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Efficiency in Vietnamese Banking: A Meta-Regression Analysis Approach

Tin H. Ho [1,2,*], Dat T. Nguyen [2,3], Thanh Ngo [4,5,*] and Tu D. Q. Le [1,2]

1 Institute for Development & Research in Banking Technology, University of Economics and Law, Ho Chi Minh City 700000, Vietnam; tuldq@uel.edu.vn
2 Vietnam National University, Ho Chi Minh City 700000, Vietnam
3 School of Finance & Banking, University of Economics and Law, Ho Chi Minh City 700000, Vietnam; datnt20704@sdh.uel.edu.vn
4 School of Aviation, Massey University, Palmerston North 4442, New Zealand
5 University of Economics & Business, Vietnam National University, Hanoi 10000, Vietnam
* Correspondence: tinhh@uel.edu.vn (T.H.H.); T.Ngo@massey.ac.nz (T.N.)

Abstract: This study explains the differences and variances in the efficiency scores of the Vietnamese banking sector retrieved from 27 studies published in refereed academic journals under the framework of meta-regression analysis. These scores are mainly based on frontier efficiency measurements, which essentially are Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) for Vietnamese banks over the period of 2007–2019. The meta-regression is estimated by using truncated regression to obtain bias-corrected scores. Our findings suggest that only the year of publication is positively correlated with efficiency, whilst the opposite is true for the data type, and sample size.

Keywords: Vietnamese banking industry; meta-regression analysis; efficiency; frontier models

JEL Classification: C13; C80; D24; G21; L25

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1. Introduction

The banking system fosters economic growth through allocating their savings to competitive firms, entrepreneurs, individuals and governments to enhance capital accumulation and profitability (Bumann et al. 2013; Pagano 1993; Rajan and Zingales 1998). Thus, efficiency measurement in the banking sector becomes one of the most intriguing issues of research in economics and finance because of the substantial impacts an efficient banking system has on the microeconomic as well as the macroeconomic development of the economy. Furthermore, the results of efficiency studies inform policy decisions and influence individual behaviors. From that branch of literature, banking has become an interesting case study for evaluating the policies of a country in attempting to regulate its national banking to increase efficiency (Aiello and Bonanno 2016; Iršová and Havránek 2010).

The ever-growing attractiveness of efficiency studies in the banking industry is also driven by various methodological concerns. Initially, the conventional view of efficient calculation using ratio analysis can be misleading as the cross-sectional variations in input and output combinations and their prices are not appropriately accounted for (Iršová and Havránek 2010). Started from Farrel (1957)'s seminal work on firms' efficiency using the so-called frontier analysis (FA) approach, researchers have developed a number of different methods to examine and evaluate the efficiency and performance of firms, or decision-making units (DMUs), in various industries, including the banking sector. Berger and Humphrey (1997) found 130 FA studies on financial institutions, mostly banks and bank branches. A more recent review of Liu et al. (2013) emphasizes that the number of studies on the banking industry accounts for the highest (about 10.31%) among 3134 empirical research papers that employed Data Envelopment Analysis (DEA) as the main methodology.

It is noted that different studies bring different outcomes (Berger and Humphrey 1997; Fethi and Pasourias 2010), mainly due to the variety of study designs underlying each work: the choice of parametric or non-parametric methods, stochastic or deterministic approaches, functional forms and specifications of the frontiers, distribution assumptions for the errors and efficiency term, the nature of the data and so on (Berger and Humphrey 1997; Boubaker et al. 2020; Fethi and Pasourias 2010; Liu et al. 2013; Paradi and Zhu 2013). Further, it has been pointed out that other factors such as the sample size, the number of inputs/outputs examined and the period covered in the study could also affect the efficiency results (Aiello and Bonanno 2016).

The conflicting results have been well-acknowledged in several fields. In social science, particularly in education, Glass (1976, p. 3) pointed out that "the individual findings of different studies can vary in confusing irregularity across contexts, classes of subjects and countless other factors". In medical, important medical questions can be studied more than once by different teams at different locations (Chalmers et al. 1977), and therefore the diverse and conflicting results of these multiple small studies on an issue makes the clinical decision-making more difficult (Haidich 2010). To address this issue, meta-analysis and then meta-regression analysis (henceforth MRA), the statistical methods that integrate the results of several independent studies together, have been used (Haidich 2010). While a certain study examines a set of observations from its own sample and generalizes the results for the whole population that the sample represents, the basic idea of MRA is very similar. In which, this analysis treats all studies on the same topic as the sample and thereafter generalizes the results for the 'true' population, i.e., the topic being examined (Tatsioni and Ioannidis 2017). Furthermore, Borenstein et al. (2009) argued that MRA collects and incorporates the results of different studies on the same topics to examine whether (and to what extent) the characteristics of each study (or expected relevant explanatory variables such as estimation method, year of publication, sample size, study design, data properties or authors' specifics, etc.) affect the findings. Even though MRA has been widely used in many fields such as psychology, epidemiology, medicine, economics (Bravo-Ureta et al. 2007; Brons et al. 2005; Nguyen and Coelli 2009; Odeck and Bråthen 2012), the use of MRA in the banking sector is still limited (Aiello and Bonanno 2016; Iršová and Havránek 2010). More especially, there is no study for the Asia-Pacific region.

Since joining the World Trade Organization (WTO) in 2007, Vietnam's economy has witnessed remarkable changes. Indeed, Vietnam is considered the next Asian dragon with an annual economic growth of approximately 6.2% from 2007 to 2019 (Nguyen et al. 2021). Since the capital market is relatively underdeveloped, the Vietnamese banking system is seen as the backbone of the emerging economy (Le 2019). To maintain a healthy and sustainable stability banking sector, it requires good quality of management, shareholder's behavior, banks' competitive strategies, risk management and efficiency. For the last criterion, several studies attempt to examine the determinants of bank efficiency in Vietnam by using DEA as a non-parametric approach and Stochastic Frontier Analysis (SFA) as a parametric approach. However, these studies show different findings. To the best of our knowledge, there is no such work summarizing the available information across prior studies to provide readers a broader overview of how frontier estimates of bank efficiency in Vietnam vary under different study circumstances. Our study, therefore, attempts to fill in this research gap by conducting an MRA examination on 27 empirical studies so far on bank efficiency in Vietnam to provide a more systematic understanding of the performance of the Vietnamese banking sector. Our research question is therefore 'Why there are differences in the efficiency scores of previous studies on Vietnamese banks?'

This study answers the above question by analyzing the differences and variances in the efficiency scores of the Vietnamese banking sector retrieved from 27 studies published in refereed academic journals during the 2007–2019 period under the framework of meta-regression analysis. To the best of our knowledge, this is the first to do so. Upon the analysis of the influences of publication year, publication type, data type, method type,

returns-to-scale assumption, sample size, efficiency estimates and the number of authors of each study on its result, we found that the efficiency scores are associated with the year of publication, data type and sample size.

The remainder of this paper is structured as follows. Section 2 provides an overview of the methodologies used in measuring bank efficiency and introduces the meta-regression analysis as our main method in this study. Section 3 presents the results and discussions while Section 4 concludes.

2. Measuring Efficiency: Methodological Issues

2.1. DEA and SFA in Banking Efficiency

Since efficiency is evaluated in relation to the best practice (Aiello and Bonanno 2016), one of the main concerns is which method is more appropriate to estimate the frontier. A common criterion of classifying the frontier models distinguishes between parametric and non-parametric approaches. The former form, based on empirical knowledge, takes inefficiency as a distance from the efficient frontier and assumes how random error will be separated from inefficiency. Among the parametric techniques, the three most common are SFA (Clark and Siems 2002), distribution-free approach (DFA) (Berger 1995) and the thick frontier approach (TFA) (Humphrey and Pulley 1997). On the other hand, the non-parametric techniques, based on employing mathematical linear programming, neither assume a particular production function nor assign a distribution to the error term. The two most commonly used formulations are DEA (Thompson et al. 1997) and its alternative variants, and the free disposal hull (De Borger et al. 1998; Cooper et al. 2007)—Appendix A provides the summary of features of these methods. In the scope of this study, we focus on DEA and SFA only, which are the most two commonly used in the technical efficiency literature irrespective of the sector being analyzed as well as in the Vietnamese banking literature.

To begin with, in DEA, the relative efficiency of a group of related decision-making units (DMUs) (i.e., a set of same-sector banks) is measured by using a linear programming technique. DEA calculates efficiency scores for DMUs by combining several inputs and outs at the same time. Next, DEA compares each DMU with those that have the same inputs and outputs using linear programming. An efficiency frontier is then described by DEA as a linear set of the most efficient units. As a result, DMUs that are not on the frontier are ineffective. The DEA determines each DMU's relative efficiency based on its distance from the efficient frontier, so the DMUs will become less efficient if they are farther away. The DEA method was first used by Charnes et al. (1978) under an input-oriented efficiency approach and the assumption of constant returns to scale (CRS), based on the principle of efficiency suggested by Farrel (1957). A variable-returns to scale (VRS) model was later proposed by Banker et al. (1984). These are the two major DEA models, and they have been used extensively in many studies.

Moving on, SFA is another popular method for estimating the efficiency proposed by Aigner et al. (1997), and Battese and Corra (1977). This approach is based on the premise that a variety of factors contribute to DMUs not being on the efficient frontier and not fully controlled by these DMUs. When building the effective frontier, SFA allows the production functions to account for the presence of errors. Random noise and inefficiency are separated from these errors. Following a symmetric normal distribution, the former reflects the factors that influence the dependent variable but not observable. Meanwhile, the latter denotes inefficiency and s often characterized by a truncated normal distribution (Berger and Humphrey 1997).

Figure 1 below illustrates the main difference between DEA and SFA. SFA can vary from the best practice DEA frontier due to measurement error and other random factors affecting output. If the error is negative, for example, SFA would be lower than DEA. On the one hand, we calculate inefficiency using DEA as the difference between the estimated output function f(x) and the x generated by x_i inputs (measured by the angled line). On the other hand, using SFA, the estimated frontier lies below and the distance from it to x is

shorter (measured by the curved line). DEA, therefore, would provide a higher estimate of inefficiency in this situation.

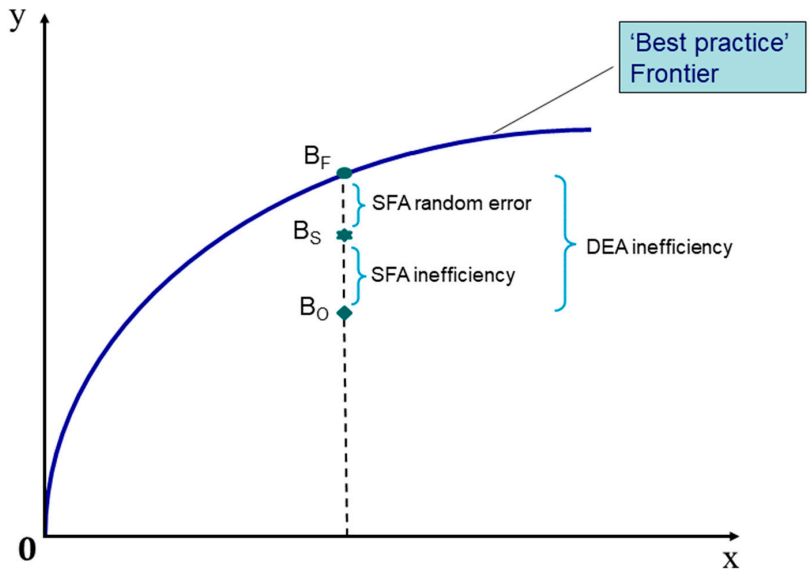

Figure 1. Illustration of SFA and DEA model

In the banking sector, DEA and SFA are widely used to measure the efficiency of banks in terms of technical (or production) efficiency, cost efficiency and profit efficiency (Berger and Humphrey 1997; Iršová and Havránek 2010). While the estimation of the former only requires physical data on inputs and outputs, which makes it become the most popular measurement in efficiency analysis (Aiello and Bonanno 2016; Odeck and Bråthen 2012), the latter two need additional information on the prices of the inputs involved (Ngo and Tripe 2016) and thus are less popular.

2.2. Meta-Regression Analysis (MRA)

It is commonly difficult to compare the findings of scientific works, even if they are on the same topic since these studies vary in several aspects. One way to deal with it is to treat each study as an independent observation and the collection of those studies as a sample representing the 'true' population which is the topic being examined. Meta-regression analysis (MRA) is a valuable statistical tool that investigates the association between the main findings of various studies (as a dependent variable of the regression model) and the characteristics of those studies, e.g., sample size, methods or studying period (as independent variables of the regression model) (Glass 1976; Glass et al. 1981; Stanley and Jarrell 1989). In this sense, MRA synthesizes different studies into a single model and assesses the impact of particular aspects of the original studies on (the variability of) the results. More details about MRA as well as its pros and cons are available in Haidich (2010); Stanley et al. (2013) and Tatsioni and Ioannidis (2017), and among others.

Even though there has been a widespread use of MRA in economics, education and medical research, only a few deals with efficiency and, when they do, the majority focuses on the agriculture sector (Bravo-Ureta et al. 2007; Thiam et al. 2001), urban transport (Brons et al. 2005), seaports (Odeck and Bråthen 2012) or hospital (Nguyen and Coelli 2009). Even though banking efficiency is among the most popular applications of FA (Berger and Humphrey 1997; Liu et al. 2013), MRA in banking efficiency is still a newly emerging issue. Iršová and Havránek (2010) are among the pioneers to use MRA to review the US banking efficiency literature with 53 observations from 32 studies in a 20-year period. Their results suggest that US banks are less efficient when generating profits than controlling costs. In another study focused on five transitional economies in Central and Eastern Europe, Iršová and Havránek (2011) found that the variety of banks' efficiency can be explained by the differences in the choice of variables (e.g., the intermediation approach

versus other approaches, see Sealey and Lindley (1997), the choice of estimation method (e.g., parametric versus non-parametric) and so on. A more recent MRA study covered 1661 efficiency scores retrieved from 120 papers published over the 2000–2014 period of Aiello and Bonanno (2016) reconfirms the above findings. Interestingly, although Aiello and Bonanno (2016) have pointed out that FA studies on bank efficiency of Asian countries accounted for 37% of their dataset, most of those studies are on Indian, Japan or Australian banks. To the best of our knowledge, however, there is no MRA study on banking efficiency in Vietnam, and our study, therefore, can contribute to the above picture.

Following Odeck and Bråthen (2012) and Aiello and Bonanno (2016), the empirical MRA model investigating the relationship between study characteristics of the Vietnamese banking efficiency scores can be presented as follows:

$$EF_i = \beta_0 + \beta_j X_{ij} \quad (1)$$

where EF_i is the (average) efficiency scores derived from study i and X_{ij} represents the matrix of covariates consisting of the study i's characteristics, and ε_i are the measurement errors. It is noted that the number of observations is equal to the number of data points extracted from the studies, i.e., one study may provide more than one observation.

By definition, the efficiency scores EFi are censored between zero and unity. Consequently, the traditional Ordinary Least Squares regression could produce biases when estimating Equation (1) and thus, Tobit regression is more appropriate to deal with such censored dependent variable (Iršová and Havránek 2010; Assaf and Josiassen 2015; Aiello and Bonanno 2016). However, it is suggested that it is practically impossible to have EF_i below or equal to zero so that EF_i is actually truncated rather than being censored—the truncated regression therefore performs even better than the Tobit regression (Simar and Wilson 2007). Our truncated MRA model is consequently represented as follows.

$$EF_i = \beta_0 + \beta_1 YEAR_i + \beta_2 DATA_i + \beta_3 METHOD_i + \beta_4 RTS_i + \beta_5 PUB_i + \beta_6 SIZE_i + \beta_7 PRODUCT_i + \beta_8 COST_i + \beta_9 AUTHOR_i + \varepsilon_i \quad (2)$$

where *YEAR* represents the year of publication of observation i; *DATA* is a dummy variable to represent the data type used in observation i that takes a value of 1 for panel data and 0 for cross-sectional data; *METHOD* is a dummy variable to account for the frontier approach of observation i that takes a value of 1 for *DEA* method and 0 for *SFA* method; *RTS* is a dummy variable that takes a value of 1 for the assumption of constant returns to scale in observation i and 0 otherwise; *PUB* is a dummy variable to represent the type of publications of observation i that takes a value of 1 for a published journal and 0 otherwise; *SIZE* represents the number of banks involved in observation i; *PRODUCT* and *COST* are the dummy variables represent the type of efficiency that are estimated in observation i, the reference measurement in this case is profit efficiency; *AUTHOR* is a dummy variable denoting the number of authors in observation i that takes a value of 1 for a single author observation and 0 otherwise.

Due to the small number of our sample, we also perform a conventional bootstrapped Tobit/truncated regression in estimating Equation (1) to improve the statistics of our results. The descriptions of our data as well as our MRA results are then presented in the next section.

3. Results and Discussions

3.1. The Data: FA Studies on Vietnamese Banking Efficiency

To construct the data sample, we searched for all studies on bank efficiency in Vietnam that use frontier analysis, both DEA and SFA. The collection of relevant literature was primarily identified through searches in several databases (Google Scholar, Science Direct and Web of Science) for a combination of the three keywords of "bank efficiency", "frontier analysis" and "Vietnam". We also used the bibliographic snowballing technique to manually check the reference lists of the retrieved articles for additional relevant studies.

Given that some studies provided more than one data point, our final sample consists of 27 studies which provide us 39 observations for the MRA estimation.

Figure 2 shows that FA studies on Vietnamese banks only emerge from 2007. In the first two years of 2007 and 2008, there were only three articles published, providing a total of five data points or observations in our sample. The number of studies has been increased since 2010, particularly after 2015, resulting in 16 articles and 21 observations for the 2015–2019 period. It is noted that the number of data points belong to the published academic journals representing for 69.23% of the sample whereas working papers accounted for 30.77%. Additionally, the number of studies conducted by a group of authors (58.97%) are higher than those performed by a single author (41.03%). Further information regarding our sample is also presented in Appendix B.

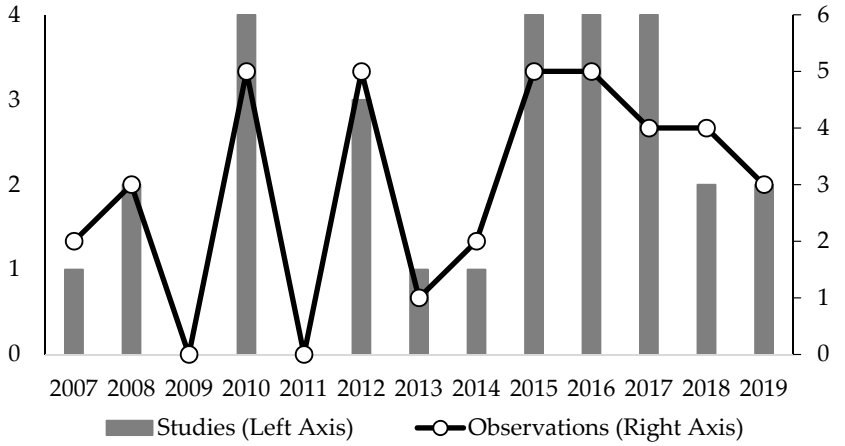

Figure 2. Numbers of SFA/DEA studies and observations on Vietnamese banks.

With respect to the type of frontier analysis, i.e., METHOD, the majority of studies (69.2%) were DEA-based while another 30.8% were SFA studies. This is understandable that DEA is often used in the context of the Vietnamese banking system due to a relatively small number of banks and the availability of their data (for example, see the dataset provided by Ngo and Le 2017)—before July 2009, Vietnamese banks were not required to publish their data (Vietnamese Government 2009). Regarding the type of data used, i.e., DATA, most studies (89.7%) used panel data whereas 10.3% used cross-section data (see Table 1). Overall, the average efficiency score of Vietnamese banks across the sampled studies/observations is 0.770, suggesting a moderate level of performance among those banks.

Table 1. Descriptive statistics of our data.

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum
EF	39	0.770	0.032	0.101	0.970
YEAR	39	2013	0.585	2007	2019
DATA (Panel = 1)	39	0.897	0.049	0	1
METHOD (DEA = 1)	39	0.692	0.075	0	1
RTS (CRS = 1)	39	0.308	0.075	0	1
PUB (Journal = 1)	39	0.692	0.075	0	1
SIZE	39	30.205	1.887	12	56
PRODUCT	39	0.769	0.068	0	1
COST	39	0.154	0.059	0	1
PROFIT	39	0.077	0.043	0	1
AUTHOR (Single = 1)	39	0.410	0.080	0	1

Notes: EF represents the average efficiency scores derived from observation *i*; *YEAR* indicates the year of publication of observation *i*; *DATA* is a dummy variable representing the data type used in observation *i* that takes a value of 1 for panel data and 0 for cross-sectional data; *METHOD* is a dummy variable accounting for the frontier approach of observation *i* that takes a value of 1 for *DEA* method and 0 for SFA method; *RTS* is a dummy variable that takes a value of 1 for the assumption of constant returns to scale in observation *i* and 0 otherwise; *PUB* is a dummy variable representing the type of publications of observation *i* that takes a value of 1 for a published journal and 0 otherwise; *SIZE* represents the number of banks involved in observation *i*; *PRODUCT* and *COST* are the dummy variables representing the type of efficiency that are estimated in observation *i*, the reference measurement in this case is profit efficiency (*PROFIT*); *AUTHOR* is a dummy variable denoting the number of authors in observation *i* that takes a value of 1 for a single author observation and 0 otherwise.

3.2. The MRA Results: Efficiency of Vietnamese Banks

Table 2 provides the MRA results for the determinants of banking efficiency in Vietnam. The consistency among the four models (i.e., Tobit regression, bootstrapped Tobit regression, truncated regression and bootstrapped truncated regression) suggests that our results are robust to the estimation method and that the findings are reliable (the final models are presented in Appendix C). The key findings for the causes of the differences in efficiency scores of previous studies on Vietnamese banks are presented as follows.

Table 2. Regression results.

	Tobit Regression		**Bootstrap Tobit**		**Truncated Regression**		**Bootstrap Truncated**	
	Coef.	***Std. Err.***	***Coef.***	***Std. Err.***	***Coef.***	***Std. Err.***	***Coef.***	***Std. Err.***
YEAR	0.029 ***	0.007	0.029 ***	0.009	0.039 ***	0.011	0.039 ***	0.012
DATA	−0.153 **	0.069	−0.153 **	0.077	−0.321 **	0.161	−0.321 ***	0.121
METHOD	0.055	0.050	0.055	0.060	0.087	0.074	0.087	0.083
RTS	−0.064	0.044	−0.065	0.051	−0.121 *	0.068	−0.121	0.075
PUB	−0.045	0.059	−0.045	0.103	−0.076	0.085	−0.076	0.132
SIZE	−0.008 ***	0.002	−0.009 ***	0.003	−0.009 ***	0.002	−0.009 ***	0.003
PRODUCT	0.120	0.071	0.120	0.150	0.163 *	0.096	0.163	0.179
COST	−0.138 *	0.078	−0.138	0.167	−0.137	0.098	−0.137	0.187
AUTHOR	−0.031	0.041	−0.031	0.053	−0.037	0.062	−0.037	0.069
Constant	−57.56 ***	14.28	−57.56 ***	18.95	−77.01 ***	22.29	−77.01 ***	24.85
Log-likelihood	31.762		31.762		39.345		39.344	
χ^2_9	47.67		45.040		54.22		48.59	
Observations	39		39		39		39	

Note: *YEAR* indicates the year of publication of observation *i*; *DATA* is a dummy variable representing the data type used in observation *i* that takes a value of 1 for panel data and 0 for cross-sectional data; *METHOD* is a dummy variable accounting for the frontier approach of observation *i* that takes a value of 1 for *DEA* method and 0 for *SFA* method; *RTS* is a dummy variable that takes a value of 1 for the assumption of constant returns to scale in observation *i* and 0 otherwise; *PUB* is a dummy variable representing the type of publications of observation *i* that takes a value of 1 for a published journal and 0 otherwise; *SIZE* represents the number of banks involved in observation *i*; *PRODUCT* and COST are the dummy variables representing the type of efficiency that are estimated in observation *i*, the reference measurement in this case is profit efficiency (PROFIT); *AUTHOR* is a dummy variable denoting the number of authors in observation *i* that takes a value of 1 for a single author observation and 0 otherwise. The dependent variable is *EF* which represents the average efficiency scores derived from observation *i*. The number of bootstraps is 2000. *Coef.* Stands for coefficient and *Std. Err.* Stands for standard errors. *, **, *** represent the significance levels at 10, 5 and 1 percent, respectively.

Firstly, the positive and significant coefficients of YEAR across the four models suggest that newer studies tend to find higher efficiency scores in Vietnamese banks. This finding is in line with another MRA study on banking efficiency of Aiello and Bonanno (2016) where it is suggested that market regulations in the financial sector over the past years have helped the banks to improve their efficiency, so do the results of efficiency studies on those banks. Note that this trend in efficiency improvement of Vietnamese banks has also been found in Nguyen et al. (2018, 2019), among others.

Secondly, DATA has a negative and significant impact on the efficiency scores, implying that FA studies utilizing panel data found the Vietnamese banks with lower performance than for studies using cross-sectional data. Similar results have been found in Iršová and Havránek (2010) and Aiello and Bonanno (2016), with a plausible explanation that cross-sectional efficiency analysis does not account for technological progress while FA studies using panel data do—technological improvement can thus contribute to the efficiency improvement of the banks (Krishnasamy et al. 2004; Ngo and Tripe 2017).

Thirdly, it is suggested that the number of banks being examined in each study/observation, i.e., SIZE (slightly) impacts the efficiency estimate: the more banks involved the lower (average) efficiency score. As discussed in Diewert (1993) and Brons et al. (2005), when the number of banks increases, the probability that those additional banks were inefficient are higher than them being efficient. Consequently, the average efficiency which is defined as the sum of all individual bank's efficiency scores divided by the number of banks will likely to decrease (Aiello and Bonanno 2016; Zhang and Bartels 1998).

Due to the limitation of our sample, we could not find a clear (and significant) relationship between other characteristics such as *METHOD*, *RTS*, *PUB*, *PRODUCT*, *COST*, *PROFIT* and *AUTHOR* and the average efficiency scores of Vietnamese banks. It is noted that this impact is inconclusive, for example, Brons et al. (2005) found that SFA studies tend to find lower efficiency scores than DEA studies whilst Aiello and Bonanno (2016) found the opposite. We suggest that further MRA on the Vietnamese banking sector when more FA studies are available in the coming years may contribute to that debate.

4. Conclusions

Our study investigated what causes the differences in the efficiency scores of Vietnamese banks retrieved from 27 bank-efficiency studies that were conducted from 2007 to 2019 using meta-regression analysis. Particularly, we examined the impacts of the year of publication, type of data used, type of method used, type of returns-to-scale assumption involved, type of publication, sample size, type of efficiency estimate involved and the number of authors of each study on its result (i.e., efficiency scores). While this study could not find a significant relationship between efficiency scores and the other characteristics (e.g., type of method or of publication involved) due to data limitation, it still provides insightful information on the efficiency of Vietnamese banks as well as its relevant studies. For instance, our findings show that efficiency scores of the Vietnamese banking sector during the 2007–2019 period is moderately high at an average of 0.770. More important, the efficiency scores tend to be higher for newer publications which may reflect the increasing trend of the performance of Vietnamese banks over time; however, it mainly comes from technological improvements rather than from the operational performance of the banks. As such, the inclusion of more (inefficient) banks in the sample tends to decrease the average efficiency score estimation. Those findings are robust to different estimation methods (i.e., Tobit and truncated regressions) and under the bootstrapping approach.

This study could be extended to a larger sample, especially for Vietnam and other emerging markets in the Asia-Pacific regions, so that more empirical evidence regarding the other characteristics (e.g., type of efficiency estimate or number of authors) can be examined. It is also interesting to apply advanced techniques such as the DEA bootstrap (Simar and Wilson 2007) or the hierarchical regression (Woltman et al. 2012) into MRA to acquire more robust and efficient results.

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Appendix A

Table A1. A Breakdown of Some Methods Used to Estimate Efficiency.

	Non-Parametric and Deterministic Approaches		**Parametric and Stochastic Approaches**		
	DEA	**FDH**	**SFA**	**DFA**	**TFA**
Functional form of the frontier	Not specified	Not specified	To be specified	To be specified	To be specified
Error disturbance	Not allowed	Not allowed	Composite term - inefficiency - random error	Composite term - inefficiency - random error	Composite term - inefficiency - random error
Efficiency	- Time variant - Point estimates	- Time variant - Point estimates	- Time variant - Point estimates	- Time variant - Point estimates	- Time variant - Only general estimate
Advantages	- No functional form, but production axioms imposed on data - No assumption on error distribution - Point estimates of each DMU	- No functional form, but production axioms imposed on data - No assumption on error distribution - Point estimates of each DMU - No assumption of production set convexity	- Composed error split into efficiency and error terms - Point estimates of each DMU	- Composed error split into efficiency and error terms - Point estimates of each DMU	- Composed error split into efficiency and error terms
Caveats	- No randomness - No parametric test for inference	- No randomness - No parametric test for inference	- Arbitrary choice of distribution for the error term - Arbitrary choice of functional form of frontier	- Arbitrary choice of functional form for the frontier - Efficiency is assumed to be time-invariant	- Arbitrary choice of functional form for the frontier - Arbitrary choice of distribution for the error term - No point estimates - Arbitrariness in the division of the distribution in quartiles

Notes: Following Aiello and Bonanno (2016), DEA—Data Envelopment Analysis; FDH—Free Disposal Hall; SFA—Stochastic Frontier Approach; DFA—Distribution Free Approach; TFA—Thick Frontier Approach.

Appendix B

Table A2. List of Studies Used.

No.	Authors (Year)	Topic	Journal/Others	Method	Data Type	Data Year	No. of Banks	No. of Estimations	Average Efficiency
1	Nguyen (2007)	Measuring Efficiency of Vietnamese Commercial Banks: An Application of Data Envelopment Analysis (DEA)	Technical Efficiency and Productivity Growth in Vietnam	DEA	Panel	2001–2003	13	2	0.650
2	Nguyen (2008)	Phan tich cac nhan to anh huong den hieu qua hoat dong của các NHTM ở VN	PhD dissertation of National Economics University, Vietnam	DEA SFA	Panel	2001–2005	32	2	0.791 0.74
3	Nguyen and De Nguyen and De Borger (2008)	Bootstrapping Efficiency and Malmquist Productivity Indices: An Application to Vietnamese Commercial Banks	Conference Paper at at the Asia-Pacific Productivity Conference 2008, Academia Sinica, Taiwan	DEA	Panel	2003–2006	15	1	0.915
4	Ngo (2010c)	Danh gia hieu qua su dung nguon luc cua mot so NHTMCP o VN—Ung dung phuong phap DEA	Working paper	DEA	CS	2008	22	1	0.917
5	Ngo (2010a)	Evaluating the Efficiency of Vietnamese Banking System: An Application Using DEA	Conference paper at the International DEA Symposium "Pushing the envelope!"	DEA	CS	2008	22	2	0.944
6	Ngo (2010b)	Evaluating Vietnamese Commercial Banks Using Data Envelopment Analysis Approach (Vietnamese Government)	SSRN eLibrary	DEA	CS	2008	22	1	0.917
7	Nguyen et al. (2013)	Efficiency and super-efficiency of commercial banks in Vietnam: Performances and determinants	Asia-Pacific Journal of Operational Research	DEA	Panel	2001–2005	32	1	0.787
8	Vu and Turnell (2010)	Cost efficiency of the banking sector in Vietnam: A Bayesian stochastic frontier approach with regularity constraints	Asian Economic Journal	SFA	Panel	2000–2006	56	1	1.015
9	Ngo (2012)	Measuring the performance of the banking system—case of VN	Journal of Applied Finance and Banking	DEA	Panel	1990–2010	21	1	0.49

Table A2. *Cont.*

No.	Authors (Year)	Topic	Journal/Others	Method	Data Type	Data Year	No. of Banks	No. of Estimations	Average Efficiency
10	Nguyen (2012)	Evaluating the efficiency and productivity of Vietnamese commercial banks: A data envelopment analysis and Malmquist index	VNU Journal of Economics and Business	DEA	Panel	2007–2010	20	3	0.763
11	Vu and Nahm (2013)	The determinants of profit efficiency of banks in Vietnam	Journal of the Asia Pacific Economy	DEA	Panel	2000–2006	56	1	0.494
12	Le (2014)	Profit and Cost Efficiency Analysis in Banking Sector: A Case of Stochastic Frontier Approach for Vietnam	Journal of Knowledge Management, Economics and Information Technology	SFA	Panel	2007–2012	45	2	40.135
13	Le (2015)	Do Bank Mergers and Acquisitions Improve Technical Efficiency of Vietnamese Commercial Banks?	Conference Paper at the 28th Australasian Finance and Banking Conference	DEA	Panel	2007–2011	21	1	0.965
14	Stewart et al. (2015)	Efficiency in the Vietnamese banking system: A DEA double bootstrap approach	Research in International Business and Finance	DEA	Panel	1999–2009	48	2	0.775
15	Tran and Phan (2015)	Banking industry development and bank efficiency in an emerging market economy	Proceedings of the Second Asia-Pacific Conference on Global Business, Economics, Finance and Social Sciences	SFA	Panel	2000–2013	27	2	0.62
16	Ngo and Tripe (2016)	Stochastic cost frontier analysis—sensitivity analysis on cost measures	Pacific Accounting Review	SFA	Panel	2003–2010	12	1	0.916
17	Nguyen et al. (2016b)	Management Behaviour in Vietnamese Commercial Banks	Australian Economic Papers	SFA	Panel	2000–2014	32	1	0.908
18	Nguyen et al. (2016a)	Efficiency, innovation and competition: evidence from Vietnam, China and India	Empirical economics	SFA	Panel	1995–2011	28	1	0.814
19	Nguyen et al. (2016c)	Bank reforms and efficiency in Vietnamese banks: evidence based on SFA and DEA	Applied Economics	SFA DEA	Panel	2000–2014	32	2	0.937 0.926
20	Le (2017b)	The efficiency effects of bank mergers—An analysis of case studies in Viet Nam	Risk governance and control: financial markets and institutions	DEA	Panel	2008–2015	35	1	0.960

Table A2. *Cont.*

No.	Authors (Year)	Topic	Journal/Others	Method	Data Type	Data Year	No. of Banks	No. of Estimations	Average Efficiency
21	Le (2017a)	The Determinants of Commercial Bank Profitability in Vietnam	Working paper	DEA	Panel	2005–2009	40	1	0.831
22	Ngo and Tripe (2017)	Measuring efficiency of Vietnamese banks—Accounting for NPLs in a single-step stochastic cost frontier analysis	Pacific Accounting Review	SFA	Panel	2003–2010	12	1	0.799
23	Nguyen (2017)	Income diversification and bank efficiency in Vietnam	Journal of Economics and Development	DEA	Panel	2007–2015	34	1	0.858
24	Nguyen et al. (2018)	Operational efficiency of bank loans and deposits: A case study of Vietnamese banking system	International Journal of Financial Studies	DEA	Panel	2008–2015	43	2	0.755
25	Vo and Nguyen (2018)	Bank restructuring and bank efficiency—The case of Vietnam	Cogent Economics and Finance	DEA	Panel	1999–2015	26	2	0.936
26	Le et al. (2019)	The impact of multimarket contacts on bank stability in Vietnam	Pacific Accounting Review	DEA	Panel	2006–2015	40	1	0.877
27	Nguyen et al. (2019)	Measuring banking efficiency in Vietnam: Parametric and Non-parametric methods	Banks and bank systems	DEA SFA	Panel	2011–2015	30	2	0.946 0.764

Source: Synthesized by the authors.

Appendix C

Table A3. The Final Models of Efficiency Scores.

Tobit:	$EF_i = -57.56 + 0.029YEAR_i - 0.153DATA_i - 0.008SIZE_i$	(A1)
Bootstrap Tobit:	$EF_i = -57.56 + 0.029YEAR_i - 0.153DATA_i - 0.009SIZE_i$	(A2)
Truncated:	$EF_i = -77.01 + 0.039YEAR_i - 0.321DATA_i - 0.121RTS_i - 0.009SIZE_i + 0.163PRODUCT_i$	(A3)
Bootstrap truncated:	$EF_i = -77.01 + 0.039YEAR_i - 0.321DATA_i - 0.009SIZE_i$	(A4)

Note: The models are based on Table 2 but only included significant (independent) variables.

Note

[1] Note that SFA studies have already accounted for the variable returns to scale assumption allowing for the calculation of scale efficiency (Ngo et al. 2019; Vu and Turnell 2010).

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