



# Cost Efficiency of Top Thai Banks: A Comparison of Classical Stochastic Frontier with Efficiency Stochastic Frontier Models

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**Abstract :** Without doubts, bank performance's evaluation has increased its importance to bank managers and policymakers as a supportive factor that will help Thailand move forward. This paper conducts an empirical investigation into the consistency of efficiency scores given by the classical stochastic frontier and efficiency stochastic frontier models. We make an estimation of cost efficiency which is based on top four Thai banks data during the period 2001 to 2016. The results suggest that all of the coefficients from efficiency SFM fall between the 5 percent and 95 percent interval and are significant compared with classical SFM which have only some significant coefficients with overestimated and underestimated signs. Relatively, the efficiency stochastic frontier model outperforms the classical stochastic frontier model in terms of higher R-squared values. Based on our finding, it shows that KBANK's TE is the only one that has moved closer to the frontier. Meanwhile, SCB bank's TE moved slightly away from the frontier. The other banks; BBL and BAY banks tend to remain steady throughout the studied period. These characteristics can be used as supplementary information for bank managers in order to achieve their higher efficiency along with observing

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financial ratios concurrently. We strongly believe that efficiency stochastic frontier models is more efficient in terms of evaluations of bank performance.

**Keywords :** cost efficiency; maximum entropy approach; Stochastic frontier analysis; Thai bank performance.

**2010 Mathematics Subject Classification :** 94A17; 68P15; 68P20.

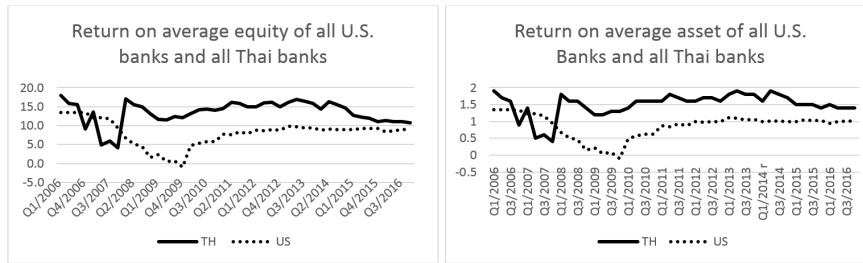
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## 1 Introduction

In order to free Thailand from the middle-income status, a lot of attention has been emphasized on financial development area where its impact has played a crucial role on bank performance. Without doubts, bank performance's evaluation has increased its importance to bank managers and policy makers as a supportive factor that will help Thailand move forward. Relatively, the growing importance of bank performance can be demonstrated in Figure 1, which shows that the return on average equity (ROE) ratio and the return on asset (ROA) ratio of Thai banks were relatively lower than those of U.S. banks a few years before the Global Financial Crisis (GFC) in 2008. Later on, the Thai banks' ratios have risen considerably, then they have stayed above the U.S. banks' ratios over the time period. However, it is obvious that there is a downward trend for the Thai banks' ratios, whereas the U.S. banks' ratios seem to have an opposite trend. The gap between them has been narrowing and this has addressed an issue whether the performance of Thai commercial banks is more efficient than U.S. commercial banks. Relatively, evaluating the effectiveness of bank performance has not only become one of the most challenging tasks in economic and econometric literature, but has also enabled bank managers to develop the way they improve financial resources across possible investment opportunities. Many studies in economic literature, such as Hermes and Lensink [1] and Demirg-Kunt and Huizinga [2], have supported that financial development plays an important role on bank performance. Meanwhile, the studies of Duisenberg [3] Petkovski and Kjosevski [4], Ayadi et al. [5], Ferreira [6] and Beck et al. [7] have showed the importance of financial development to economic growth.

It has been known that there are mainly two popular approaches to evaluate bank performance, which are the stochastic frontier analysis (SFA) and the nonparametric data envelopment analysis (DEA). The scope of this study mainly focuses on SFA and leaves DEA untouched with a comparison between classical frontier estimations and efficient frontier estimations. Classical frontier estimations are widely referred to ordinary least squares (OLS), dummy variables (within estimator), generalized least squares (GLS) estimation, the Hausman-Taylor estimation and maximum likelihood. Meanwhile efficient frontier estimation represents generalized maximum entropy (GME).

Figure 1: ROE and ROA of U.S banks and Thai banks from database of Federal Reserve Banks of St. Louis and Bank of Thailand respectively



Many researchers have tried to propose new estimation approaches. Campbell et al. [8] is one of them, who has importantly emphasized on the most important advantage of GME. With GME, it requires no bootstrapping for statistical inference. Moreover, a number of advantages generated by GME are the following. The first one is that GME is suitable for both linear and nonlinear regression models, especially for samples with small size, and non-normal errors interfered by collinearity. Furthermore, it is for the models where the number of parameters to be estimated exceeds the number of observation available. The last one is that it does not need the traditional parametric assumptions on the error distributions, especially the error inefficiency component (Golan et al.[9]).

Another study carried out by Sriboonchitta et al. [10] is another attempt to improve a stochastic frontier model with copulas function and their finding shows that the double-copula stochastic frontier model outperforms the standard model in terms of AIC. Meanwhile, Liu et al. [11] have emphasized on a Zero Inefficiency Stochastic Frontier Model (ZISFM), which developed scenarios of potential production increase and resource conservation in case of technical inefficiency removed.

This paper aims to estimate cost efficiency for Thai commercial banks with classical frontier estimation and efficient frontier estimation. The paper is divided into the following sections: Section 2 outlines the methodologies of SFA including classical frontier estimation and efficient frontier estimation respectively. Section 3 presents data. Section 4 presents empirical results including the SFA cost frontier estimators along with estimators generated by GME. Concluding remarks are provided in the last Section.

## 2 Methodology

### 2.1 Stochastic Frontier Analysis (SFA)

Stochastic frontier analysis (SFA) is not only widely applied to bank sector, but also to industries. It was initially proposed by Aigner et al. [12] and Meeusen and van Den Broeck [13] with a primary objective for efficiency measurement. Later

on, its applications to banking have broadly been revised discussed, especially in the study of Berger and Mester [14]. In this study, Thai commercial banks are regarded as multi-product firms. We begin with a standard cost or profit function with the estimation of the minimum cost or maximum profit frontier from balance sheet data. Its distance from the frontier is regarded as the efficiency measure.

The single-equation cost function is firstly introduced due to changing the sign of the one sided error of the single-equation cost function, the equation will be transformed to the production function instead (Schmidt and Sickles [15]). The model is expressed as

$$\ln TC_t = f(Q_t, W_t, Z_t; \beta) + v_t + u_t \quad t = 1, \dots, T, \quad (2.1)$$

where at  $t$  time,  $\ln TC$  presents the logarithm total cost for a bank. Meanwhile,  $Q_t$  and  $W_t$  present the various products or services produced by the bank in time  $t$  and the price of inputs in time  $t$  respectively. In other word,  $\ln TC$  refers to the cost frontier, in other words, it presents the minimum cost of producing output  $Q_t$  with input prices  $W_t$ . Furthermore,  $Z_t$  represents time trend.  $\beta$  represents a vector of technology parameters.

There are also two components involved in the random disturbance;  $v$  and  $u$ . The first component represents measurement error and other uncontrollable factors. In other words, it represents a two-side normal disturbance term with mean 0 and variance  $\sigma_v^2$  and the effects of statistical noise. In the meantime, the second component, which can be influenced by management, represents technical and allocative inefficiency sides. It represents non-negative random disturbance term that captures the effect of cost inefficiency. Relatively, the ratio of the best-practice minimum cost to the actual cost is a measure of cost efficiency (CE) (Dong et al. [16]).

Normally,  $u$  is assumed to be iid with mean  $u$  and variance  $\sigma_u^2$  and has no relationship with  $v_t$ . For the  $u$ , a half-normal distribution may or may not be assumed. Moreover, the  $u$  may or may not be assumed to be not correlated with the regressors. This might be because this depends on whether  $u$  is known or not. For  $T > 1$  (pure cross section of  $N$  firms), the equation in (2.1) is entirely the stochastic frontier of Aigner et al. [12].

## 2.2 Classical Frontier Estimation

As stated earlier, this study emphasizes on Classical frontier estimations which include ordinary least squares (OLS), dummy variables (within estimator), generalized least squares (GLS) estimation, the Hausman-Taylor estimation and maximum likelihood estimation (MLE) in company with their strengths and weaknesses in the study of Schmidt and Sickles [15].

We begin with OLS and apply it to the equation (2.1), specially to treat the term of  $v_t + u_t$  as the disturbance. Schmidt and Sickles indicated that the results of estimators are consistent only if  $N \rightarrow \infty$ , not  $T \rightarrow \infty$ , in case the individual effects ( $u$ ) are not correlated with the regressors. Consequently, OLS estimation is not preferred compared with the others.

For within estimator, one of the main considerable disadvantages is that it is not manageable to contain in the specification regressors that are unchanged over time. In fact, they vary across firms. As a result, the estimator contains some bias and is not preferred to use as a representation of inefficiency.

For GLS,  $(u)$  is regarded as random along with an assumption of no correlation with the regressors. So that, GLS is based on the consistent estimates. The consistent estimation of  $\sigma_u^2$  requires  $N \rightarrow \infty$ . Especially in case when  $T$  is small and  $N$  is large, GLS will become the strongest, and the assumption of no correlation of effects and regressors will gain additional efficiency. It can be concluded that GLS is practical in case both  $N$  and  $T$  are enormous; however if  $N$  becomes small, it becomes unworkable.

Then, MLE is proposed with an assumption of no correlation between the effects and regressors and specific distributional assumptions. In other words, it requires specific assumptions on the distribution of the inefficiency part (Tonini and Pede [6]). Usually normal distribution assumption is made for  $v$  and half normal for  $u$ . When MLE is applied, it is still possible to make these assumptions. Consequently, MLE is the most practical method compared to the previous ones.

Referring to equation (2.1), the  $v$  is assumed to be iid with density  $f(v)$  and also the  $u$  is assumed to be iid with density  $g(u)$ . Meanwhile, there is no correlation between  $u$  and  $v$  and neither of them with the regressors. Relatively, we define  $\epsilon_t = v_t + u$ , and note that these are independent over  $i$ , then the likelihood function follows easily from the joint density of  $(\epsilon_1, \dots, \epsilon_T)$ . It is expressed as

$$h(\epsilon_1, \dots, \epsilon_T) = \int_0^\infty g(u) \prod_{t=1}^T f(\epsilon_t - u) du \tag{2.2}$$

Given this density, the likelihood function is

$$L = \prod_{j=1}^N h(y_{j1} - X'_{j1}\beta, \dots, y_{jT} - \alpha - X'_{jT}\beta) \tag{2.3}$$

### 2.3 Efficiency Frontier Estimation

Comparing with the requirements of ad-hoc assumptions on the distribution of the inefficiency component for MLE, generalized maximum entropy (GME) proposed by Golan et al. [9] has been widely used to overcome the previous requirements with its following strengths. Firstly, GME can be used with both linear and nonlinear regression models, especially with small size samples. Moreover, with its ability of no assumption required on the error distributions and the error inefficiency, it is appropriate for the models that have non-normal errors and are effected by collinearity. It is also efficient for the model with its number of estimated parameters exceeding the number of available observations. Finally, it requires no assumption on the error distribution, specifically the error inefficiency component (Macedo et al. [17], Tonini and Pede [6]).

We begin to apply the cost frontier equation in (2.1) with GME according to the studies of Campbell et al. [8] and Macedo et al. [17]. The parameter vector  $\beta$  with  $R$  elements is divided into 2 parts. The first part consists of a set of  $T$  support points ( $Z_R$ ) and the second part is for probability weights ( $p_R$ ) with  $2 \leq T < \infty$  for each parameter. Each parameter will be equivalent to the product of a support point and its associated probability weight, summed over all support points. The upper and lower bounds for the supports for  $\beta_R$  refer to  $Z_{RT}$  and  $Z_{R1}$ . The coefficient vector is expressed as

$$\beta = Zp = \begin{bmatrix} Z'_1 & 0 & \cdots & 0 \\ 0 & Z'_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & Z'_R \end{bmatrix} \begin{bmatrix} p_1 \\ p_1 \\ \vdots \\ p_R \end{bmatrix} \tag{2.4}$$

where  $Z'_R$  and  $p_R$  are considered in terms of  $T \times 1$ , so  $Z$  is  $R \times RT$ , whereas  $p$  is  $RT \times 1$ .

It is also similar that there is a set of  $L$  supports with probability weights ( $w_i$ ) for the random disturbances ( $v_i$ ) with  $i=1,\dots,N$  and  $2 \leq L < \infty$  for each observation. The random disturbance vector can be expressed as

$$v = Aw = \begin{bmatrix} a'_1 & 0 & \cdots & 0 \\ 0 & a'_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & a'_N \end{bmatrix} \begin{bmatrix} w_1 \\ w_1 \\ \vdots \\ w_N \end{bmatrix} \tag{2.5}$$

where  $a'_N$  and  $w_N$  are considered in term of  $L \times 1$ , so  $v$  is  $N \times NL$ , whereas  $w$  is  $NL \times 1$ .

According to Campbell et al. [8], the GME is also extended to cover inefficiency side  $u$ . For each observation with setting up  $2 \leq J < \infty$ , we begin with a set of  $J$  support points ( $b'_i$ ) with probability weights ( $\rho_1$ ). However, the lower bound of the support points for the one-side inefficiency component is zero with positive number for all other support points for all observations, which is opposite to the two-sided disturbances.

$$b'_{i1} = 0 \forall i \\ b'_{ij} > 0 \forall i \quad \text{and} \quad j \geq 2$$

In matrix form

$$u = B\rho = \begin{bmatrix} b'_1 & 0 & \cdots & 0 \\ 0 & b'_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & b'_N \end{bmatrix} \begin{bmatrix} \rho_1 \\ \rho_1 \\ \vdots \\ \rho_N \end{bmatrix} \tag{2.6}$$

where  $b'_i$  and  $\rho_i$  are considered in terms of  $j \times 1$ , so  $u$  is  $N \times NJ$ , whereas  $\rho$  is  $Nj \times 1$ .

After combining equations (2.4), (2.5) and (2.6), the general linear equation can be expressed as

$$C = XZp + Aw + B\rho \tag{2.7}$$

where  $C$  represents the dependent variable, whereas  $X$  represents the matrix of explanatory variables from data. A priori information will be used to select the support points for  $Z$ ,  $A$ , and  $B$ . Meanwhile, the probability weights for  $om$   $w$  and  $\rho$  are produced by maximizing the entropy function:

$$H(p, w, \rho) = -p' \ln p - w' \ln w - \rho' \ln \rho \tag{2.8}$$

subject to the model constraint and the additivity constraints

$$\begin{aligned} \ln q &= XZp + Aw + B\rho; \\ I_R &= \left( I'_R \otimes 1'_M \right) p, \\ I_N &= \left( I'_N \otimes 1'_J \right) w, \\ I_N &= \left( I'_N \otimes 1'_M \right) \rho, \end{aligned} \tag{2.9}$$

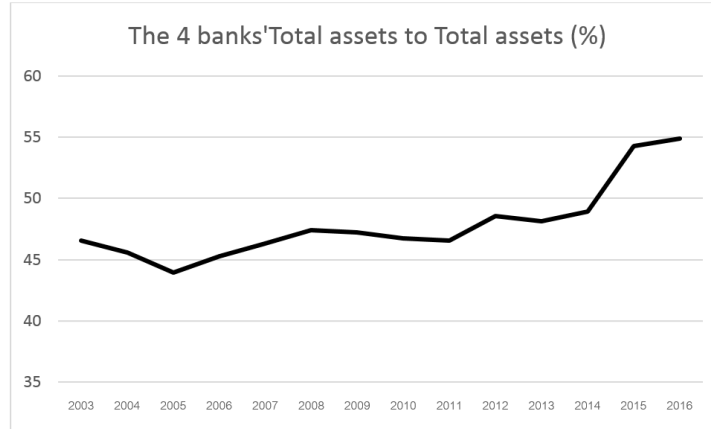
where  $I'$  presents a column of ones and  $I$  presents an identity matrix. Moreover,  $\otimes$  represents the Kronecker product. The linear cost function is imposed by the first constraint, whereas the remaining constraints make each set of probability weights sum to one. The most uniform distribution consisting of the information in the constraints will be captured by GME solution. Finally, there is only a priori information required in order to set up the support points. No assumption is required for  $u$ .

### 3 Data

As mentioned earlier, four largest banks in total assets will be selected with respect to a condition that they should be over 50 percent in terms of their total assets to all Thai commercial banks total assets. According to individual banks annual report of 2016 required by Bank of Thailand (BOT), the selected banks in alphabetical order are Bangkok Bank Public Company limited, Bank of Ayudhya Public Company limited (BAY), Kasikorn Bank Public Company limited (KBank), and Siam Commercial Bank Public Company limited (SCB).

Figure 2 presents a plot of total assets of the selected banks against time over the period from 2003 to 2016. The selected data also show that the first largest bank is BBL with assets of Baht 2,838 trillion. SCB with assets of Baht 2,661 trillion is the second largest one, followed by KBANK with assets of Baht 2,467 trillion and BAY with assets of Baht 1,805 trillion. Figure 2 also shows an upward trend in their combined assets throughout the studied period. At the end of studied period, their total assets reached almost 50 percent as demonstrated in Figure 2.

Figure 2: Total asset of four Thai commercial banks to Total asset of all Thai banks



We identify both outputs and inputs according to the intermediation definition described by Sealey and Lindley [4], who treated a bank as intermediary; a firm that receives deposited money and gains profits from them in terms of loans and other earning assets, and we also use the translog form as the deterministic kernel of cost SFA in the equation in (2.1). Three outputs are identified as three outputs; total loans, other earning assets and non-interest income, whilst three inputs are total borrowed funds, total physical capital, and labor. In order to control the effect of technical progress, time trend is included (Dong et al. [16]). The cost SFA is expressed as follows;

$$\begin{aligned}
 \ln \frac{TC}{W_3} = & \beta_0 + \sum_{i=1}^3 \beta_i \ln(Q_i) + \sum_{m=1}^2 X_i \ln\left(\frac{W_m}{W_3}\right) + \ln Z + \frac{1}{2} \sum_{i=1}^3 \sum_{j=1}^3 \varphi_{ij} \ln(Q_i) \ln(Q_j) \\
 & + \frac{1}{2} \sum_{m=1}^2 \sum_{n=1}^2 \eta_{mn} \ln\left(\frac{W_m}{W_3}\right) \ln\left(\frac{W_n}{W_3}\right) + \sum_{i=1}^3 \sum_{m=1}^2 \iota_{im} \ln(Q_i) \ln\left(\frac{W_m}{W_3}\right) \\
 & + \frac{1}{2} \ln Z + \sum_{m=1}^2 \ln Z \ln\left(\frac{W_m}{W_3}\right) + \sum_{i=1}^3 \ln Z \ln(Q_i) + u_t + v_t \quad (3.1)
 \end{aligned}$$

As stated earlier, their collected data are mainly divided into the following categories; input, output and time trend. For the Thai banks  $X_i$  is identified as input at given prices  $W_i$  that minimize total costs  $TC$  to produce output  $Q_i$ .  $TC$  refers to the sum of all costs related to borrowed funds, salaries, wages and other operational expenses. Whilst outputs consist of the three items; total loans  $Q_1$ , other earning assets  $Q_2$  and non interest income  $Q_3$ .  $Q_1$  contains customer loans, bills discounted, trade bills, entrusted loans and impaired loans with exclusion of loan loss reserves. Meanwhile,  $Q_2$  consists of balances due from other depository institutions and the central bank, inter-bank loans, investments, and securities



with exclusion of investment loss reserves. For  $Q_3$ , it contains commissions and net fees, other operating income and gains related to other relevant investments and foreign exchange transaction.

On the other side, the three input variables consist of the unit price of borrowed funds, the unit price of borrowed funds and the unit price of labor which are  $W_1$ ,  $W_2$  and  $W_3$ , respectively.  $W_1$  is the proportion of total interest expenses on borrowed funds to total borrowed funds including both short and long term deposits, deposits from other commercial banks, other depository institutions and the central bank, inter-bank funds purchased, securities sold and short and long term bonds. Meanwhile,  $W_2$  is the proportion of other operating expenses which is calculated as the operating expenses deducted by the personnel expenses of employees to the book value of fixed assets which is net of depreciation. Whereas  $W_3$  is the proportion of personnel expenses to the number of employees. However, it is importantly noted that the number of BAY employees increased sharply during 2012 - 2013 due to becoming a member of Japans largest financial group.

Table 1 provides a summary statistics for all the variables used in this study. The summary includes the minimum, maximum values of each variable including the mean, standard deviation across the top five banks for the period 2001 until 2016.

Table 1: Summary statistics of the input, output and time trend.

Variables	Mean	Min	Max	St.dev
Total costs (TC)	16.6260	96.8654	52.2115	24.8643
Total loans (Q1)	342.2765	1950.8220	984.7136	468.5483
Total other earning assets (Q2)	35.0366	894.5539	354.9702	223.5586
Non-interest income (Q3)	2.7384	66.9196	23.1394	16.0076
Price of borrowed funds (W1)	0.0049	0.0370	0.0198	0.0072
Price of physical capital (W2)	0.3061	0.9885	0.6356	0.1424
Price of labor (W3)	0.0002	0.0011	0.0007	0.0002
Time trend (Z)	1	16	8.5	4.6462

Unit : one thousand million Baht

## 4 Empirical Results

We begin to focus on the relationship between the ratios of total cost ( $TC$ ) to the ratio of personnel expenses to the number of employees ( $W3$ ) and time trend as shown in Figure 3. It is interesting to note that all variables have been applied with logarithm transformation. The only relationship between them showing a negative sign belongs to BBL throughout the studied period. Meanwhile, for BAY, KBANK, and SCB the relationships are positive during the same period.

The next step is to focus on the relationship between  $TC$  and each variable

across all the studied banks. Figure 4 shows that it is clear for all of them that have the positive relationship over the studied period except the relationship between  $TC$  and  $W1$  which is slightly negative throughout the studied period.

Figure 3: Plotting  $\ln(TC/W3)$  to time trend for each bank 2001-2016

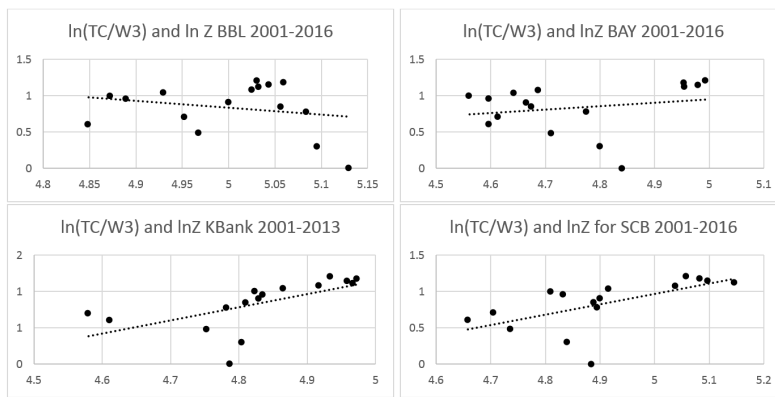
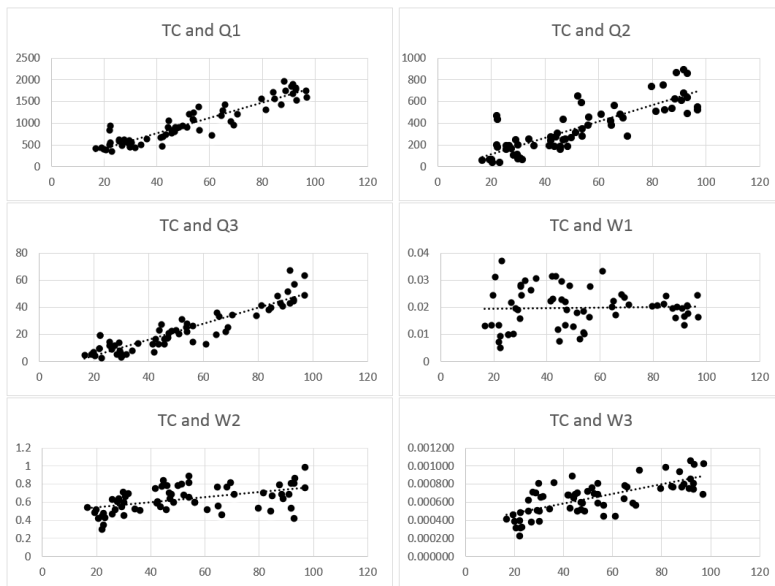


Figure 4: Plotting  $TC$  with all variables 2001-2016



The results of R-squared performance shown in Table 2 report that R-squared values of the efficiency frontier estimation and classical efficient frontier estimation

fall between 0 and 1.  $R^2$  values obtained from the first method are 0.999999183, 0.999997279, 0.999999642, and 0.9999997080 for BBL, BAY, KBANK and SCB, meanwhile, the second one generated 0.999998694, 0.999993608, 0.999999322, 0.999996674 respectively. Overall efficiency frontier estimation seems a better fit as its  $R^2$  values for each bank are higher than those values of classical efficient frontier estimation.

Table 2: R-squared Efficiency Frontier Estimation and Classical Efficient Frontier Estimation

Method	BBL	BAY	KBANK	SCB
Efficiency Frontier Estimation	0.999999183*	0.999997279*	0.999999642*	0.9999997080*
Classical Efficient Frontier Estimation	0.999998694	0.999993608	0.999999322	0.999996674

Note \* denotes the higher values compared with the other method

Table 3 shows the coefficients for each bank generated by both classical SFM and Efficiency SFM. An interesting point is that all of the coefficients from efficiency SFM falls between the 5 percent and 95 percent interval compared with classical SFM which has only some significant coefficients. Furthermore, they are both overestimated and underestimated.

For BBL bank, four significant variables consist of intercept, total other earning assets, price of borrowed funds and price of physical capital with their positive values of 2.766, 0.346, 0.451 and 0.127 respectively. In comparison between the two methods, only the price of physical capital is significant at 5 percent with an underestimated sign, meanwhile the rest are significant at 1 percent with an overestimated sign.

Furthermore, the results for BAY banks are significantly similar to the previous results, but with only three variables that have a positively significant sign. The variables consist of total loans, price of borrowed funds and price of physical capital and the coefficients of the first variable is significant at 1 percent with an overestimated sign, compared with the other variables with an underestimated sign.

Considering the fewer number of significant coefficients generated by classical SFM, KBANK is the only one with two variables. They are total loans and price of borrowed funds with coefficients of 1.063 at significant level of 5 percent and 0.365 at significant level of 1 percent with an overestimated sign and an underestimated sign respectively.

In contrast, SCB Bank is the only one that has a variable with a negatively significant coefficient at 1 percent level. That variable is price of labor with an overestimated sign for its coefficient. The variable of total loans shows an overestimated sign which is 1.052 at 1 percent significant level. Meanwhile, the variables of price of borrowed funds and price of physical capital show positive coefficients which are 0.304 and 0.392 at 1 percent significant level, respectively with an underestimated sign.

Table 3: A comparison between Classical SFM and Efficiency SFM

Banks	Variables	Classical SFM		Efficiency SFM		
		Coefficient	Std. Error	Coefficient	Q5	Q95
BBL	Intercept	2.766***	0.600	1.145 <sup>†</sup>	0.104	1.211
	Total loans	0.059	0.163	0.478 <sup>†</sup>	0.361	0.500
	Total other earning assets	0.346***	0.094	0.309 <sup>†</sup>	0.176	0.380
	Non-interest income	0.016	0.075	0.008 <sup>†</sup>	-0.009	0.010
	Price of borrowed funds	0.451***	0.053	0.418 <sup>†</sup>	0.367	0.445
	Price of physical capital	0.127**	0.046	0.321 <sup>†</sup>	0.295	0.479
	Price of labor	0.034	0.080	-0.052 <sup>†</sup>	-0.124	0.053
BAY	Intercept	0.159	0.165	0.199 <sup>†</sup>	-0.159	0.640
	Total loans	1.092***	0.104	0.929 <sup>†</sup>	0.775	1.105
	Total other earning	-0.138	0.112	-0.044 <sup>†</sup>	-0.064	0.009
	Non-interest income	0.014	0.046	-0.011 <sup>†</sup>	-0.016	0.014
	Price of borrowed funds	0.453***	0.052	0.479 <sup>†</sup>	0.402	0.521
	Price of physical capital	0.371***	0.045	0.432 <sup>†</sup>	0.233	0.503
	Price of labor	-0.050	0.048	-0.013 <sup>†</sup>	-0.116	0.056
KBANK	Intercept	0.363	0.937	0.500 <sup>†</sup>	0.184	0.661
	Total loans	1.063**	0.391	0.902 <sup>†</sup>	0.769	1.000
	Total other earning	0.073	0.137	0.092 <sup>†</sup>	0.026	0.100
	Non-interest income	-0.048	0.361	-0.007 <sup>†</sup>	-0.011	0.005
	Price of borrowed funds	0.365***	0.029	0.373 <sup>†</sup>	0.355	0.450
	Price of physical capital	0.284	0.178	0.347 <sup>†</sup>	0.316	0.480
	Price of labor	-0.170	0.153	-0.116 <sup>†</sup>	-0.127	-0.038
SCB	Intercept	0.606	0.142	0.659 <sup>†</sup>	0.379	0.745
	Total loans	1.052***	0.119	0.858 <sup>†</sup>	0.729	0.900
	Total other earning	-0.121	0.055	-0.020 <sup>†</sup>	-0.047	0.046
	Non-interest income	-0.025	0.043	-0.004 <sup>†</sup>	-0.011	0.004
	Price of borrowed funds	0.304***	0.016	0.342 <sup>†</sup>	0.317	0.397
	Price of physical capital	0.392***	0.012	0.437 <sup>†</sup>	0.412	0.532
	Price of labor	-0.160***	0.036	-0.093 <sup>†</sup>	-0.117	-0.016

Note \*\*\* and \*\* denote significance level at 1, 5 percent. <sup>†</sup> denotes the values falling between the interval.

Figure 5: Technical efficiency for each bank

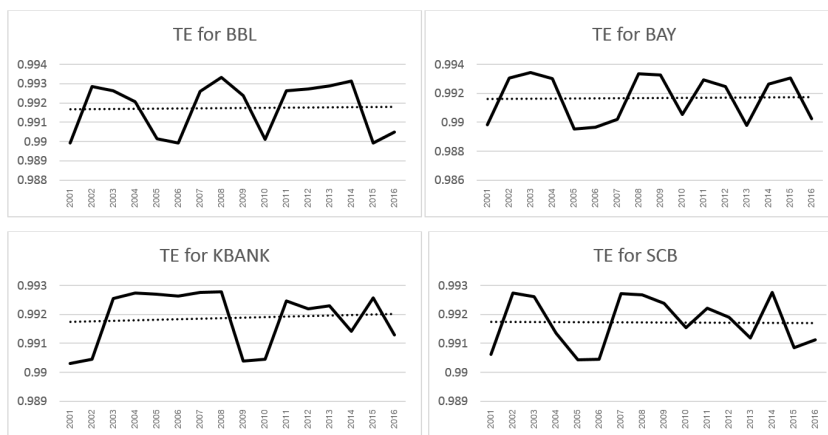


Figure 5 contains a summary of results of technical efficiency (TE) during the studied period. Results for individual bank can be compared with one another's.

It is known that TE change is a measure of how far each bank has moved from the efficient frontier over the time period of interest. The results suggest that each bank has moved slightly away from the frontier and remained almost steady on overall. One of the interesting things is that KBANK's TE is the only one that has clearly moved closer to the frontier during 2003-2008. Meanwhile, the rest moved in the same pattern throughout the study period. The average line of SCB Bank moved slightly away from its frontier. On the contrary, the average line of KBANK moved closer to its frontier and the rest remained steady throughout the studied period. We also found that all of the selected banks' TEs moved away from their frontier with a downward trend during the period 2008 - 2010 due to the financial global crisis and big flooding in Thailand.

## 5 Conclusion

The study has drawn more attention to both bank managers of the selected banks, namely Bangkok Bank Public Company limited, Bank of Ayudhya Public Company limited (BAY), Kasikorn Bank Public Company limited (KBANK), and Siam Commercial Bank Public Company limited (SCB) and policymakers in order to monitor the banks' performance with respect to classical SFM and efficiency SFM. The empirical results of R-squared values show that efficiency SFM is a better fit than classical SFM in terms of providing higher  $R^2$  values. This empirical result is consistent with the study of Campbell et al. [8] and Macedo et al. [17].

The study also shows an interesting point that all of the coefficients from efficiency SFM fall between the 5 percent and 95 percent interval and are significant compared with classical SFM which have only some significant coefficients with overestimated and underestimated signs.

For technical efficiency, it is interesting to know that KBANK's TE is the only one that has clearly moved closer to the frontier. Meanwhile, SCB's TE moved slightly away from the frontier. The other banks tend to remain steady throughout the studied period. This results can be used as supplementary information for bank managers in order to achieve their higher efficiency along with observing financial ratios concurrently.

However, another research question focusing on the possible efficiency differences between banks of different size has still remained too. Four selected banks used as the sample size in this study are still considered a small number to represent the overall performance in banking sector. Primary recommendation for further study focuses on larger sample size which contains all commercial bank data in Thailand in order to investigate the previous question.

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