

# **A Meta-frontier Approach for Comparing Bank Efficiency Differences between Indonesia, Malaysia and Thailand**

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## **Abstract**

The purpose of this paper is to employ the Meta-Frontier Cost Function to compare the bank efficiencies in Indonesia, Malaysia, and Thailand during the period of 2002–2009. We propose two new variables: income on loans and non-performing loans, to identify whether the banks are both cost and profit efficient and to control the quality of loans in contrast with early studies using loans and securities as the output variables. Evidence is found that the Indonesian banks are the most efficient. The empirical results illuminate the governments' policies and bank management. The declining trend of the efficiency in Indonesia needs to be eliminated. If the Thai banks continue to progress in employing superior technology and increasing cost efficiency they may catch up with the Indonesian banks in regards to efficiency. In the case of Malaysia, great efforts have to be made to improve its efficiency.

**JEL classification numbers:** C33, G21, O57

**Keywords:** Meta-frontier cost function, Bank efficiency, Indonesia, Malaysia, Thailand

## **1 Introduction**

This paper aims to assess the performance of banking industry by using the meta-frontier cost efficiency function based on the models proposed by Battese and Coelli (1992), and Battese et al. (2004) to explain the differences in efficiency across selected East Asian

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commercial banks during the period of 2002 and 2009. This study focuses the analysis on three countries – Indonesia, Malaysia and Thailand.

A cross-country comparison of banking efficiency in these three countries is of interest for three reasons. First, the weak corporate governance has been found to be one of the causes of the East Asian financial crisis in 1997 (Laeven, 1999). Notably banks in Indonesia, Malaysia, and Thailand were badly hit during the crisis. It would be interesting to investigate if the efficiencies of the banks in these countries improved after the deregulation of foreign investment in the domestic banking industry and the introduction of many restructure measures. Second, it is also our motivation to evaluate the effects on the banks' efficiencies in Indonesia and Malaysia where the sharp increases of the revenue due to crude oil prices led to the rising importance of their roles in Islam finance in comparison with those in Thailand. Third, there is significant implication in studying the changes of the performance of banks in the three countries after the negative impact of the subprime crises in 2008. The empirical evidence illuminates the government policy and the management of these banks.

This paper makes two contributions to the literature. It is the first paper to focus on comparing the changes of banking efficiencies in the three worst-hit countries after the East Asian financial crisis in 1997 by applying the meta-frontier function which is more appropriate than conventional measures. Second, we propose two new output variables: income on loans and non-performing loans instead of loans and securities employed by previous works especially in the study of these three countries.

The empirical results demonstrate that the average cost efficiency of the Indonesian banks leads the other two but the gaps shrink with the Thai banks during this period. The cost efficiency of the Thai banks progressed steadily while that of the Malaysian banks remained the lowest.

The Indonesian banks needs to reverse the declining trend of the banking efficiency to maintain its competitive advantages so far. The efficiency of the Thai banks may catch up with that of the Indonesian banks in the coming years if they continue to progress in employing superior technology (TGR) and increasing the cost efficiency (CE). In the case of Malaysia, great efforts have to be made in improving its banking efficiency.

The remainder of the paper proceeds as follows: Section II reviews the existing literature and emphasizes the comparative perspective of this study. Section III presents the econometric model, Section IV analyzes the empirical results, and Section V concludes the paper.

## **2 Literature Review**

Recent literatures have applied either a parametric or non-parametric approach to examine the banks' efficiencies. Berger and Humphrey (1997) surveyed over 100 studies that apply the above efficiency analyses to financial institutions in 21 countries. In studying cross-border banking performance, Berger and Mester (1997) reviewed the literature that provides international comparison of banking efficiency. Berg et al. (1993), Pastor et al. (1997) used the DEA approach study bank efficiency in Norway, Sweden and Finland and eight developed countries, respectively. Singh and Munisamy (2008) used the DEA approach to derive technical and scale efficiency measures for the top 300 Asia Pacific Bank in sixteen countries for estimating the bank efficiency through a cross-country analysis. The DEA approach was also applied to examine the efficiency of banks by

Sufian and Habibullah (2010) in the case of Thailand and by Hadad et al. (2011) in the case of Indonesia. Allen and Rai (1996), and Zaini and Karim (2001) employed stochastic cost frontier approach to compare cost efficiency of banks across fifteen developed countries and selected ASEAN countries, respectively. Traditionally, the assumption is that cross-country efficiency differences are determined by structural characteristics (Berger and Humphrey 1997).

Although these studies are informative, they do not allow the evaluation of efficiency across countries. It is suggested that the environment faced by firms differs across regions or countries in important ways such as type of regulation, supervision, and technology. Thus, earlier studies are unable to address the differences in bank performance caused by different types of technology adopted by banks in different countries or regions. Meta-frontier technique was proposed by Battese and Coelli (1992), and Battese (2004) as a primal production function which enabled the researchers to measure technical efficiency for banks operating under different technologies.

The concept of meta-frontier production function model is based upon the hypothesis that all firms have potential access to the same production technology, but each may choose a different process, depending on specific circumstances, such as regulation, environments, production resources, and relative input prices. The meta-frontier production function was later applied to studies in various industries and sectors, for example: Witte, and Marques (2009), Mulwa et al. (2009), Moreira and Bravo-Ureta (2010), Chen and Song (2008), Assaf et al. (2010), Matawie and Assaf (2008), Lin (2011), Mariano et al. (2011), Oh (2010). It is also applied in the banking literature such as Bos and Schmiedel (2007), and Huang et al. (2010), who both adopt this model in examining European banking industry. Kontolaimou and Tsekouras (2010) use it to evaluate the cooperatives' efficiency in European Banking Industry, and Chen and Yang (2011) employ it to assess the banking efficiency in China and Taiwan.

So far many banking literature use the cost-efficiency-oriented concept, i.e. cost function (such as, Altunbas et al. 2001, Bauer et al. 1998, Berger and Mester 1997, Bos and Schmiedel 2007, Huang 2010). Some adopt production function, for instance: Berg et al. (1992, 1993), Yao et al. (2007), and Sufian and Habibullah (2009). These studies employ volume of loans and investment as the measure of banking output. However, we use cost function and further propose that the profit instead of loans, i.e. income on loans, and the non-performing loans are more significant than the volume of loan and investment in evaluating banking efficiency. Casu and Molyneux (2003) suggest that maximizing profits requires the minimization of total cost and not just production. Vennet (2002) follows Berger and Mester (1997) and adopts their concept of profit efficiency.

Profit efficiency is based on the more accepted economic goal of profit maximization, which requires that the same amount of managerial attention be paid to raising a marginal dollar of revenue as to reducing marginal dollar of costs. Theoretically, in comparing one bank's efficiency to another's, the comparison should be made between banks producing the same output quality. There are likely to be unmeasured differences in quality because the banking data does not fully capture the heterogeneity in bank output. The amount of service "flow" associated with financial products is by necessity usually assumed to be proportionate to the dollar value of the "stock" of assets or liability on the balance, which can result in significant mismeasurement. For example, commercial loans can vary in size, repayment schedule, type of collateral, etc. These differences are likely to affect the costs to the banks of loan origination, ongoing monitoring and control, and financial expenses. Unmeasured differences in product quality may be incorrectly measured as differences in

cost inefficiency (Berger and Mester 1997). Berger and Mester (1997) compare the empirical results obtained by cost functions with the use of profits and conventional output variables loans and securities. They make the comparison and conclude that the profit efficiency is more superior to the cost efficiency in measuring financial institutions efficiency.

Similarly, Altunbas et al. (2001) use both profits and loans in examining different type of banks efficiencies. Yao et al. (2007) use two models: profit model and loan model in evaluating China's banking efficiency. Furthermore, taking the quality of bank output into account, Hughes and Mester (1993), Hughes et al. (1996 a, b), Mester (1996) include the volume of non-performing loans as a control for loan quality in the banking efficiency studies of US banks, and Berg et al. (1992) include loan losses as an indicator of the quality of loan evaluations in a DEA study of Norwegian bank productivity. Berger and Mester (1997) use the ratio of non-performing loans to total loans to control the negative shocks that may affect bank efficiency. Altunbas et al. (2001), Drake and Hall (2003), and Sufian and Habibullah (2009) all stress the importance of controlling the non-performing loans in assessing the banking efficiency.

In this paper, we follow the meta-frontier production function proposed by Battese and Coelli (1992), and Battese et al. (2004). This model enables us to calculate technical efficiencies (CE) for banks operating under different technologies as well as the technology gap ratios (TGRs), measuring the extent to which the cost frontiers of individual countries deviate from the meta-frontier cost function. Technical efficiency here refers to the ability of optimal utilization of available resources either by producing maximum output for a given input bundle or by using minimum inputs to produce a given output (Lovell, 1993). Moreover, we adopt the profit-efficiency-oriented concept in this paper. We use the profits including income, and non-performing loans (a negative output) as banks' outputs to examine the bank efficiency instead of the conventional idea of employing the volume of loans and securities.

### **3 The stochastic Meta-frontier Model**

#### **3.1 The variable definition**

The variables of inputs and outputs are adopted according to the intermediation approach. The input variables include labor, physical capital, and borrowed funds. They are all quite standard and well-established in efficiency estimation (Altunbas et al. 2000, 2001, Beccalli 2004, Bauer et al. 1998, Bos 2007, Huang 2010 and Weill 2004). The price of labor is calculated as the ratio of personnel expenses to total assets. The price of physical capital is defined as the ratio of other non-interest expenses to fixed assets. The price of borrowed funds is measured by the ratio of paid interests to total funding. Therefore total costs are the sum of the above three items of expenditures. Meanwhile, we employ two outputs as discussed in the previous section. We suggest that it would be more intriguing in examining the capability and efficiency on the diversification of banks' risks and revenue if we further break down the profit into: interest income, non-interest income, and the loan impairment charge. Due to the conventional culture in Indonesia and Malaysia, the data of interest income on loans in these two countries is not available. We therefore use the income on loans to represent the profit for three countries in question. The income on loans and the loan impairment charge are theoretically a proxy to evaluate

the quality of banks' outputs.

All the data in the three countries are from the Bankscope electronic data bank. This source is widely used in many previous banking industry studies so the data is reliable. To be consistent on the data during the observation period, we selected 16 banks in Indonesia, 22 banks in Malaysia and 9 banks in Thailand (the names of these banks are listed in the Appendix).

Table 1: Descriptive statistics for banks in the three countries

| Country       | Sample size | TC                       | y1                        | y2                     | w1                 | w2                 | w3                 |
|---------------|-------------|--------------------------|---------------------------|------------------------|--------------------|--------------------|--------------------|
| Indonesia     | 128         | 4922.0640<br>(6298.4250) | 7196.2610<br>(21120.9000) | 530.4616<br>(937.6001) | 0.0157<br>(0.0072) | 2.0724<br>(2.3129) | 0.0657<br>(0.0249) |
| Malaysia      | 176         | 1561.1760<br>(2012.1770) | 1934.6610<br>(2678.0520)  | 244.4528<br>(307.4066) | 0.0102<br>(0.0124) | 2.5765<br>(3.7231) | 0.0262<br>(0.0112) |
| Thailand      | 72          | 24.6195<br>(14.5387)     | 30.9233<br>(15.9798)      | 6.3766<br>(6.2807)     | 0.0087<br>(0.0035) | 1.3055<br>(1.8057) | 0.0199<br>(0.0076) |
| All countries | 376         | 2312.9960<br>(4354.1460) | 3239.7830<br>(12752.8100) | 281.0321<br>(613.8984) | 0.0117<br>(0.0095) | 2.0804<br>(2.9108) | 0.0380<br>(0.0260) |

Note: Numbers in the brackets are the standard deviation.

Table 1 summarizes the descriptive statistics and the distributions of the sample banks in all three countries. These statistics indicate that there are considerable differences so far as the means and standard deviations of the input and outputs are concerned. Banks in the three countries may employ inputs of various qualities and produce heterogeneous outputs through dissimilar production techniques. In other words, the performance of banks in the three countries cannot be compared directly as they are assessed on the basis of various standards. This justifies the use of the meta-frontier model.

### 3.2 The meta-frontier cost function

In this paper, we follow the model proposed by Battese and Coelli (1992) and Battese *et al.* (2004) and further apply the regional stochastic frontier cost function developed by Huang *et al.* (2010) with inefficiency effects and time-varying structure.

Suppose that, for the *j*th country, the stochastic cost frontier model for bank *i* at time *t* can be defined as follows:

$$TC_{it(j)} = f(Y_{it(j)}, W_{it(j)}; \beta_j) e^{v_{it(j)} + u_{it(j)}}, \quad i = 1, \dots, N, t = 1, \dots, T, j = 1, \dots, R, \quad (1)$$

where *TC* is the realized total cost; *Y*, *W* and  $\beta$  are the vector for outputs, input prices; and unknown technology parameters, respectively.  $v_{it(j)}$  is a random variable which is assumed to be  $N(0, \sigma^2_{v(j)})$ . Additionally, following Battese and Coelli (1992), the term  $_{(j)}$  is parameterized as:

$$_{(j)} = u_{ij} \exp[-\eta_j (t - T)], \quad (2)$$

where  $u_{ij}$  is a non-negative random variable which is assumed to account for cost

inefficiency in production and is assumed to be half-normal distribution at zero of the  $N(0, \sigma^2_{u(j)})$ .  $\eta_j$  is a parameter to be estimated. A positive (negative) value of  $\eta_j$  indicates that the cost inefficiency of banks in the  $j$ th country decreases (or increases) over time.

Furthermore, we use the Cobb-Douglas cost frontier function including two outputs and three input prices. Because the homogeneity constraint is imposed on the cost function theoretically, some properties can be assessed accordingly when the parameters are estimated. The model based on the Cobb-Douglas function with panel data therefore can be written as follows:

$$\ln\left(\frac{TC_{it(j)}}{W_{1it(j)}}\right) = \beta_{0(j)} + \beta_{1(j)}\ln y_{1it(j)} + \beta_{2(j)}\ln y_{2it(j)} + \beta_{3(j)}\ln\left(\frac{W_{2it(j)}}{W_{1it(j)}}\right) + \beta_{4(j)}\ln\left(\frac{W_{3it(j)}}{W_{1it(j)}}\right) + u_{it(j)} + v_{it(j)}, \quad (3)$$

where the unknown technology parameters  $\beta$  of the cost function can be estimated by employing the maximum likelihood method (MLE). The measures of cost efficiency ( $_{(j)}$ ) or overall economic efficiency ( $_{(j)}$ ) for the bank  $i$  of the  $j$ th country in the year of  $t$  is derived by the ratio of frontier minimum cost to observed cost, which can be calculated as  $CE_{i(j)} = \exp(-u_{it(j)})$  and is bounded between 0 and 1.

The model of Battese et al. (2004) assumes that there is merely one data-generation process for those banks operating under a given technology for each country. The overall cross-country data is individually generated from the respective frontier models in the different countries. The meta-frontier is assumed to take the same functional form as the individual stochastic frontiers in the different countries. The meta-frontier can be defined as a deterministic parametric function enveloping the deterministic parts of the individual cost frontiers such that its values must be less than or equal to the deterministic components of the stochastic cost frontiers of the different countries involved. Therefore the meta-frontier cost function for the whole sample banks of all countries can be expressed as follows:

$$TC_{it(j)}^* = f(Y_{it}, W_{it}; \beta^*), \quad i = 1, \dots, N, t = 1, \dots, T, \quad (4)$$

$TC_{it}^*$  is the optimal level of production cost with the most advanced technique.  $\beta^*$  is the corresponding parameter vector of the related meta-frontier cost function.

This function should satisfy the following restriction:

$$f(Y_{it}, W_{it}; \beta^*) \leq f(Y_{it(j)}, W_{it(j)}; \beta_j), \quad (5)$$

Equation (5) implies that the meta-frontier cost function reflects the minimum possible production cost for producing a given level of outputs. In other words, it is the minimum cost corresponding to the most efficient production technique. The inequality constraint of equation (5) is required to hold for all countries and time periods. The meta-frontier is thus an envelope curve beneath the individual cost frontiers of the different countries. Therefore, the meta-frontier cost efficiency ( $CE_{it}^*$ ) for bank  $i$  in the year  $t$  is derived by the ratio of the meta-cost to the actual cost. i.e.:

$$CE_{it}^* = \frac{f(Y_{it}, W_{it}; \beta^*) e^{v_{it(j)}}}{TC_{it}}, \quad (6)$$

Equation (6) implies that the higher the  $CE_{it}^*$  is, the actual output level bank  $i$  is closer to the meta-frontier cost and vice versa.

In addition, the term on the right-hand side of the equation (6) is referred to as the technology gap ratio (TGR), i.e.  $TGR_{it}$  shows the technology gap ratio for bank  $i$  of year  $t$  as follows:

$$TGR_{it} = \frac{f(Y_{it}, W_{it}; \beta^*)}{f(Y_{it(j)}, W_{it(j)}; \beta_j)}, \quad (7)$$

$TGR_{it}$  measures the scale of the technology gap for the country  $j$  whose current technology adopted by its banks lags behind the technology available for all countries, represented by the meta-frontier cost function. The evaluation of TGR employs the ratio of the potentially minimum cost that is defined by the meta-frontier cost function to the cost of the frontier function for country  $j$ , given the observed output and input prices. Clearly, the TGR has a value between zero and one because of equation (5). The higher the average value of the TGR is for a country, the more advanced the production technology it adopts.

The meta-cost efficiency measure of equation (6) can be rewritten as follows:

$$CE_{it}^* = CE_{it(j)} \times TGR_{it}. \quad (8)$$

Equation (8) indicates that  $CE_{it}^*$  is composed of two factors. One is the conventional technical efficiency measuring the deviation of a bank's actual cost from the country specific cost frontier. The other is a new one measuring the deviation of the country specific cost frontier from the meta-frontier cost function.  $CE_{it}^*$  also lies between zero to one because both CE and TGR are in the same range. The meta-cost frontier efficiency score of a bank implies how well it performs relative to the predicted performance of the best practice banks that adopt the best technology available for all countries to produce a given output mix. In other words, banks operating on the meta-cost frontier serve as a benchmark for all banks involved because they employ the best available technology in the production process.

To obtain the technology parameters estimates of  $\hat{\beta}_j$ ,  $j = 1, 2, \dots, R$ , we apply the stochastic frontier model which allows for temporal variant technical efficiency proposed by Battese et al. (2004). Furthermore, we can yield the estimates of  $\hat{\beta}^*$  in the meta-frontier cost function by using two different mathematical programming techniques. These two techniques include one that is dependent on the sum of absolute deviations of the meta-frontier values from those of the country frontiers (minimum sum of absolute deviations), and the other depends on the sum of squares of the same distances (minimum sum of squared deviations).

The "minimum sum of absolute deviations" is also known as linear programming (LP).

Vector  $\hat{\beta}^*$  can be obtained by filling the  $\hat{\beta}_j$  into the following equations:

$$\text{Min } L \equiv \sum_{t=1}^T \sum_{i=1}^N \left| \ln f(Y_{it(j)}, W_{it(j)}; \hat{\beta}_j) - \ln f(Y_{it}, W_{it}; \beta^*) \right|, \quad (9)$$

$$\text{s.t. } \ln f(Y_{it}, W_{it}; \beta^*) \leq \ln f(Y_{it(j)}, W_{it(j)}; \hat{\beta}_j). \quad (10)$$

Equation (9) and (10) indicate the estimated meta-frontier vector minimizes the sum of the absolute logarithms. The weights of the deviations for all sample banks are the same. In addition all the deviations are positive due to equation (9) and all the absolute deviations are exactly equal to the differences.

The “minimum sum of squared deviations” is to calculate  $\hat{\beta}^*$  by solving a quadratic programming (QP) issue. It is written as follows:

$$\text{Min } L \equiv \sum_{t=1}^T \sum_{i=1}^N [\ln f(Y_{it(j)}, W_{it(j)}; \hat{\beta}_j) - \ln f(Y_{it}, W_{it}; \beta^*)]^2, \quad (11)$$

$$\text{s.t. } \ln f(Y_{it}, W_{it}; \beta^*) \leq \ln f(Y_{it(j)}, W_{it(j)}; \hat{\beta}_j). \quad (12)$$

Equation (11) and (12) imply that the larger (or lesser) the TGR is for a bank, the higher (lower) the weight it owns. In addition, it also indicates the weights for each country are different.

The calculation of parameter  $\hat{\beta}^*$  of the meta-frontier function can be obtained by applying the above two approaches. Regarding the estimation of the standard errors of the meta-frontier function, we adopt the bootstrapping method because the underlying data generation process is unknown. The analytic estimates of the standard errors of the estimators are difficult to obtain. The bootstrapping method is to provide a better finite sample approximation (Huang et al. 2010).

## 4 Empirical Results

The parameter estimates of the stochastic cost frontier for the banks in Indonesia, Malaysia and Thailand are shown in Table 2.

The results of a likelihood-ratio test are applied for the null hypothesis that the three countries' stochastic cost frontiers are the same. The value of LR test statistics is 112.0702, which is significant even at the 1% level. Thus, the null hypothesis is rejected. This result corresponds with the presumption of this study that the banks in Indonesia, Malaysia, and Thailand belong to different technological basis and own distinct frontiers.

Table 2: Parameter estimates of the Cobb-Douglas Cost frontier function

| Coefficients   | Indonesia     |                 | Malaysia      |                 | Thailand      |                 | All sample data |                 |
|----------------|---------------|-----------------|---------------|-----------------|---------------|-----------------|-----------------|-----------------|
|                | Estimates     | Standard Errors | Estimates     | Standard Errors | Estimates     | Standard Errors | Estimates       | Standard Errors |
| $\beta_{0(j)}$ | 3.7523**<br>* | 0.3074          | 6.0882**<br>* | 0.4107          | 1.9517**<br>* | 0.5296          | 4.0266**<br>*   | 0.2271          |
| $\beta_{1(j)}$ | 0.7634**<br>* | 0.0559          | 0.2487**<br>* | 0.0671          | 0.7628**<br>* | 0.1022          | 0.6105**<br>*   | 0.0493          |
| $\beta_{2(j)}$ | 0.0038        | 0.0050          | -0.0051       | 0.0052          | -0.0163       | 0.0119          | 0.0013          | 0.0037          |

|   |               |        |               |        |               |        |               |        |
|---|---------------|--------|---------------|--------|---------------|--------|---------------|--------|
| $\beta_{3(j)}$                                      | 0.1084**<br>* | 0.0418 | 0.0840*       | 0.0436 | 0.4827**<br>* | 0.0694 | 0.1648**<br>* | 0.0317 |
| $\beta_{4(j)}$                                      | 0.5927**<br>* | 0.0625 | 0.5602**<br>* | 0.0454 | 0.1851**<br>* | 0.0406 | 0.4555**<br>* | 0.0311 |
| $\sigma^2 (= \sigma_u^2 + \sigma_v^2)$              | 1.3899**      | 0.6077 | 8.3976**<br>* | 2.9008 | 0.9401**      | 0.4206 | 3.1032**<br>* | 0.8697 |
| $\gamma (= \sigma_u^2 / (\sigma_u^2 + \sigma_v^2))$ | 0.9493**<br>* | 0.0241 | 0.9894**<br>* | 0.0041 | 0.9456**<br>* | 0.0264 | 0.9685**<br>* | 0.0098 |
| $\eta$  | -0.0226**     | 0.0114 | -0.0074*      | 0.0042 | 0.0470**<br>* | 0.0119 | 0.0018        | 0.0047 |
| log likelihood                                      | -40.6884      |        | -81.4234      |        | -17.5776      |        | -195.7245     |        |
| LR test of the one-sided error                      | 173.2117      |        | 190.2387      |        | 88.9248       |        | 440.4223      |        |

1. The sample size of Indonesia, Malaysia, and Thailand is 128, 176, and 72. Thus the total number of observation is 376.
2. \*\*\* denotes the significance at 1% level, \*\* denotes the significance at 5% level, and \* denotes the significance at 10% level.

Table 3: The Estimates of the Meta-frontier Cost Function

| Coefficients | linear programming (LP) |                 | quadratic programming (QP) |                 |
|--------------|-------------------------|-----------------|----------------------------|-----------------|
|              | Estimates               | Standard Errors | Estimates                  | Standard Errors |
| $\beta_0$    | 4.3956                  | 0.2741          | 4.4338                     | 0.2811          |
| $\beta_1$    | 0.7160                  | 0.0208          | 0.7217                     | 0.0177          |
| $\beta_2$    | 0.0122                  | 0.0112          | 0.0063                     | 0.0095          |
| $\beta_3$    | 0.2155                  | 0.0319          | 0.2038                     | 0.0315          |
| $\beta_4$    | 0.3254                  | 0.1076          | 0.3202                     | 0.1140          |

Note: The standard error is calculated by Bootstrapping methods. The estimated standard error of the meta-frontier parameter is calculated as the standard deviation of the 3000 new parameter estimates. Thus, there are 3000 parameter estimates for each coefficient.

According to Table 3, the LP coefficient estimates and the bootstrapped standard deviations are very close to those of the QP estimates. This indicates that the LP and QP coefficients are quite precisely estimated. The estimation results of LP and QP are identical. We only adopt the results of LP in the following analysis. Basic summary statistics for these two measures are presented in Table 4. The estimates of the cost efficiency and the technology gap with the application of LP parameter estimates are shown in Figures 1 to 6.

Table 4: Summary Statistics of TGRs and CE measures for Three Sample Countries with LP and QP estimates

| Group         | Statistic  | LP     |        |        |          | QP     |        |        |          |
|---------------|------------|--------|--------|--------|----------|--------|--------|--------|----------|
|               |            | Mean   | Min.   | Max.   | St. Dev. | Mean   | Min.   | Max.   | St. Dev. |
| Indonesia     |            |        |        |        |          |        |        |        |          |
|               | $CE_{(j)}$ | 0.5253 | 0.0506 | 0.9221 | 0.2576   | 0.5253 | 0.0506 | 0.9221 | 0.2576   |
|               | $TGR$      | 0.6714 | 0.4192 | 1.0000 | 0.1223   | 0.6644 | 0.4327 | 1.0000 | 0.1171   |
|               | $CE^*$     | 0.3475 | 0.0292 | 0.8789 | 0.1670   | 0.3430 | 0.0302 | 0.8223 | 0.1617   |
| Malaysia      |            |        |        |        |          |        |        |        |          |
|               | $CE_{(j)}$ | 0.1704 | 0.0107 | 0.9055 | 0.2258   | 0.1704 | 0.0107 | 0.9055 | 0.2258   |
|               | $TGR$      | 0.2260 | 0.0350 | 1.0000 | 0.1885   | 0.2256 | 0.0364 | 1.0000 | 0.1891   |
|               | $CE^*$     | 0.0612 | 0.0004 | 0.4775 | 0.1053   | 0.0605 | 0.0004 | 0.4790 | 0.1040   |
| Thailand      |            |        |        |        |          |        |        |        |          |
|               | $CE_{(j)}$ | 0.4248 | 0.1279 | 0.9218 | 0.2447   | 0.4248 | 0.1279 | 0.9218 | 0.2447   |
|               | $TGR$      | 0.3179 | 0.2390 | 1.0000 | 0.1007   | 0.3205 | 0.2425 | 1.0000 | 0.1013   |
|               | $CE^*$     | 0.1488 | 0.0325 | 0.8907 | 0.1401   | 0.1502 | 0.0330 | 0.8907 | 0.1417   |
| All countries |            |        |        |        |          |        |        |        |          |
|               | $CE_{(j)}$ | 0.3561 | 0.0107 | 0.9221 | 0.2883   | 0.3561 | 0.0107 | 0.9221 | 0.2883   |
|               | $TGR$      | 0.4011 | 0.0350 | 1.0000 | 0.2472   | 0.3992 | 0.0364 | 1.0000 | 0.2438   |
|               | $CE^*$     | 0.1810 | 0.0004 | 0.8907 | 0.1855   | 0.1795 | 0.0004 | 0.8907 | 0.1827   |

Note: as shown in Equation 8:  $CE_{it}^* = CE_{it(j)} \times TGR_{it}$ .

Table 4 reports the measure of the TGR and the relative cost efficiency to the stochastic frontier for individual countries: CE, and the meta-frontier efficiency score:  $CE^*$ . The meta-frontier model divides the  $CE^*$  into CE and TGR ratios. This allows for further insights on banks' cost efficiencies. The observed cost efficiency and the technology adopted render more information for the government competent authorities and the bank management to examine the soundness of banks operation, and lower the possibility of banking failure greatly. Furthermore, this can be applied to assess the reallocation of their valuable resources to where they are most needed. In short these results can be a useful guide to cost reduction and increase of service quality by adopting superior technology so as to enhance the competitiveness of the banking industry.

For the whole sample banks in the three countries, the mean value of CE is 0.3561. The CE values of the three countries range from 0.5253 for Indonesia, 0.1704 for Malaysia, and 0.4248 for Thailand. These values imply that, on average, the potential cost saving for the Malaysian banks are around 83% of their actual costs, which could be attributed to the poor bank management on the cost reduction. Meanwhile, the Indonesian banks on average lie near the cost frontier. The cost efficiency of the Thai banks is better than that

of Malaysian banks. It indicates that banks in Malaysia need to largely reduce their costs. In terms of the TGR, the Indonesian banks also lead the banks of the other two countries. In fact, the result is the same as the CE, Thailand is the second and Malaysia has the lowest TGR value. Thus the Indonesian banks with the value of the TGR: 0.6714 adopt the most advanced production technology to provide financial service among the three countries. The value of the TGR: 0.3179, which indicates the technology to the meta-frontier employed by Thai banks is lower than the Indonesian ones. The Malaysian banks with the value of the TGR: 0.2260 shave their frontier costs by up to around 77% if the potential technology available to all countries is adopted. This empirical finding gives us a better understanding about the degrees of technology difference among these three countries. There is a distinguished technology gap between the Indonesian and the Malaysian banks. The result shows that banks in Malaysia need to take measures to catch up with the potential technology available to all of the three countries in order to shift its frontier cost function down to be more competitive.

Combining the above results of CE and TGR values in the three countries under study, we obtain the mean cost efficiency relative to the meta-frontier: the value of the CE\* for the Indonesian banks: 0.3475 ranks first, followed by: 0.1488 for the Thai banks, and lastly Malaysian banks: 0.0612. It shows that the Indonesian banks are the most efficient among all sample banks in these three countries. In contrast, the Malaysian banks should make considerable efforts in increasing the cost efficiency.

However, interestingly the values of CE\* for the Indonesian banks are gradually declining from 0.4345 in 2002 to 0.3079 in 2009 though they are still higher than the other two countries during the observation period from 2002 to 2009 according to Figure 1.

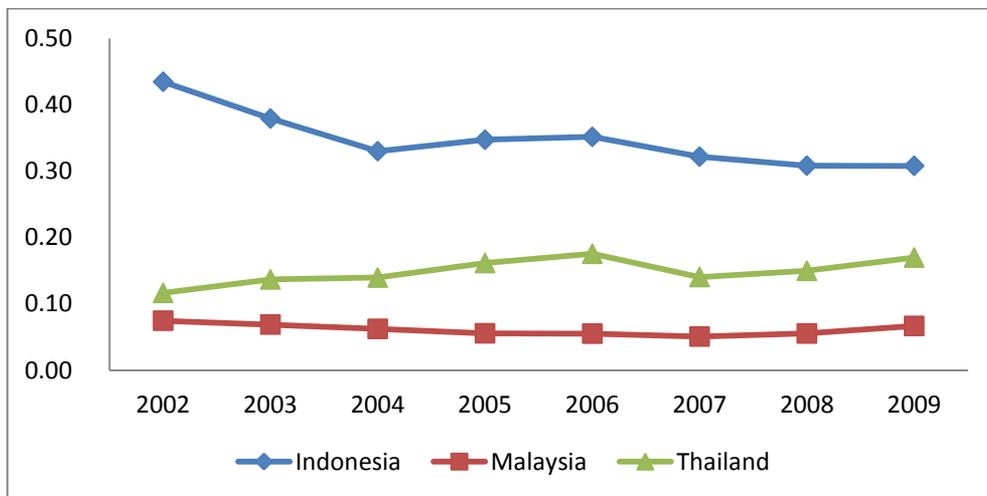


Figure 1: Mean Values of CE\* for Banks in the Three countries over time

The CE\* values for the Thai banks are trending higher over this period though they are lower than those for Indonesia. The efficiency of the Thai banking industry is improving slowly from 0.1166 (2002) to 0.1752 (2009). Conversely, the CE\* values for the Malaysian banks are almost flat or decline slightly from 0.0747 (2002) to 0.0667 (2009). Overall, the efficiencies of the banking industry in the three countries do not seem to move towards higher direction after the Asian Financial Crisis in 1997. Also their efficiencies are not negatively impacted by the subprime crisis originally started in the US

in the end of 2007. It is deteriorating gradually in terms of the Indonesian banking efficiency though it tops the three countries during the observation period. Meanwhile, the efficiencies in Thai and Malaysian banks both are in the lower levels during this period with the Thai banks efficiency increasing slowly and the Malaysian banks not showing upward signs. Therefore the efficiencies of the three countries can all be improved further. In Figure 2, the CE values of the Thai banks are catching up with that of the Indonesian banks during this period. The CE curve of the Thai banks moved upwards from 2002 to 2009 which implies the Thai banks have made a significant achievement in cost reduction while that of the Indonesian is falling gradually though maintaining the highest position during this period. The CE curve of the Malaysian banks shows little improvement on their cost efficiency. There is a significant gap between the TGR values of the Indonesian banks and those of the banks in the other two countries though the TGR curve of the Indonesian banks is slowly progressing downward over this period according to Figure 3.

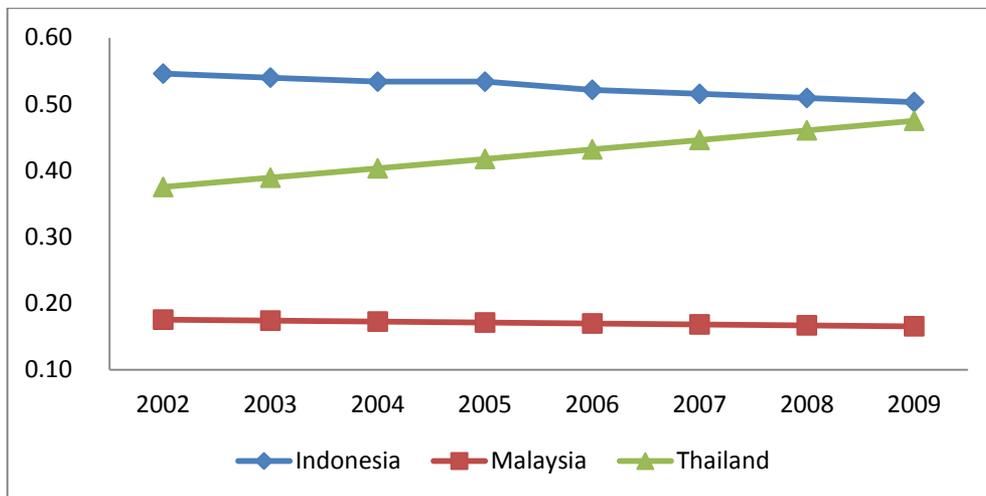


Figure 2: Mean Values of CE for Banks in the 3 countries over time

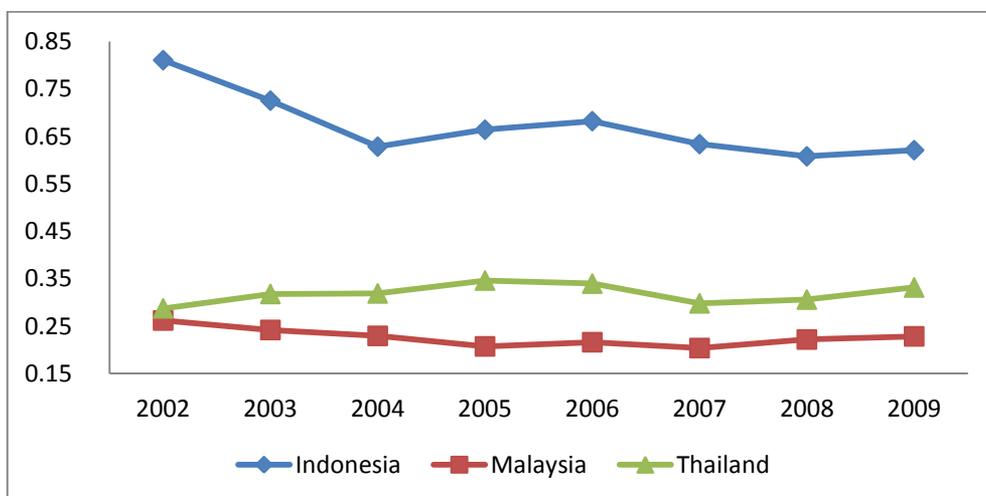


Figure 3: Mean Values of TGR for Banks in the 3 countries over time

Figure 4 to Figure 6 show the changes of the CE and TGR values in each country over this period. In the case of Indonesia (Figure 4), both the values of CE and TGR demonstrate a downward trend though these values are the highest of the three countries. It appears that the Indonesian banks improved the cost efficiency and adopted the advanced technology after the East Asian Financial Crisis. However, their efficiency has been slowly deteriorating since 2002. For example, the TGR values are down from the relatively high level above 0.8 (2002) to approximately 0.6 (2009). On the other hand the values of TGR and CE in 2008 and 2009 show that the US subprime crisis in 2008 has less spillover effect on them. This result might imply that the competent authorities and banks in Indonesia need to make further efforts to reverse the downward trends to maintain their competitive advantages so far.

Figure 5 presents the efficiency of the Malaysian banks, which remains at a relatively lower level over this period. It appears that it might have improved to some extent after the Asian crisis but it gradually deteriorated in terms of both the values for CE and TGR. On the other hand, it shows that the US subprime crisis has less negative impact on them. The TGR values are going upwards from year 2007 to 2009 but the CE values have a slight downward trend. Different from the cases of Indonesia and Malaysia, both CE and TGR values of the Thai banks are sloping upwards, while those in Indonesia and Malaysia are sloping downwards. The values of CE are higher than those of TGR all over this period in the case of Thailand, while those in Indonesia and Malaysia are reversed. It indicates that the efficiency is improving slowly but steadily after the Asian crisis and is not impacted by the US subprime crisis.

Overall, the cost efficiency of the Indonesian banks leads that of the Malaysian and Thai banks throughout this period. However, it is declining gradually while that in Thailand is moving upwards slowly but steadily. It is very possible that in terms of the CE values, Thai banks may move higher than the Indonesian banks in the near future as shown in Figure 2. Meanwhile, the efficiency of the Malaysian banks appears to be the least competitive among the three countries. It needs to eliminate the declining trend of the banking efficiency in Indonesia to maintain its competitive advantages so far. The efficiency of the Thai banks may catch up with that of the Indonesian banks in the coming years if Thai competent authorities and banks keep up their progress in employing superior technology (TGR) and increasing the cost efficiency (CE). In the case of Malaysia, clearly a great deal efforts have to be made in improving its banking efficiency to enhance its competitive position in the region.

Finally, the empirical results presented and analyzed above indicate that the efficiencies of the banks in Indonesia and in Malaysia do not benefit from the rapid development of Islam Finance with the sharp revenue increases in the Middle East countries due to the fast rising crude oil prices during this period.

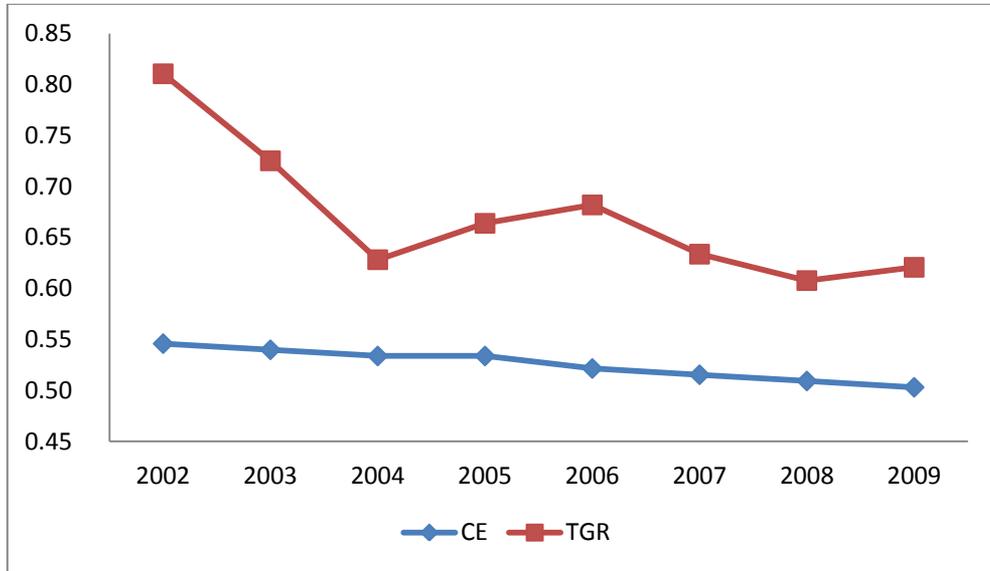


Figure 4: Mean Values of CE and TGR for Banks in Indonesia over time  
 Note: Sixteen sample banks are employed.

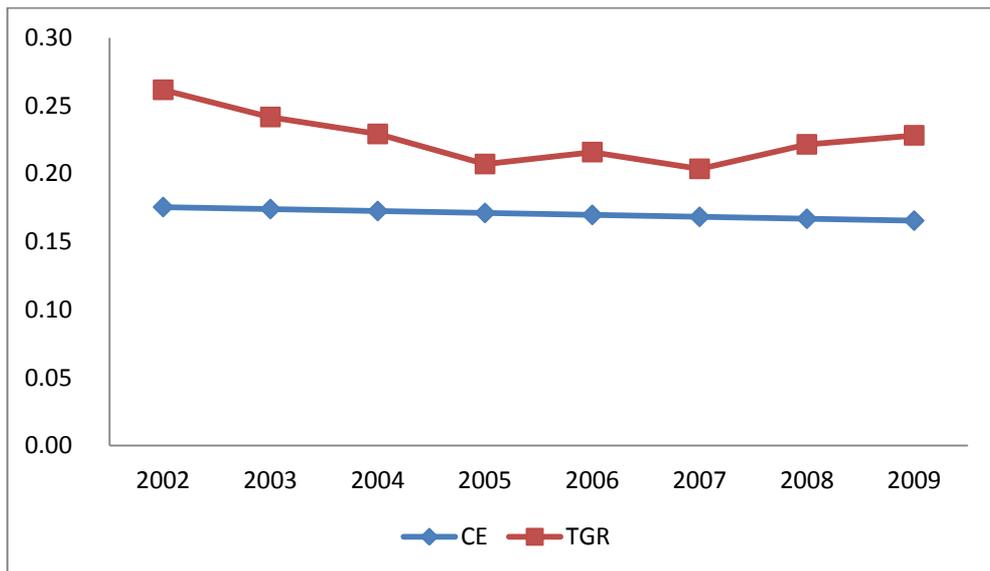


Figure 5: Mean Values of CE and TGR for Banks in Malaysia over time  
 Note: Twenty-two sample banks are employed.

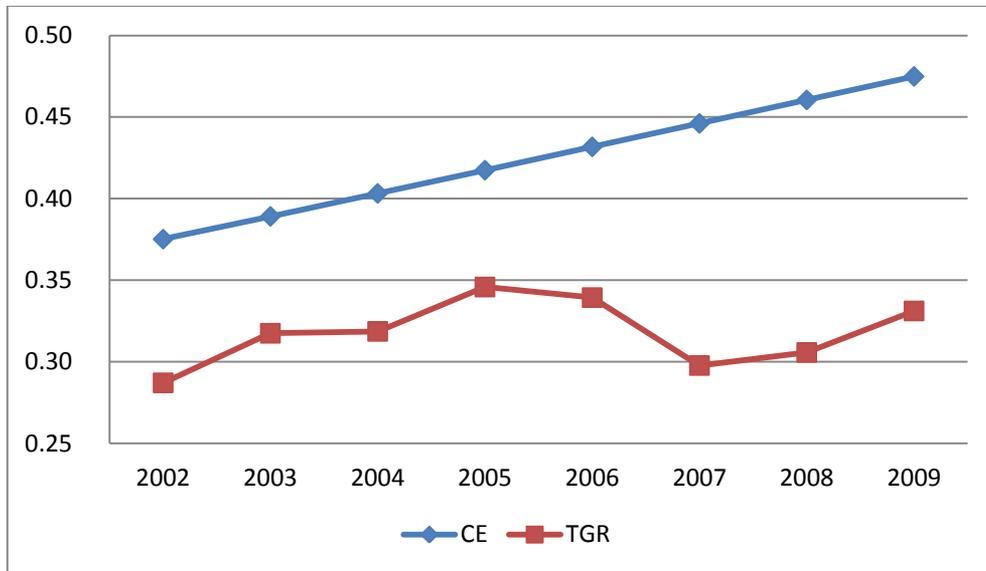


Figure 6: Mean Values of CE and TGR for Banks in Thailand over time  
*Note:* Nine sample banks are employed.

## 5 Conclusion

This paper applies the meta-frontier model to evaluate the performance of banks in Indonesia, Malaysia and Thailand from 2002 to 2009, in terms of the cost-efficiency and technology gap ratios. The meta-frontier model can be used to distinguish the TGR from CE score and gains further insights on banks' cost efficiencies. In other words, the model provides more information by subdividing the measure of CE\* into two elements: CE and TGR. The empirical results illuminate the governments' policies and bank management.

Different from the early literature using loans and securities as the output variables to examine the banking efficiency, we adopt two new variables: interest income on loans and non-performing loans to identify whether the banks are both cost and profit efficient and to control the quality of loans. Evidence is found that the average cost efficiency of the Indonesian banks leads the banks from the other two countries. However, the cost efficiency of the Indonesian banks deteriorates while that of the Thai banks improves steadily during the observation period.

The empirical results imply that the banking efficiency in Indonesia and Malaysia improved to some extent soon after the Asian Financial Crisis in 1997 but the efficiencies in both countries appear to be declining gradually from the year 2002 to 2009. Meanwhile, the US subprime crisis in 2008 seems to have less spillover effects on the banking efficiency in Indonesia and Malaysia. It even shows that there is no negative impact on the banking efficiency in the case of Thailand.

Additionally, from the future perspective of the banking industries in the three countries, we may conclude that it needs to reverse the declining trend of the banking efficiency in Indonesia to sustain its competitive advantages so far. The efficiency of the Thai banks may catch up with that of the Indonesian banks in the coming years if Thai competent authorities and banks keep up their progresses in employing advanced technology (TGR)

and increase the cost efficiency (CE). In the case of Malaysia, clearly a great deal efforts have to be made in improving its banking efficiency. Both the Indonesian and in particular Malaysian banks may have to adopt more superior technology such as introducing sophisticated financial products, using new software packages to expand income sources and promote cost reduction programs to maintain its competitiveness in the region and attract more Islam finance from the Middle East countries.

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## Appendix

Table 1: Overall Ranking of Banks in Indonesia, Malaysia and Thailand by Cost Efficiency Scores (MCE-LP)

| Rank | Bank                               | MCE-LP | TGR-LP | CE     |
|------|------------------------------------|--------|--------|--------|
| 1    | PT Bank Swadesi Tbk(I)             | 0.6482 | 0.7073 | 0.9159 |
| 2    | Bank Bumi Arta(I)                  | 0.5317 | 0.6597 | 0.8057 |
| 3    | PT Bank Mayapada International(I)  | 0.5226 | 0.8148 | 0.6401 |
| 4    | Thanachart Capital Public Com(T)   | 0.5188 | 0.5841 | 0.8876 |
| 5    | Bank Chinatrust Indonesia(I)       | 0.4805 | 0.5366 | 0.8954 |
| 6    | Bank ICB Bumiputera(I)             | 0.4606 | 0.6075 | 0.7576 |
| 7    | Bank Sinarmas(I)                   | 0.4400 | 0.6390 | 0.6892 |
| 8    | PT Bank OCBC Indonesia(I)          | 0.4283 | 0.5371 | 0.7971 |
| 9    | Bank Rakyat Indonesia (Persero)(I) | 0.3331 | 0.6569 | 0.5049 |
| 10   | Royal Bank of Scotland Berhad(M)   | 0.3290 | 0.3642 | 0.9031 |
| 11   | Bank Perusahaan Kecil(M)           | 0.3290 | 0.5379 | 0.6120 |
| 12   | Kasikornbank Public Company(T)     | 0.3180 | 0.3503 | 0.9077 |
| 13   | Bank Mutiara Tbk(I)                | 0.3106 | 0.7332 | 0.4235 |
| 14   | Bank Danamon Indonesia Tbk(I)      | 0.2913 | 0.7237 | 0.4006 |
| 15   | PT Bank CIMB Niaga Tbk(I)          | 0.2717 | 0.6772 | 0.3999 |
| 16   | Bank International Indonesia(I)    | 0.2642 | 0.6911 | 0.3798 |
| 17   | Bank Mandiri (Persero) Tbk(I)      | 0.1932 | 0.8000 | 0.2392 |
| 18   | Bank Negara Indonesia (Persero)(I) | 0.1849 | 0.7167 | 0.2555 |
| 19   | Siam Commercial Bank(T)            | 0.1710 | 0.2638 | 0.6484 |
| 20   | EON Bank Berhad(M)                 | 0.1648 | 0.7307 | 0.2265 |
| 21   | Bank Central Asia(I)               | 0.1634 | 0.6821 | 0.2359 |
| 22   | United Overseas Bank PCL(T)        | 0.1432 | 0.3062 | 0.4699 |
| 23   | Krung Thai Bank Public Company(T)  | 0.0974 | 0.2951 | 0.3265 |
| 24   | Citibank Berhad(M)                 | 0.0897 | 0.3325 | 0.2688 |
| 25   | Siam City Bank Public Company(T)   | 0.0869 | 0.2923 | 0.2980 |
| 26   | Government Saving Bank(T)          | 0.0853 | 0.3063 | 0.2778 |
| 27   | Bank of America Malaysia Berhad(M) | 0.0822 | 0.2922 | 0.2817 |
| 28   | TMB Bank Public Company Limited(T) | 0.0806 | 0.2921 | 0.2748 |
| 29   | Bangkok Bank Public Company(T)     | 0.0769 | 0.2747 | 0.2776 |

|    |                                     |        |        |        |
|----|-------------------------------------|--------|--------|--------|
| 30 | Hong Leong Capital Berhad(M)        | 0.0758 | 0.2810 | 0.2712 |
| 31 | Maybank International Ltd(M)        | 0.0684 | 0.2728 | 0.2502 |
| 32 | Bank of Tokyo-Mitsubibishi UFJ(M)   | 0.0525 | 0.1973 | 0.2664 |
| 33 | RHB Investment Bank Bhd(M)          | 0.0490 | 0.2769 | 0.1762 |
| 34 | Malaysian Industrial Development(M) | 0.0437 | 0.2647 | 0.1651 |
| 35 | Bank Kerjasama Rakyat Malaysia(M)   | 0.0395 | 0.2880 | 0.1369 |
| 36 | Bank Rabobank International(I)      | 0.0357 | 0.5602 | 0.0645 |
| 37 | Hong Leong Bank Berhad(M)           | 0.0131 | 0.3782 | 0.0344 |
| 38 | AmBank Berhad(M)                    | 0.0057 | 0.1216 | 0.0467 |
| 39 | Public Bank Berhad(M)               | 0.0057 | 0.0638 | 0.0887 |
| 40 | HSBC Bank Malaysia Berhad(M)        | 0.0046 | 0.1021 | 0.0455 |
| 41 | Hong Leong Financial Group Bhd(M)   | 0.0042 | 0.0934 | 0.0448 |
| 42 | OCBC Bank Berhad(M)                 | 0.0037 | 0.0728 | 0.0510 |
| 43 | AMMB Holdings Berhad(M)             | 0.0031 | 0.1003 | 0.0310 |
| 44 | RHB Bank Berhad(M)                  | 0.0023 | 0.1097 | 0.0208 |
| 45 | RHB Capital Berhad(M)               | 0.0020 | 0.1236 | 0.0162 |
| 46 | CIMB Bank Berhad(M)                 | 0.0017 | 0.0974 | 0.0166 |
| 47 | Malayan Banking Berhad-Maybank(M)   | 0.0005 | 0.0442 | 0.0121 |

*Note:* (I) in the parentheses stands for the Indonesian banks, (M) and (T) in the parentheses stands for the Malaysian and Thai banks.