.8070 (0.1024)	0.6778 (0.0832)	0.7747 (0.0890)	0.7146 (0.0878)	<b>0.7252</b> (0.1027)
<b>2002</b>	0.8067 (0.1678)	0.6630 (0.0709)	0.6972 (0.0808)	0.9063 (0.1397)	0.6749 (0.1171)	<b>0.7496</b> (0.1153)
<b>2003</b>	0.7258 (0.1654)	0.7335 (0.0170)	0.8365 (0.0671)	0.7822 (0.1204)	0.7090 (0.1756)	<b>0.7574</b> (0.1091)
<b>2004</b>	0.7327 (0.1161)	0.8346 (0.0232)	0.8053 (0.1146)	0.7437 (0.1735)	0.7534 (0.1291)	<b>0.7739</b> (0.1113)
<b>2005</b>	0.7749 (0.1654)	0.8501 (0.0170)	0.8150 (0.1110)	0.7538 (0.1204)	0.7231 (0.1756)	<b>0.7834</b> (0.1179)
<b>2006</b>	0.8172 (0.0671)	0.8514 (0.0195)	0.8326 (0.0878)	0.7447 (0.1702)	0.7404 (0.1580)	<b>0.7973</b> (0.1005)
<b>2007</b>	0.7951 (0.0765)	0.8463 (0.0217)	0.8014 (0.1090)	0.7917 (0.0936)	0.7196 (0.0234)	<b>0.7908</b> (0.0648)
<b>2008</b>	0.8024 (0.1325)	0.8574 (0.0845)	0.7960 (0.0736)	0.7861 (0.1696)	0.8385 (0.1344)	<b>0.8161</b> (0.1189)
<b>Period Average</b>	0.7271 (0.1294)	0.8036 (0.0429)	0.7680 (0.0859)	0.7400 (0.1283)	0.7204 (0.1194)	<b>0.7518</b> (0.1012)

**Figure 2 Mean efficiency scores estimated from DEA and SFA**



of random error that cannot be captured by the DEA model.

Recalling our first research question, it postulates that cost efficiencies of banks in 2008 are higher than the efficiencies measured at the start of the crisis in 1997. The *t*-test, the Wilcoxon, and the Kruskal-Wallis tests are used to test the null that the mean and median of cost efficiency scores in 2008 are higher than that of 1997. Table 3 reports summaries of these significance tests on the proposition. The results for the sample average cost efficiency from DEA indicate that there is no evidence to suggest that the mean cost efficiency

scores in 2008 is higher than that of 1997 (*t*-statistic = 0.67, *p*-value = 0.2515).<sup>2</sup> In addition, the results for cost efficiency from SFA suggest that the mean cost efficiency score of 85.13% in 2008 is not statistically different from that of 82.06% in 1997 (*t*-statistic 0.91, *p*-value = 0.3636). The Wilcoxon and the Kruskal-Wallis tests also support these findings. Hence, the results do not support our first proposition as there is no evidence indicating that bank cost efficiencies in 2008 are statistically higher than the efficiencies measured at the start of the crisis in 1997.

<sup>2</sup> Since a sign of a coefficient is posited a priori, one-tailed test is used throughout the thesis, unless specified.

**Table 3 Summary of parametric and non-parametric tests on the proposition**

		<i>t</i> -test	Wilcoxon Rank-Sum test	Kruskal-Wallis test
<b>Proposition 1 (Efficiency<sub>2008</sub> &gt; Efficiency<sub>1997</sub>)</b>				
Indonesia	$CE_{DEA}$	1.96(0.0536)*	1.34(0.1801)	1.81(0.1783)
	$CE_{SFA}$	1.68(0.0964)*	1.61(0.1069)	2.61(0.1057)
Malaysia	$CE_{DEA}$	2.60(0.0125)**	2.45(0.0143)**	6.05(0.0138)**
	$CE_{SFA}$	2.54(0.0130)**	1.80(0.0713)*	3.29(0.0696)*
Philippines	$CE_{DEA}$	-0.95(0.3487)	-0.99(0.3209)	1.01(0.3138)
	$CE_{SFA}$	1.49(0.1431)	1.40(0.1611)	2.00(0.1568)
South Korea	$CE_{DEA}$	0.51(0.6114)	0.41(0.6783)	0.19(0.6632)
	$CE_{SFA}$	0.28(0.7762)	0.08(0.9355)	0.01(0.9169)
Thailand	$CE_{DEA}$	0.75(0.4586)	0.73(0.4623)	0.57(0.4509)
	$CE_{SFA}$	-0.95(0.3507)	-0.99(0.3177)	1.03(0.3087)
<b>Sample Average</b>	$CE_{DEA}$	<b>0.67(0.2515)</b>	<b>0.21(0.7347)</b>	<b>0.04(0.8339)</b>
	$CE_{SFA}$	<b>0.91(0.3636)</b>	<b>0.89(0.3687)</b>	<b>0.81(0.3681)</b>

$CE_{DEA}$  = cost efficiency estimated from DEA;  $CE_{SFA}$  = cost efficiency estimated from SFA; The *t*-test is a parametric test that tests the null hypothesis, that cost efficiency in different years has the same mean; the Wilcoxon Rank-Sum, and the Kruskal-Wallis are non-parametric tests that test the shift in the location of the distribution; P-values are given in parenthesis; \*, and \*\* indicate 10%, and 5% one-tailed significance levels, respectively.

### 6.3 Determinants of cost inefficiency

The coefficients reported in Table 4 provide an answer for our proposition 2. They indicate that domestic mergers (*MER*) appear to have a negative relationship with bank inefficiency. In other words, merged banks, during the post-crisis period, appear to be more efficient in managing inputs to produce their outputs. This evidence supports previous research that focus on technical efficiency of Asian banks during the post-crisis period (Thoraneenitiyan & Avkiran, 2009). However, the coefficient estimated here is significant only in the SFA regression. Therefore, generalisation of the result should be taken with care.

A proxy for the foreign bank takeover (*FOR*) and state intervention (*SI*) are significant in both equations. A positive relationship between *FOR* and inefficiency suggest that foreign-owned banks perform worse than locally-owned banks during the post-crisis period. This may be explained by locally-owned banks being more likely to have the home-field advantage in extending their products at lower costs, even though some regulations may have been relaxed for foreign banks. In addition, banks under state intervention were found to be more cost inefficient than non-intervened banks. This suggests that the banks that were subject to government intervention appear to have more excess input usage

and output shortfalls than non-intervened banks. This result supports the literature which suggests that state-owned banks are inefficient by nature of their operations because they are used to rewarding political support (Williams & Nguyen, 2005).

Although we include the country-specific factors to analyse the impact of different economic conditions, the statistically significant coefficients correspond to different variables under DEA and SFA, and thus, no clear conclusions can be drawn.

**Table 4** Determinants of cost inefficiency

<i>Independent Variables</i>	<i>Dependent Variables</i>			
	<i>DEA Cost Inefficiency</i>		<i>SFA Cost Inefficiency</i>	
	<i>Coefficient</i>	<i>t-statistic</i>	<i>Coefficient</i>	<i>t-statistic</i>
<i>Constant</i>	-0.9519	1.9565	0.1491	1.3923
<i>Form of Ownerships</i>				
<i>Domestic merger</i>	-0.2136	0.8285	-0.0928	3.5431**
<i>Foreign takeover</i>	0.1865	2.0609**	0.3721	11.8357**
<i>State intervention</i>	0.1766	2.8908**	0.4188	16.0416**
<i>Country-Specific Variables</i>				
<i>Market concentration</i>	-1.2026	-5.7445**	0.1693	3.8742**
<i>Interest rate</i>	0.3261	2.8058**	0.8166	30.4223**
<i>Intermediation ratio</i>	-0.0875	0.3657	-0.3345	-0.0231
<i>Per capita GDP</i>	0.0007	9.9764**	0.0098	3.8188**
<i>Individual Bank Control Variable</i>				
<i>Size</i>	0.0040	1.1727	0.00219	0.5935

Note: \*\* 5% significance level

#### 6.4 Consistency of results

Table 5 shows summary of test for the means efficiency scores estimated from DEA and SFA. Although they are visually seen as similar in Figure 1 presented earlier, the *t-test*, *F-test*, the Wilcoxon signed rank, the Kruskal-Wallis and the Kolmogorov-Smirnov test reject the null that the DEA and SFA efficiency scores have the same mean and similar distributions at the 99%

significance level. Thus, this suggests that there are inconsistencies amongst efficiency scores generated by different frontier techniques. This answers our third research question raised in the introduction, and supports the observations based on the U.S. and European studies, which usually find differences between mean efficiency scores provided by parametric and non-parametric approaches.

**Table 5 Summary of tests of the hypothesis that DEA and SFA efficiencies are similar**

	<i>t-test</i>	<i>F-test</i>	<i>Wilcoxon Rank-Sum test</i>	<i>Kruskal-Wallis test</i>	<i>Kolmogorov-Smirnov test</i>
1997	10.6376***	149.6020***	5.2491***	80.6959***	0.8480***
1998	6.6165***	40.7915***	5.4328***	35.6720***	0.7151***
1999	8.3524***	84.4565***	6.8891***	63.8356***	0.8172***
2000	10.5921***	130.5457***	9.1831***	84.4245***	0.8354***
2001	12.1597***	162.5143***	10.2528***	101.2151***	0.8425***

The *t*-test and *F*-test are parametric tests that test the null hypothesis, that cost efficiencies estimated from DEA and SFA have the same mean; the Wilcoxon Rank-Sum, and the Kruskal–Wallis are non-parametric tests that test the shift in the location of the distribution, the Kolmogorov–Smirnov Test is a non-parametric test that tests the hypothesis of the equality of the distributions; \*\*\* indicates a 1% two-tailed significance level.

In order to address our fourth and final research question, we analyse the correlation between cost efficiency scores estimated from DEA (*CEDEA*) and SFA (*CESFA*), and four traditional non-frontier measures of performance; return on assets (*ROA*); return on equity (*ROE*); cost-to-income ratio

(*COSIN*); and cost-to-total asset ratio (*COSTA*). The Spearman rank-order correlation coefficients are calculated to determine how close the implied rankings of banks are as per frontier techniques and traditional accounting ratios.

**Table 6 Spearman rank-order correlations among efficiency estimates and non-frontier ratios**

	<i>DEACE</i>	<i>SFACE</i>	<i>ROA</i>	<i>ROE</i>	<i>COSIN</i>
<i>SFACE</i>	0.4006**				
<i>ROA</i>	0.2290**	0.3643**			
<i>ROE</i>	0.1861**	0.2466**	0.8643**		
<i>COSIN</i>	-0.4509**	-0.3283**	-0.5275**	-0.4979**	
<i>COSTA</i>	-0.4432**	-0.8239**	-0.2609**	-0.2815**	0.3281**

Note: \*\* 5% significance level

The results in Table 6 show that all the coefficients are significantly different from zero at the 5% level of confidence, indicating identifiable relationships among frontier efficiency measures and

more traditional measures of performance. Although the rank-order correlation between DEA and SFA is low, it is significant and positive for both tests. This implies that even though the different

approaches provide quantitatively different results, there are some similarities in rankings. The numbers in Table 5 also reveal positive correlations between cost efficiency and profitability ratios, and negative correlations between cost efficiency and the two cost ratios. Therefore, our last research question is answered in favour of a relationship between frontier efficiency and traditional non-frontier performance ratios, although the magnitudes of the majority of coefficients are below 0.5.

## 7. Summary and conclusions

We estimate cost efficiency of Asian banks in five countries over the 1997 - 2008 period using frontier techniques. This paper is the first Asian cross-country cost efficiency study which applies both non-parametric and parametric approaches. The DEA analysis reveals moderately high cost efficiency across the period of study. We find that cost efficiency of selected Asian banks does not statistically improve. This finding is also supported by the parametric analysis. Although SFA yields higher mean efficiency scores, the movements of mean efficiency scores in the two techniques is similar. The results show that forms of ownership do affect cost efficiency of banks during the crisis recovery period. Merged banks appear to operate more efficient than non-merged banks, while foreign-owned as well as state-intervened banks perform worse than locally-owned and non-intervened banks. The findings consistent with literature in technical efficiency study for Asian countries, but oppose to the evidence from the western countries.

The consistency tests reveal that different frontier techniques do not provide comparable average efficiency scores although there are some similarities in ranking. However, the directions of efficiency scores estimated by the frontier techniques are consistent with traditional measures of performance although the correlations are not strong.

Our findings should be considered with care. Since there is a lack of literature about the comparison of frontier techniques on Asian bank data, it is hard to draw conclusions until more publications emerge. Also macro-economic policies during the transition period and measurement errors could confound the robustness of efficiency measured. In addition, measuring cost efficiency in this study provides an assessment of how well banks convert the inputs into outputs by the production process. However, using the efficiency measure alone can be a misleading measure of productivity for a banking industry during a period of significant change (e.g., restructuring). This is because total factor productivity of the banking system may change between period one and period two by the changes in bank efficiency as well as bank technology. Thus, the Malmquist index that decomposes total factor productivity change into efficiency change, which reflects the ‘catch-up’ effect, and technological change, which reflects the shift in the efficient frontier, is needed to identify sources of efficiency during the transition period.

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