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Incorporating Risk into Technical Efficiency via a Semiparametric Analysis: The Case of ASEAN Banks

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Abstract: The objective of this paper is to incorporate risk in the technical efficiency of listed ASEAN banks in a panel data framework for the period 2000 to 2015. Many researchers apply frontier estimation techniques such as data envelopment analysis (DEA) or stochastic frontier analysis (SFA) for their efficiency analysis. However, the banks' complex production process requires more sophisticated techniques to account for internal structures within the black box, so relying on only traditional DEA or SFA is not adequate to deal with a multiple-input and multiple-output production technology. To incorporate undesirable outputs such as risk into inefficiency, we rely on the directional distance function (DDF). We employ the DDF under both a parametric (SFA) and semi-parametric (SEMSFA) framework to make comparison efficiency scores with risk adjusted in two scenarios. Our results suggest that risk is such an important factor that bank managers should pay more attention to achieve long-term efficiency in ASEAN banks.

Keywords: Technical efficiency, risk, directional distance function (DDF), semiparametric estimation of stochastic frontier models (SEMSFA), ASEAN Banks.

1. Introduction

We try to incorporate risk into measuring the technical efficiency of banking institutions in the Association of Southeast Asian Nations (ASEAN)[1] alliance. Our motivation commences from a gap that exists in the literature. From a search of efficiency analysis in the ASEAN banking sector we find risk is ignored in examining efficiency in the articles of Wong and Deng (1999), Karim (2001), Gardener, Molyneux and Nguyen-Linh (2011), Williams and Nguyen (2005), Sarifuddin, Ismail, and Kumaran (2015), Chan, Koh, Zainir, and Yong (2015) [1-6]. The ignorance of risk in the

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[1] Originally established in Bangkok in 1967 and consisted of five member countries (Indonesia, Malaysia, Philippines, Singapore, and Thailand), the Association of Southeast Asian Nations (ASEAN) is nowadays a diverse group of five original states (ASEAN-5) and five newer members: Brunei Darussalam, Cambodia, Lao P.D.R., Myanmar, and Vietnam (BCLMV), aiming towards a politically cohesive, economically integrated, and socially responsible community.

literature can lead to a bias in efficiency estimation. For example, Berger and Humphrey (1997) argue that efficiency can be underestimated without risk consideration [7]. Some articles included risk as an environmental variable or regarded it as exogenous in the analysis of efficiency effect, such as Khan (2014), Yueh-Cheng Wu (2016) [8, 9]. Sarmientoa and Galán (2015) also posit the inaccuracy of efficiency (over and under estimation) when risk measures are not modeled [10]. To avoid the problem, we follow the intermediation approach to model bank production with loans, investment, and non-interest income seen as good outputs whereas non-performing loans (NPL) is seen as a bad output.

In the circumstance that financial liberalization is an inevitable trend of global and regional integration, it is very meaningful to properly incorporate risk in banking efficiency analysis for policy implications. At the end of 2015, the creation of the ASEAN Economic Community (AEC) has created both chances and challenges for member nations on the road to achieving a highly integrated and cohesive economy in ASEAN. To support economic development, the banking systems in many ASEAN countries are still a primary source for raising capital. Banking assets made up more than 82% of total financial assets in ASEAN in 2009 and for the BCLMV[2], the figure was even higher, at 98%, according to a study of ADB (2013) [11]. To promote financial integration, ASEAN members have implemented the ASEAN Banking Integration Framework (ABIF) since December 2014, allowing banks satisfying certain criteria (Qualified ASEAN Banks - QABs) to expand their business in other member nations and be equally treated as domestic banks.

One benefit of the integration is that domestic banks could have more chances to attract capital flows from foreign investors to raise their chartered capital under the QABs' requirements. However, the greater the integration in the banking sector and the greater the competition and improved quality of services, the higher the pressure is for commercial banks in the ASEAN region to adapt and operate efficiently so that they can shorten competitiveness gaps in the common playground. Since QABs' basic standards require banks to meet appropriate risk management and internal control, risk and efficiency become more connected. Greater banking openness, on the other hand, could lead to greater vulnerability as risks to financial stability in one country can spill over more quickly to another. The stories about the regional financial crisis in 1997 and the global economic downturn in 2008 remind us that incorporating risk in banking efficiency for banks in ASEAN nations is not only important for financial intermediaries but also for supervising sectors to promote safe and sound policies for the ASEAN banking system.

This paper, therefore, aims not only to measure efficiency of the commercial banks in ASEAN, but also the incorporating of risk into efficiency. Efficiency with good outputs and efficiency with both good and bad outputs in the ASEAN banking industry can be solved by applying the directional distance function (DDF), originally proposed by Färe et. al (2005) [12] and customized by Huang, Chiang, and Tsai (2015) [13], and semi-parametric (SEMSFA), a new approach developed by Vidoli and Ferrara (2015) [14].

The remainder of this paper is organized as follows. In Section 2, the literature on incorporating risk in banking efficiency analysis in the ASEAN region is reviewed. In Section 3, we describe the methodology used in the paper and Section 4 discusses the data and input/output selection. Section 5 presents the empirical results, and finally the conclusion and future research are given in Section 6.

[2] Brunei Darussalam, Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, and Vietnam.

2. Literature on incorporating risk in banking efficiency in ASEAN

2.1. Incorporating risk into bank efficiency

There are two strands of focusing on the incorporating of risk in efficiency. One regards risk as exogenous factors, i.e. not relevant in the production process, and the other way considers risk as endogenous elements in production modeling. Berger and DeYoung (1997) considers risk as an exogenous factor in a Granger-causality model to examine the relationship between NPLs (a credit risk proxy) and cost efficiency [15]. By a totally different way, Chang (1999) [16] follows the nonparametric model proposed by Fare, Grosskopf, and Lovell (1985) [17] and treats risks as endogenous and undesirable outputs, namely NPLs, allowance for loan losses, and risky assets. To test the statistically significant differences between efficiency scores when employing three risk indicators alternatively, he uses ANOVA, Kruskal-Wallis and Wilcoxon rank-sum methods. Zhu, Wang, Yu, and Wu (2016) [18] call on the advantages of both the parametric and non-parametric directional distance function to estimate technical efficiency of forty-four Chinese commercial banks during 2004-2011 and use NPLs as a proxy for risk as one undesirable output, to freely adjust direction vectors to incorporate banks' risk preferences. Collecting unbalanced panel data over the period 1995-2008 from 17 Central and Eastern European countries, Huang, et al. (2015) [13] develop a new meta-frontier directional technology distance function under a SFA framework and regard NPLs as an undesirable output in cost efficiency estimation.

While the current literature mainly focuses on the impact of credit risk indicators on bank efficiency, Chang and Chiu (2006) [19] consider how credit (NPLs) and market risks (Value at Risk of bank asset portfolios) associate with efficiency via a DEA model and Tobit regression in Taiwan's banking industry from 1996-2000. They employ the Wilcoxon matched-pairs signed-ranks test to test statistically significant differences in the efficiency index of each scenario: without risk, with credit risk or market risk only, and with both risk types. Sarmientoa and Galán (2015) [10] propose a Bayesian SFA model to incorporate different types of risk, including credit risk, liquidity, capital and market risk, to derive bank-specific distributions of efficiency and risk random coefficients for Colombian banks for the period 2002-2012.

2.2. Incorporating risk into bank efficiency in the ASEAN banking sector

In this section, we try to review the studies related to incorporating risk into bank efficiency in ASEAN. To have a better look at this issue, we also direct our attention to East Asian studies of banking efficiency where necessary.

Both SFA and DEA approaches are employed for incorporating risk in banking efficiency estimation in ASEAN banks. Following the SFA approach, Karim, Sok-Gee, and Sallahudin (2010) [20] examined the relationship between efficiency and NPLs of banks in Malaysia and Singapore between 1995 and 2000. In the first stage, they use a normal-gamma efficiency distribution model proposed by Greene (1990) [21] to estimate cost efficiency scores. And in the second stage they regressed efficiency scores against NPLs and other control variables. Manlagnit (2011) [22] used the SFA model to examine the cost efficiency of Philippine commercial banks for the period from 1990 to 2006. Their findings suggest risk and asset quality affect the efficiency of banks.

The DEA approach is employed by many more researchers for its flexibility in not requiring the pre-specification of production function, its linearity and its suitability for relatively small data size for each banking system as in explanations from Gardener, et al. (2011) [3]. Khan (2014) [8] proposes the intermediation DEA approach with an input-oriented model to incorporate external environmental variables on Southeast Asian banking efficiency analysis. Using bank data from five countries in the region from 1999-2005 in a four-stage DEA procedure, they calculate adjusted values for inputs by allowing slack or surpluses due to the environment variables.

Laeven (1999) [23] also applies the DEA technique to measure the efficiencies of banks in Indonesia, Korea, Malaysia, the Philippines, and Thailand for the pre-crisis period 1992-1996 with some adjustments. Choosing the intermediate approach but using it differently from other researches, he bases his attention on the output orientation to calculate technical efficiency, instead of aiming to input minimization. He also points out that, due to weak enforcement of banking regulations, bad loan data may not be inadequately reported as NPLs so applying this data in efficiency models might lead to incorrect conclusions. In the case of East Asia, his finding is that banks may be in better shape than they seem to be because of distinct NPL classification. In those countries, until 1997, only loans overdue for over one year were classified. To avoid this problem therefore, he chooses excessive loan growth as a good proxy for bank risk-taking, instead of NPLs. However, in his research, Laeven (1999) [23] also shows some weaknesses of DEA, including difficulty in efficiency comparison, not considering statistical noise or small samples. Hence, Tone and Tsutsui (2014) [9] instead of choosing a traditional DEA, applies a newly developed dynamic network DEA (DN-DEA) formulated by Tone and Tsutsui (2014) [24] to measure inefficiency with loan loss provision as a bad output. This method is useful in measure inefficiency of divisions and branches of banks because it allows for interaction between divisions and branches embedded inside the banks' production process.

2.3. Applying the directional distance function under parametric (SFA) and semi-parametric (SEMSFA) framework to incorporate risk into measuring ASEAN banking efficiency

The literature relating to incorporating risk in banking efficiency almost always proposes either DEA or SFA or a combination of both for comparison purposes. As pointed out by Andor and Hesse (2014) [25], DEA is a linear-based technique that constructs a nonparametric envelopment frontier over the data points. As to DEA's advantage, it does not require the pre-specification of production function but it estimates efficiency without considering statistical noise and is thus deterministic. Conversely, SFA requires an assumption about the functional form of the production function and allows measuring efficiency while simultaneously considering the existence of statistical residuals. Because of their methodological differences and equivalent advantages and disadvantages, they are the two most popular approaches for measuring efficiency.

Even though DEA is frequently used in the banking sector for efficiency measurement, the approach is "not sufficient to measure the banks' complex production process because these models assume the system as a single black box that converts inputs to outputs" [9]. Instead, bank production requires techniques to account for internal structures within the production process. Regarding traditional SFA, the traditional stochastic frontier model[3] also cannot solve the multi-output production, which is very common in the banking industry. Hence, some researchers, such as Huang, et al. (2015) [13] and Zhu, et al. (2016) [18], apply the directional distance function (DDF) to freely

[3] The SFA model is defined as $y_{it} = f\left(x_{it};\beta\right)+\upsilon_{it}-u_{it}$, where $Y_{it} \in \Re_{+}$ is the outputs of bank i at time t, $X_{it} \in \Re_{+}^{p}$ is the vector of inputs, $f(.)$ defines a production (frontier) relationship between inputs X and the outputs Y, $v_i \sim N(0,\sigma_v^2)$ is a symmetric two-side error representing random effects and $u_i > 0$ is one-side error term representing technical inefficiency $u_i \sim N(0,\sigma_u^2)$.

adjust direction vectors. Huang, et al. (2015) [13] apply DDF under a SFA framework whereas Zhu, et al. (2016) [18] compare efficiency indexes under both parametric and non-parametric frameworks. The DDF is useful in modeling undesirable outputs in a different manner of desirable outputs while other inefficiency measurements only permit either inputs' savings or output expansion, but not both simultaneously. Allowing dealing with a multiple-input, multiple-output production technology, DDF can support simultaneously quantifying input saving and output expansion.

Vidoli and Ferrara (2015) [14] recently introduced and combined the strengths of the SFA and DEA methods, using a semi-parametric (SEMSFA) method that is stochastic and semi-parametric, requiring no a priori explicit assumption about the functional form of the production function. In this study, we employ the DDF under both a parametric (SFA) and semi-parametric (SEMSFA) framework and then compare efficiency scores with risk adjusted in two scenarios. The next section provides more details about our methodology for measuring ASEAN's banking efficiency concerning risk.

3. Methodology

To incorporate undesirable outputs into inefficiency, we rely on the DDF measures that treat both sets of outputs differently. This requires a redefinition of the production technology where outputs $y \in \Re_{+}^{M}$ are partitioned into desirable and undesirable outputs $y,b=(y,b), y \in \Re_{+}^{D}, b \in \Re_{+}^{u}$. Then, the production technology with undesirable outputs is given by

$$T=\{(x,(y,b)): x \text{ can be used by banks to produce } (y,b)\} \quad (1)$$

The DDF measure can be extended in a way that maximizes the radial increase in good outputs as well as the radial decrease in both inputs and bad outputs along the directional vector.

$g=(g_x, g_y, g_b) \in \Re_{+}^{N} \times \Re_{+}^{D} \times \Re_{+}^{B} : g \neq 0$:

$$\vec{D}_T(x,y,b;g_x,g_y,g_b)=\max_{\beta}\{\beta \in \Re_{+} : x-\beta g_x, y+\beta g_y, b-\beta g_b, \in T\} \quad (2)$$

To solve this optimization, there are two options. Firstly, one can follow a non-parametric approach, which finds β that maximizes the equation (2). Secondly, one can choose a parametric approach by following functional form with translation property:

$$\vec{D}_T(x-\beta g_x, y+\beta g_y, b-\beta g_b; g_x,g_y,g_b)=\vec{D}_T(x,y,b;g_x,g_y,g_b)-\beta \quad (3)$$

The translation property suggests that if we "translate" the vector (x,y,b) into $(x-\beta g_x, y+\beta g_y, b-\beta g_b)$, then the value of the distance function is reduced by the scalar β. We apply the translation property to measure efficiency via the quadratic DDF regression equation. Following Färe et. al (2005) [12] and Huang, et al. (2015) [13], we arbitrarily choose $\beta = x_1$ to "translate" the quadratic DDF into:

$$\begin{aligned}
-x_1 &= \vec{D}_T(x-\beta g_x, y+\beta g_y, b-\beta g_b; 1,1,1,t,\theta)+\upsilon-u \\
&= \alpha_0+\sum_{n=2}^{N}\alpha_n(x_n-x_1)+\sum_{m=1}^{M}\beta_n(y_m+x_1)+\sum_{j=1}^{J}\lambda_j(b_j-x_1) \\
&+\frac{1}{2}\sum_{n=2}^{N}\sum_{n'=2}^{N}\alpha_{nn'}(x_n-x_1)(x_{n'}-x_1)+\frac{1}{2}\sum_{m=1}^{M}\sum_{m'=1}^{M}\alpha_{mm'}(y_m+x_1)(y_{m'}+x_1) \\
&+\frac{1}{2}\sum_{j=1}^{J}\sum_{j'=1}^{J}\lambda_{jj'}(b_j-x_1)(b_{j'}-x_1) \\
&+\sum_{n=2}^{N}\sum_{m=1}^{M}\gamma_{nm}(y_m+x_1)(x_n-x_1) \\
&+\sum_{n=2}^{N}\sum_{j=1}^{J}a_{jn}(b_j-x_1)(x_n-x_1) \\
&+\sum_{m=2}^{M}\sum_{j=1}^{J}c_{jm}(b_j-x_1)(y_m+x_1)+\delta_1 t+\frac{1}{2}\delta_2 t^2+\sum_{n=2}^{N}\psi_n t(x_n-x_1) \\
&+\sum_{m=1}^{M}\mu_m t(y_m+x_1)+\sum_{j=1}^{J}c_j t(b_j-x_1)+\varepsilon
\end{aligned} \quad (4)$$

where $\theta = (\alpha, \beta, \lambda, \gamma, a, c, \delta, \psi, \mu)$ is a vector of parameters to be estimated and $\varepsilon = u - \upsilon$ is the composed error term. Hence, $\vec{D}_T(\cdot)$ is the translated DDF. $u = \vec{D}_T^*(x, y, b; 1,1,1, t, \theta)$ is technical inefficiency, and υ is a two-sided, normally distributed error with a mean of zero and a constant variance σ_υ^2, which is traditionally assumed to be independent of u.

In applications, the link between x_1 and other variables in equation (4) can be estimated incorrectly by assuming that the link belongs to some specified functions such as Translog or Cobb-Douglas. To overcome these drawbacks, we use a Generalized Additive Model (GAM) framework to fit the response variable x_1 "*using a sum of smooth functions of the explanatory variables*". Thus, the model is:

$$\mu = E(x_1 | X = x) = \alpha + \sum_{j=1}^{p} f_j(X_j) \qquad (5)$$

In a panel regression setting, equation (4) becomes:

$$x_{1it} = f(x_{it}) + \upsilon_{it} + u_{it} \qquad i = 1, ..., n \qquad (6)$$

where we employ GAM to model the unknown function $f(.)$ to relax the linear assumption between inputs and outputs. We estimate the conditional expectation of the mean frontier $E(x_1 | X = x)$ and two error term parameters $(\sigma_\upsilon, \sigma_u)$. To smooth the fitted production frontier, we use thin plate regression splines to represent the $f_j^{'}s$ smooth function with smoothing parameters selected by Generalized Cross Validation (GCV) criterion:

$n * \dfrac{D}{(n - \text{DoF})^2}$ where D is the deviance, n is the number of data and *DoF* the effective degrees of freedom of the model.

Relying on the mean frontier $E(x_1 | X = x)$ we estimate the production function $f(.)$ by shifting the estimation of the conditional expectation in an amount equal to the average estimate of the expected value of the term of inefficiency. Then we consider the estimation of model (6) with the unknown $f(.)$ modeled using penalized regression splines with a penalty by introducing the effects of interactions among covariates in the following way:

In step 1, we use the semiparametric (or nonparametric) regression techniques to relax parametric restrictions of the functional form representing technology.

$$f(.) = \alpha + \sum_{j=1}^{p} f_j(x_j) + \sum_{j=1}^{p} \sum_{k<p}^{p} f_{kj}(x_k, x_j) + \beta_z + ..., \qquad (7)$$

In step 2, we estimate variance parameters by pseudo-likelihood estimators.

$$\min_{\alpha,\beta,\delta,f} \left\{ \left\langle \sum_{i}^{n} \left(y_1 - \hat{f}_i - z_i\delta \right)^2 \middle| \begin{array}{l} \hat{f}_i = \alpha_i + \beta_i^{'} x_i, \forall i = 1, ..., n \\ \alpha_i + \beta_i^{'} x_i \le \alpha_h + \beta_h^{'} x_i, \forall h = 1, ..., n \\ \beta_i \ge 0, \forall i = 1, ..., n \end{array} \right\rangle \right\} \qquad (8)$$

where δ is the average impact of variables z_i on performance and $z_i'\delta + u_i$ is viewed as the overall efficiency of bank i, $z_i'\delta$ represents technical inefficiency that is explained by the contextual variables, and the component u_i represents the proportion of inefficiency that remains unexplained.

4. Data description

The data used in this study are taken from FitchConnect. Our main target is listed banks from ASEAN countries. Relying on the FitchConnect database, we compile unbalanced panel data from 2000-2015 from 6 ASEAN countries, including Indonesia, Laos, Malaysia, the Philippines, Thailand, and Vietnam. We exclude bank-year observations with *n.a* value for our input and output variables, forming a sample of 1,296 bank-year observations.

We identify inputs and outputs in accordance with the intermediation approach. For the inputs of banks, we select labour expense (x_1), fixed assets as physical capital (x_2), and borrowed funds (x_3) which are total deposits and short-term borrowings. For the desirable outputs, we employ total loans (y_1), investment (y_2), and noninterest income (y_3). In addition to these good outputs, we consider provision for loan loss (b) as a proxy for undesirable output. We also include micro and macro environmental factors to reflect the different atmospheres to explain technical inefficiency. The micro factors include the ratio of equity to total assets (z_1) and the liquidity position (z_2) which is the ratio of liquid assets to total assets. The macro environment factors are GDP growth (z_3) and the Herfindall-Hirschman index (HHI) competition index (z_4). We use GDP growth to represent the overall economic condition, influencing the bank activities and this efficiency. HHI is used to measure the market concentration or competition pressure where banks operate.

Table 1 shows the sample statistics for inputs, outputs, and environmental factors. The average amounts of good outputs, including loans, investments, noninterest income, are 6,895, 2,269, and 158 million US dollars, respectively. The mean of bad outputs (loan loss provision) is equal to 61 million US dollars. Three inputs have means at 119, 145, and 9,382 million US dollars, respectively. The micro environmental factors reveal banks in ASEAN with good capitalization and in a liquid position, showed by an average equity ratio at 12.03% and liquidity at 70%. Finally, the macro environment factors suggest a highly-concentrated market with a HHI index at 2,938 and relatively high GDP growth rate at 5.38%.

Table 1. Descriptive statistics

Variables	**Symbol**	**Mean**	**St. Dev.**
Outputs			
Loans	y_1	6,895.62	13,907.39
Investment	y_2	2,269.53	4,199.92
Noninterest income	y_3	158.86	306.52
Undesirable	b	61.69	134.84
Inputs			
Labour	x_1	119.97	209.62
Physical capital	x_2	145.47	231.48
Borrowed funds	x_3	9,382.86	16,857.11
Environment			
Equity/Total assets (%)	z_1	12.03	9.83
Liquidity (%)	z_2	70.31	20.52
GDP growth (%)	z_3	5.38	1.73
HHI	z_4	2,938	2233.11

Source: Authors' computation from FitchConnect.

5. Estimation results

5.1. Primary results of DDF and SEMSFA

In this section, we present results of ASEAN bank efficiency by DDF and SEMSFA. Technical efficiency is the outcome of comparing one bank to the best performing bank on the frontier line. Our efficiency estimation is displayed in Figures 1a and 1b. Both approaches yield the efficiency with provision for loan loss (as a proxy for an undesirable output) that is higher than the efficiency without the bad output. Their corresponding efficiencies are 67% and 63% under SEMSFA, and 71% and 69% under DDF. Figures 1a and 1b show the densities of efficiency, in which the density of efficiency with bad outputs (the red line) lies to the right of the density of efficiency with good outputs (the green line). The difference looks illogical because efficiency with bad output should be lower than that with good ones.

The reason for the illogical difference originates from the adjustment of the performance of the best banks in terms of risk. The adjustment degrades the performance of the best bank so that the frontier line moves toward the coordinate angle. Once the performance of the benchmark decreases, the performance of other banks tends to upgrade. From the degradation of the best bank and the upgradation of the rest of the banks when we take risk into account, we can conclude that the best performer faces higher risk. Hence, it is necessary to incorporate risk into examining bank performance.

5.2. Efficiency of ASEAN banks

Results from DDF show that there is not much difference between the two types of efficiency: with and without the bad output for ASEAN banks. One interesting finding for Vietnam banks is their relatively better performance compared to banks from other ASEAN countries even after taking risk into account. In other words, banks in Vietnam are both more efficient and safer than their peers in ASEAN as indicated in Figure 2d.

However, we are doubtful about the amount of provision for loan loss of banks in Vietnam. The provision is set up relying on their nonperforming loans. Our suspicion originates from the very low nonperforming loans which are disclosed by both banks and the State Bank of Vietnam. As the non-performing loans are underestimated, the disclosure does not capture the real risk of banks in the country and banks in Vietnam may become riskier because of their low provision for loan loss.

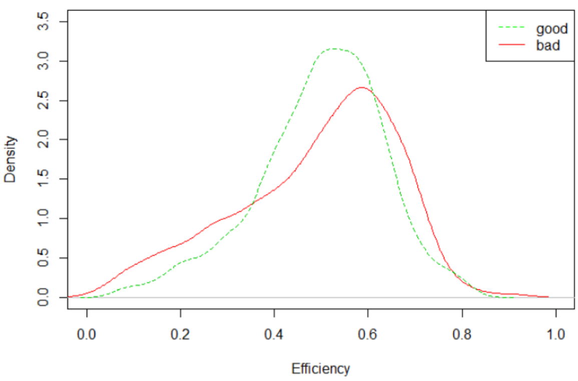

Figure 1a. Efficiency under SEMSFA.

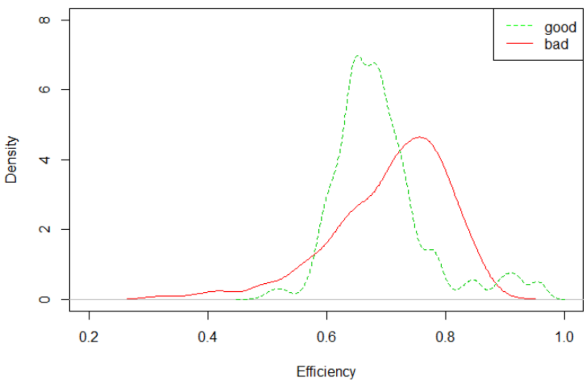

Figure 1b. Efficiency under DDF.

Source: Authors' computation from FitchConnect.

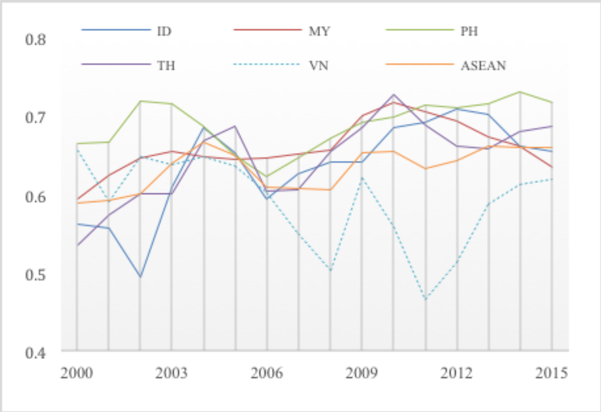

Figure 2a. SEMSFA's efficiency without risk.

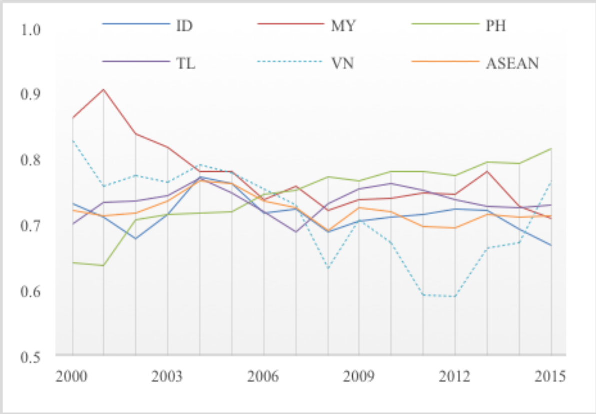

Figure 2b. SEMSFA's efficiency with risk.

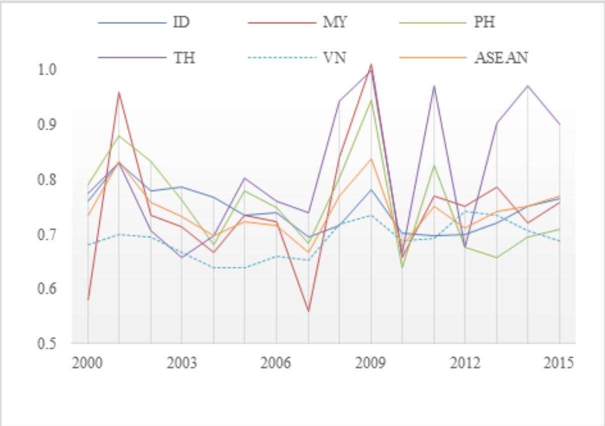

Figure 2c. DDF's efficiency without risk.

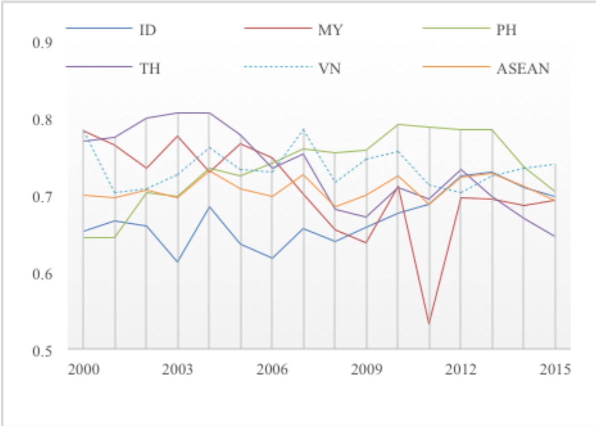

Figure 2d. DDF's efficiency with risk.

Source: Authors' computation from FitchConnect.

If their clients cannot pay loans when due, the banks may not have enough resources to deal with the credit risk and liquidity risk. To stop "systemic risk" among banks, the State Bank of Vietnam has recently acquired 5 distressed banks. The acquisition supports our scepticism about the fact that nonperforming loan ratio of banks in Vietnam is "flattened". Hence, we plan to look for other risk measures, such as market risk or liquidity risk, to incorporate into efficiency measurement because these alternative risk measures are harder to flatten like NPL.

Under SEMSFA, our results review a more accurate efficiency of banks from Vietnam. To put it specifically, Figures 2a and 2b show their relatively poor performance during 2006-2014. The poor performance taking place for a long period since 2006 is a signal of the instability of the Vietnamese banking industry. We emphasize that the low level of loan loss provision is a root cause of this instability and it takes a longer period for Vietnam's banks to have enough loan loss provision to remove the true high level of bad loans.

6. Conclusion

Credit risk is an important undesirable output which has been missing in efficiency analysis in ASEAN banks. In the literature, there are two traditional approaches (nonparametric and parametric) to incorporate the undesirable output into efficiency. In this paper, we incorporate risk into efficiency measurement by the semiparametric estimation of stochastic frontier models (SEMSFA), a combination of both parametric and nonparametric approaches. Thanks to the SEMSFA, we can point out how poor the performance of banks is in Vietnam.

We argue that the poor performance originates from the perspective of bank managers and regulators in risk underestimation. Once the risk is disclosed inaccurately, the over-estimated efficiency or performance of banks in Vietnam may be sustained. We hope our suspicion of risk underestimation will be an useful suggestion for improving bank efficiency in the long term. In addition, we think that this topic can attract future research if employing alternative risk measures to nonperforming loans and loan loss provision, which are easily manipulated. Two types of alternative risk can be market risk and liquidity risk under BASEL III. The market and liquidity risk have attracted attention from scholars and policy makers because a bank cannot quickly fulfill its functions as a financial intermediary. The lateness of executing its intermediary function can lead to a negative domino effect to the whole banking system as arose in the recent financial crisis in 2007-2008.

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