Print ISSN: 2288-4637 / Online ISSN 2288-4645
doi:10.13106/jafeb.2022.vol9.no7.0053

Data Envelopment Analysis on Measuring the Performance of Vietnamese Joint-Stock Commercial Banks

Duc Tien NGO[1], Thu Ha PHUNG[2], Tuan Minh DINH[3], Thuy Lien NGUYEN[4]

Received: April 10, 2022 Revised: June 25, 2022 Accepted: July 05, 2022

Abstract

Commercial banks have a significant impact on the economy of Vietnam because they provide the majority of transactional capital. Therefore, the operational efficiency of commercial banks is a viral topic for the study of the Vietnamese banking system. The research aims to examine the efficiency and inefficiency of joint-stock commercial banks in Vietnam from 2016 to 2020 and then classify them into the efficient group and inefficient group. The study employs the time series data of 29 joint-stock commercial banks during the period 2016–2020. Based on the data collected from the annual audited financial statements of 29 Vietnamese joint-stock commercial banks, the authors select input and output variables for the standard DEA models and anti-efficient DEA models. This research uses two stages, first, by applying the standard DEA model, we investigate the efficient banks; second, by employing the anti-efficient DEA model, we find out the inefficient banks. The results reveal that the average efficiency score of 29 joint-stock commercial banks tends to increase in the period 2016–2018 and decrease gradually in the period 2019–2020. The findings of this study suggest that several small and medium-sized banks in the Vietnamese banking sector have both promising and risky performances and the efficiency of state-owned commercial banks has also improved significantly during the study period.

Keywords: Bank Performance, Efficiency, Anti-Efficient DEA, Standard DEA, Commercial Banks

JEL Classification Code: G20, G21, G24

1. Introduction

Due to the impacts of the worldwide economic crisis in 2008, the State Bank of Vietnam issued flexible monetary policies to control high inflation and prevent economic depression as well as support the sustainable growth of the Vietnamese economy. From 2011 to 2015, the State Bank of Vietnam conducted two important policies which affected deeply on the Vietnamese banking system, namely "Project on restructuring the system of credit institutions for the period 2011–2015" (Decision 254/QD-TTg dated March 1, 2012) and "Project on dealing with bad debts of the system of credit institutions" (Decision 843/QD-TTg dated 31 March 2012). These projects help the government to control the weak credit institutions, deal with the shortcomings and weaknesses of the banking system gradually, and handle bad debts step by step. The restructuring of the banking system, particularly the commercial banks, has altered the ownership cohorts and sources of the Vietnamese banking system's productivity (To & Le, 2020). Consequently, the Vietnamese banking system has experienced substantial growth between 2016 and 2020, contributing significantly to macroeconomic stability and fostering economic growth. The total assets and equity of these banks have increased gradually from 2016 to 2020 (See Appendix 2 and 3). In addition, transaction offices of these banks have proliferated across the nation, which directly contributes to the success of joint-stock commercial banks.

In the Vietnamese credit market, 31 joint-stock commercial banks are now accounting for the biggest market

[1]First Author and Corresponding Author, Lecturer, Faculty of Banking and Insurance, Academy of Finance, Vietnam [Postal Address: No 9/82/4 Nghia Tan Street, Cau Giay District, Hanoi, 122301, Vietnam] Email: ngoductien@hvtc.edu.vn
[2]Lecturer, Faculty of Public Finance, Academy of Finance, Hanoi, Vietnam. Email: phungthuha@hvtc.edu.vn
[3]Researcher, Institute of Science and Technology Strategy and Policy, Ministry of Science and Technology, Hanoi, Vietnam. Email: dinhtuanminh.maastricht@gmail.com
[4]Researcher, Viet Analytics Joint Stock Company, Hanoi, Vietnam. Email: nguyen.thuylien@vietanalytics.vn

share (Figure 1). Among these joint-stock commercial banks, fierce competition has taken place for several years. At first, joint-stock commercial banks controlled by the Government ranked first. However, there is a trend that joint-stock commercial banks owned by private sectors have been raising their market shares moderately, on the way to getting over joint-stock commercial banks controlled by the government. Hence, private joint-stock commercial banks are operating more effectively than governmental ones. And whether private joint-stock commercial banks are generally having more credit risks than governmental ones. To deal with these matters, the task of this study is to examine the efficiency of 29 joint-stock commercial banks from 2016 to 2020 by the DEA method (Because there were two joint-stock commercial banks which the authors could not collect all data at the moment of researching). Based on the results of DEA, the author will assess the efficiency and inefficiency of the Vietnamese joint-stock commercial banks by applying standard DEA models and the anti-efficient DEA model (Liu et al., 2006).

The structure of this paper includes five parts as follows. The first part is an introduction that presents the reason for topic selection. The next part is a literature review providing the basic theory relating to the study. Then the third part describes the research methodology. The empirical results with a comparison among efficient scores and inefficient scores follow. Finally, the last section presents the conclusions from the results obtained.

2. Literature Review

DEA method is a non-parametric mathematical programming approach to productive efficiency, which was first built by Charnes et al. (1978) based on the theory of effective frontier introduced by Farrell (1957). Since its first time of publication, various DEA models have been used by many researchers to assess the efficiency of production in several industries, including the banking sector. Paradi et al. (2012) considered DEA as an outstanding tool to analyze the banking sector because it can be modified to many factors without predetermined models.

The research of Kao and Liu (2009) indicated that the result of efficiency measurement by traditional DEA might not totally be the truth. Since a set of DMUs in the DEA model needs constant input/output data while many observations do not qualify this requirement because of their stochastic nature, leading to the fluctuation of the resulting efficiency. Accordingly, stochastic DEA is applied for a case study on measuring the efficiency of Taiwan commercial banks. Unlike the traditional 0–1 categorization sample, this innovative DEA provides a DMU opportunity to be identified as efficient. The important research finding is that the stochastic data approach will reveal more reliable and informative results than that are produced by the average-data and interval-data approaches. Among Taiwan's banks chosen, two banks are always assessed as efficient after 2000 replications; there are 19 banks having different

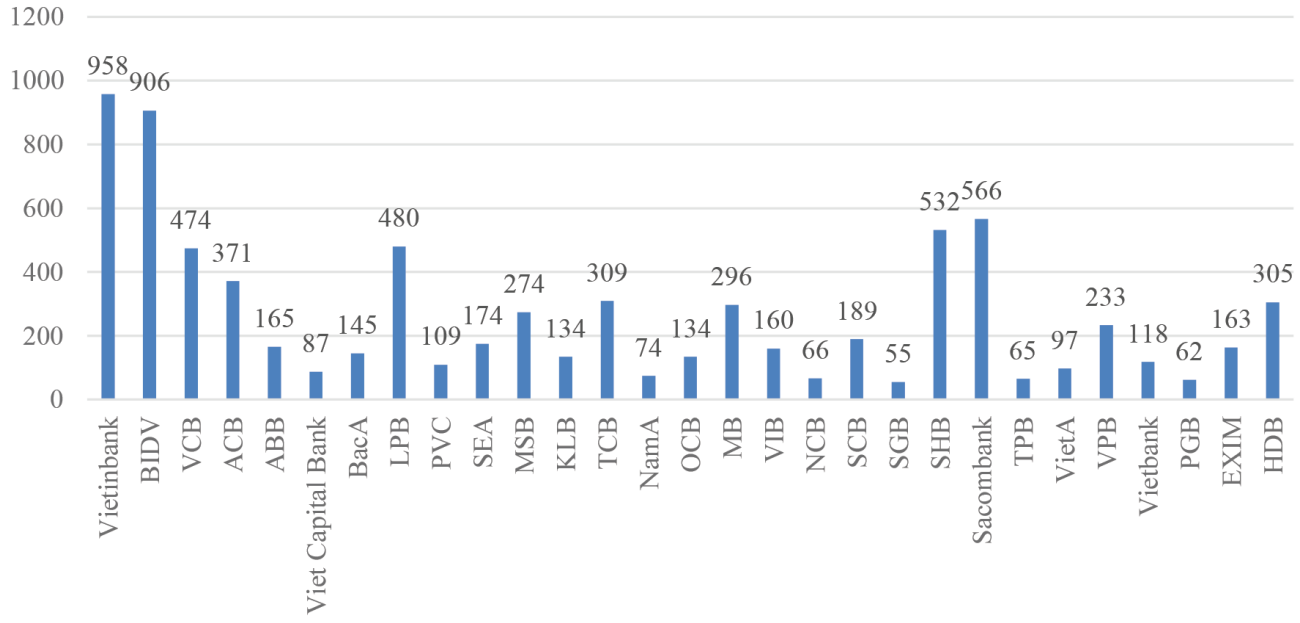

Figure 1: The Number of Transaction Offices of Vietnamese Joint-Stock Commercial Banks in 2020

Source: Authors summarized from websites of banks

probabilities of being efficient and 4 banks resulting inefficient.

Banna et al. (2017) utilized DEA when evaluating the efficiency of commercial banks in Bangladesh from 2000 to 2013. The researchers used four inputs in their model: interest expenses, non-interest expenses, personal expenses, and deposits. Then, three outputs were added, which included total loans, liquid assets, and other earning assets. Based on the results of DEA, the authors were able to determine that the year in which these banks performed the best with the highest efficiency score was 2001, and the year in which they performed the worst with the lowest efficiency score was 2010 due to the aftermath of the 2008 global economic crisis. In the same field, to evaluate the effectiveness of Islamic banks, Mohd Noor et al. (2020) also applied DEA. Three input variables, including total deposits, fixed assets, and administration expenses, and two output variables, including loans and investments, were utilized in the DEA model. Based on the results of DEA, the banking sectors of Islamic high-income countries are more efficient than those of low- and middle-income countries.

Glass et al. (2014) examined the performance of cooperative bank models in Japan during the period 1998–2009 by using DEA with bad debt as undesirable output. When applying the Cuesta et al. (2009) trans-log enhanced hyperbolic distance function model for measuring the efficiency of Japanese cooperative banks, there are two important findings, which we would rather highlight because of their relevance to our research, as followed: (i) the efficiency of banks relating to the size of banks, (ii) regulars to reduce bad debts impacting on both the operating result and efficiency of banks.

To resolve the deposit dilemma in measuring bank efficiency, Holod and Lewis (2011) proposed an alternative DEA model treating deposits as an intermediate product, consequently highlighting the double duty of deposits in the process of banking operation. The research shows the fact that the efficiency at both stages of the bank production process influences the effect of the amount of deposit on bank performance. Then the main purpose of this study is to provide more certain efficiency estimates. In another hand, the research of Alhassan and Tetteh (2017) applied a Two-Stage DEA bootstrapping approach to assessing the relationship between non-interest income and bank efficiency in Ghana. In the first stage, the efficiency scores of 26 banks in Ghana between 2003 and 2011 are estimated. And the impact of contextual variables on bootstrapped efficiency scores is then examined by using a truncated bootstrapped regression to estimate. The results show that the efficiency scores of banks will decrease if non-interest income is not counted as an output variable.

To measure the credit risk of firms, Paradi et al. (2004) used the worst practice DEA to find out the worst performers based on their places on the frontier. In their research, they establish a DEA framework with output variables reflecting the poor practices of resource usage or being unsatisfactory outcomes and input variables selected similarly. The firms making up the frontier in this framework are those with the lowest of those (good) inputs while having the highest level of the (bad) outputs. Using data from public companies with assets of over $500M or less than $10M that filed for bankruptcy between 1996 and 1997 and applying normal and worst practice DEA models, the results of the study showed 100% bankruptcy and 78 percent non-bankruptcy prediction accuracy, as well as equally convincing 100 percent and 67 percent out-of-sample classification accuracy.

Regarding applying DEA on measuring the performance of banks in Vietnam, there are several studies. Stewart et al. (2016) used the DEA approach to examine bank efficiency in Vietnam between 1999 and 2009. The number of staff, deposits from the State Bank of Vietnam and other banks in the system, and client deposits are the three input vari-ables in this study. They choose client loans from the business and private sectors, other loans (excluding customer loans), and securities for three bank inputs (including investment and trading securities of the bank). The results of the efficiency scores show that small and medium-sized banks have lower scores and hence are less efficient than large and very large banks. Furthermore, the study shows that banks with vast branch networks and those around for a long period are less efficient than others. Vo and Nguyen (2018) used DEA to examine the performance of 26 commercial banks in Vietnam from 1999 to 2015 to determine the impact of bank restructuring on bank efficiency. Total deposits, interest costs, and non-interest expenses are the three bank inputs chosen. And three output variables capturing both traditional bank lending activities and non-traditional activities are the total amounts of loans, interest revenue, and non-interest revenue. According to the findings of the DEA applied in two stages, 1999–2006 (pre-restructuring) and 2007–2015 (during restructuring), bank efficiency declines during the bank restructuring period due to not only transition costs but also changes in other environment variables, such as the financial crisis or a slowdown in the domestic economy.

However, during the period 2016-to 2020, the efficiency of Vietnamese Joint Stock commercial banks has changed sharply due to the results from a list of innovative strategies of the Vietnamese government. In this paper, we would like to employ the DEA method to assess not only efficiency performance but also the inefficient performance of the joint-stock commercial banks in Vietnam and use the results from the DEA method to analyze the current situation of these banks. The research results will provide practical information to researchers, policy-makers, bank managers, and investors to further studies on the Vietnamese banking system and policy issuance of bank management.

3. Methodology

3.1. Efficient DEA and Anti-Efficient DEA

DEA is a mathematical programming tool that should be used to assess the relative efficiency of a decision-making unit (DMU) with several inputs and outputs. The performance of a DMU is solely determined by the efficient frontier identified by DMUs with a unity efficiency score. The efficiency value of a DMU ranges from zero to one. A linear programming approach is used to calculate this scalar value (Charnes et al., 1978). Because it is supposed to be the radial measure that deals with input excess, this radial measure is calculated from an optimistic viewpoint for each DMU. However, from the research by Entani et al. (2002), the DEA efficiencies could be considered from not only optimistic but also pessimistic viewpoints. In their study, they use both efficient and anti-efficient frontiers to assess the efficiencies. Then, Amirteimoori (2007) continued to develop this idea with detailed mathematical approaches. Hence, in this paper, we use DEA with both optimistic and pessimistic viewpoints to evaluate the efficiency and credit risk of Vietnamese commercial banks, based on the study of Entani et al. (2002). We will create two different DEA models: standard DEA and anti-efficient DEA.

Assume that there are n evaluated DMUs, all of which use m inputs to produce s different outputs. Then, by using the classical DEA model, the technical efficiency point of a DMU will be estimated as given by

$h' = \max \theta$

$$\text{Subject to: } \sum_{j=1}^{n} x_{ij}\lambda_j \geq \theta x_{i0},\ i = 1,\ldots,m,$$
$$\sum_{j=1}^{n} y_{ij}\lambda_j \geq y_{r0},\ r = 1,\ldots,s,$$
$$\lambda_j \geq 0,\ j = 1,\ldots,n$$

And with standard DEA, the efficiency point will be represented by hb' (b as best). The outputs of standard DEA will be chosen as the desirable ones which are used to describe an efficient DMU. Using the standard DEA, one can easily find the best practice reference – the efficient frontier that is realizable. This output-oriented efficient DEA model evaluates DMUs on the frontier as the most efficient and the DMUs within the frontier as the inefficient. DMUs located further away from the frontier are less technically efficient. Hence, with the same constant inputs, these units can increase outputs by improving technicals. In contrast, the anti-efficiency point will be presented by hw' ("w" as worst). To find out the worst DMU or anti-efficient DMU, we simply choose both undesirable inputs and outputs and then apply the DEA model with these inputs and outputs. The aim of this appliance is clearly to find the anti-efficient frontier, which illustrates DMUs with undesirable characteristics Liu et al. (2006, 2010).

3.2. Inputs and Outputs of DEA Models

To measure the efficiency and anti-efficiency of Vietnam joint-stock commercial banks from 2016 to 2020, we apply standard DEA models to find out the banks with efficient performance and anti-efficient DEA models to find out the banks with inefficient performance. The data is collected

Table 1: Inputs and Outputs of Standard DEA Models and Anti-Efficient DEA Models

No	Inputs	Outputs
Standard DEA Model		
1	Total asset, Interest expense, Equity	Earnings before interest and taxes, Retained earnings, Earning per share
2	Total assets, Operational expense, Equity	Earnings before interest and taxes, Earning per share
3	Operational Expense, Equity	Earnings before interest and taxes, Earning per share
Anti-Efficient DEA Model		
1	Total asset, Retained earnings, Provision for credit losses	Total liabilities per total equity, Interest expense, Non-performing loan
2	Total asset, Retained earnings, Provision for credit losses	Interest expense, Non-performing loan
3	Total asset, Retained earnings, Operational Expenses	Interest expense, Non-performing loan
4	Total asset, Retained earnings	Total liabilities per total equity, Interest expense, Non-performing loan

from consolidated financial reports of 29 Vietnamese joint-stock commercial banks over 5 years (2016–2020).

And inputs that we choose for DEA models include total asset (TA), interest expense (IE), operational expense (OE), equity (EQ), retained earnings (RE), and provision for credit losses (PCL). Outputs employed in DEA models consist of earnings before interest and taxes (EBIT), retained earnings (RE), earning per share (EPS), total liabilities per total equity (TL/EQ), interest expense (IE), and non-performing loan (NPL).

Based on the inputs and outputs for the DEA models chosen (Table 1), we use Spearman's rank correlation coefficient to find out the most suitable variables for our research. We considered the first standard DEA model and the first anti-efficient DEA model to be original. Then we apply Spearman's rank correlation coefficient test to examine the original models with others to assess whether the variables chosen in the original models are reasonable or not. This rank correlation coefficient indicates the degree of correlation between the arrangement of banks in the other model with the original model, and it is given in the form as below:

$$r_s = 1 - 6\left[\frac{\sum_1^n d_i^2}{n^3 - n}\right]$$

With r_s : rank correlation coefficient
d_i: difference between the ratings of the bank i in the two models
n: the number of banks ranked

Following the results of Spearman's correlation coefficient test, the ratings of original models have a high correlation with the remaining models. The results of r_s are all above 0,9 (See Table 2). Thus, the variables used to measure the performance of joint-stock commercial banks in Vietnam will be the variables of the two original models.

4. Empirical Results

From the results of the standard DEA model and anti-efficient DEA model (Table 3), we can deliver several key findings as below:

First, the average efficiency score tends to increase in the period 2016–2018 and decrease gradually in the period 2019–2020. This fact is consistent with the economic situation of Vietnam. During the 2016–2018 period, the Vietnamese economy was stable, businesses developed quickly, and the business operation of the joint-stock commercial banks also achieved many successes. In the period 2019–2020, the fluctuations of the economic cycle and the influence of the COVID-19 pandemic have directly impacted the

Table 2: The Results of the Spearman's Correlation Coefficient Test

	Standard DEA model (2)					Standard DEA Model (3)					Anti-Efficient DEA Model (3)									
	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
r_s	0.999386	0.99998	0.999881	0.999937	0.999953	0.99938	0.999973	0.999873	0.999931	0.999945										
	Anti-Efficient DEA Model (2)					Anti-Efficient DEA Model (3)														
	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020					
r_s	0.999981	0.999998	0.999984	0.999999	0.999995	0.999942	0.999986	0.999832	0.999918	0.999978	0.999972	0.999991	0.999956	0.99992	0.999992					

Table 3: The Results of the Original Standard DEA Model and Anti-Efficient DEA Model

Bank	2016		2017		2018		2019		2020		2016		2017		2018		2019		2020	
	h_b'	Rank	h_b'	Rank	h_b	Rank	h_b'	Rank	h_b'	Rank	h_w'	Rank	h_w'	Rank	h_w'	Rank	h_w'	Rank	h_w'	Rank
Vietinbank	1.000	1	0.544	15	0.664	13	0.790	8	0.796	9	1.000	1	1.000	1	0.882	4	0.835	6	0.714	8
BIDV	0.583	11	0.728	9	0.870	8	0.534	15	0.437	17	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1
VCB	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	0.501	16	0.496	15	0.399	17	0.504	13	0.451	17
ACB	0.886	5	0.701	11	1.000	1	1.000	1	1.000	1	0.748	9	0.769	9	0.400	16	1.000	1	0.631	10
ABB	0.609	10	0.727	10	0.894	5	0.895	6	0.967	3	0.745	10	0.867	4	0.772	7	0.819	7	0.628	11
VietCapital	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1
BacA	0.872	6	0.843	7	0.892	6	0.670	10	0.620	13	1.000	1	1.000	1	0.564	12	1.000	1	1.000	1
LPB	0.814	7	0.890	6	0.711	11	0.639	12	0.663	12	0.693	11	0.738	11	1.000	1	1.000	1	0.823	6
PVC	0.349	15	0.331	19	0.346	17	0.358	17	0.364	18	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1
SEA	0.582	12	0.630	13	0.491	15	0.595	13	0.577	14	0.889	2	0.838	5	0.775	6	1.000	1	0.730	7
MSB	0.671	9	0.450	16	0.735	10	0.667	11	0.824	8	0.817	5	0.755	10	0.669	11	0.628	11	0.495	15
KLB	1.000	1	1.000	1	1.000	1	0.966	4	0.969	2	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1
TCB	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	0.622	13	0.647	13	0.547	13	1.000	1	0.431	18
NamA	0.984	2	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	0.865	5
OCB	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	0.796	6	0.789	6	0.770	8	0.839	5	0.635	9
MB	1.000	1	0.798	8	0.970	3	0.996	2	0.884	4	0.568	15	0.543	14	0.443	15	0.577	12	0.462	16
VIB	0.690	8	0.959	3	1.000	1	1.000	1	1.000	1	0.582	14	0.788	7	0.727	9	0.720	9	0.593	12
NCB	1.000	1	1.000	1	1.000	1	0.827	7	0.850	5	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1
SCB	0.276	17	0.259	20	0.258	18	0.247	18	0.236	19	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1
SGB	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1
SHB	0.426	14	0.560	14	0.710	12	0.671	9	0.504	15	0.845	4	0.958	2	1.000	1	1.000	1	1.000	1
Sacombank	0.311	16	0.353	18	0.599	14	0.571	14	0.671	11	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1
TPB	0.891	4	0.999	2	0.979	2	1.000	1	1.000	1	0.657	12	0.666	12	0.463	14	0.658	10	0.570	13
VietABank	0.919	3	0.907	5	0.936	4	0.981	3	0.827	7	0.861	3	1.000	1	0.785	5	0.902	3	0.886	4
VPB	1.000	1	0.946	4	1.000	1	1.000	1	1.000	1	0.792	7	0.906	3	1.000	1	1.000	1	1.000	1
VietBank	1.000	1	1.000	1	0.873	7	0.914	5	0.834	6	1.000	1	1.000	1	0.959	2	0.971	2	1.000	1
PGB	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	1.000	1	0.950	2
EXIM	0.243	18	0.416	17	0.350	16	0.384	16	0.477	16	1.000	1	1.000	1	0.919	3	0.897	4	0.895	3
HDB	0.538	13	0.653	12	0.817	9	1.000	1	0.744	10	0.775	8	0.781	8	0.687	10	0.741	8	0.560	14
Mean	0.781		0.782		0.831		0.817		0.801		0.858		0.881		0.819		0.900		0.804	

business performance of the banks. Based on the results of the anti-efficient DEA model, the averaged anti-efficient score fluctuated during the observation period but always being higher than the efficient score of the same year. The anti-efficient score presents the credit risk of the banks with outputs referring to total liabilities per total equity, interest expense, and non-performing loan. Hence, the credit risk of Vietnam's joint-stock commercial bank system is still higher than the business performance of these banks.

Second, we find out two main important groups among 29 Vietnamese joint-stock commercial banks:

- Group 1: This group includes five banks, namely PVC, SCB, SHB, Sacombank, and Eximbank, medium-size banks with total assets ranging from over VND 9,000 billion to under VND 30,000 billion. With this group, the efficient scores rated by the standard DEA model are under 0.5, so we can consider them inefficient. And the results of the anti-efficient DEA model are the same for this group. With undesirable outputs, their inefficient scores range from over 0.8 to 1 (the highest level). It leads to the fact that the business activities of these banks are risky and not efficient.
- Group 2: This group includes three banks, namely Viet Capital, SGB, and PGB. The efficient score and inefficient score of each member in this group reach the highest points, as 1 or nearly 1. It seems to be that the business activities of these banks are both risky and potential. Three banks in this group are all small size banks with the total asset under VND 10,000 billion.

Third, among the four biggest joint-stock commercial banks of Vietnam with the highest amounts of stocks belonging to the State, including BIDV, VCB, Vietinbank, and MB, the efficient score and anti-efficient score are different. While Vietinbank and BIDV have lower efficient scores and higher anti-efficient scores, VCB and MB have higher efficient scores and lower anti-efficient scores. Especially, the average efficient score of VCB during the period 2016–2020 is 1, while the average anti-efficient score is under 0.5 (a low level). Hence, VCB earned the highest profit after tax in the Vietnamese banking industry in 2019 and 2020. Besides, Vietinbank and BIDV, with the large size of total assets, still need to transform more innovatively to gain better performance, for which they have the potential.

5. Conclusion

Business activities of Vietnamese joint-stock commercial banks had strong fluctuations in the 2016–2020 period. The period 2016–2019 can be considered as the recovery period of the Vietnamese economy, leading to the fact that the performance of the system of Vietnam Joint Stock Commercial Banks also has many flourishing features. During this period, the business situation of Vietnamese joint-stock commercial banks was very positive due to the fast growth of the economy, and the effectiveness of public financial policies to promote economic development showed their obvious impacts. However, at the end of 2019 and the beginning of 2020, when the Covid-19 pandemic broke out globally, the business activities of Vietnamese joint-stock commercial banks were also significantly affected.

In this paper, we would like to describe the overall picture of the performance created by the joint-stock commercial banks in Vietnam. The study offers a different overview of efficiency improvement among the Vietnamese joint-stock commercial banks. According to Stewart et al. (2016) and Vo and Nguyen (2018), state-owned commercial banks are not effective in improving efficiency. However, during the period 2016–2020, this changed. The four largest joint-stock commercial banks, all of which have significant government holdings, continue to have higher efficiency scores than the average. Furthermore, VCB could be considered the most successful joint-stock commercial bank with the continuous rise in the total assets as well as profit after tax in the observation time. To gain this achievement, VCB has conducted several innovative strategies as well as applied more advanced technology in the operational process. Therefore, we suppose that the Vietnamese joint-stock commercial banks should concentrate more on innovation, and the Vietnamese government should continue to integrative policies to enhance competition and transparency of the banking system.

References

Alhassan, A. L., & Tetteh, M. L. (2017). Non-interest income and bank efficiency in Ghana: A two-stage DEA bootstrapping approach. *Journal of African Business*, *18*(1), 124–142. https://doi.org/10.1080/15228916.2016.1227668

Amirteimoori, A. (2007). DEA efficiency analysis: Efficient and anti-efficient frontier. *Applied Mathematics and Computation*, *186*(1), 10–16. https://doi.org/10.1016/j.amc.2006.07.006

Banna, H., Ahmad, R., & Koh, E. H. Y. (2017). Determinants of commercial banks' efficiency in Bangladesh: Does crisis matter? *Journal of Asian Finance, Economics, and Business*, *4*(3), 19–26. https://doi.org/10.13106/jafeb.2017.vol4.no3.19

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operations Research, 6*(78), 429–444. https://doi.org/10.1016/0377

Cuesta, R. A., Lovell, C. A. K., & Zofío, J. L. (2009). Environmental efficiency measurement with translog distance functions: A parametric approach. *Ecological Economics*, *68*(8–9), 2232–2242. https://doi.org/10.1016/j.ecolecon.2009.02.001

Entani, T., Maeda, Y., & Tanaka, H. (2002). Dual models of interval DEA and its extension to interval data. *European Journal of*

Operational Research, *136*(1), 32–45. https://doi.org/10.1016/S0377-2217(01)00055-8

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society Series A*, *120*(3), 253–290. https://doi.org/10.2307/2343100

Glass, J. C., McKillop, D. G., Quinn, B., & Wilson, J. O. S. (2014). Cooperative bank efficiency in Japan: A parametric distance function analysis. *European Journal of Finance*, *20*(3), 291–317. https://doi.org/10.1080/1351847X.2012.698993

Holod, D., & Lewis, H. F. (2011). Resolving the deposit dilemma: A new DEA bank efficiency model. *Journal of Banking and Finance*, *35*(11), 2801–2810. https://doi.org/10.1016/j.jbankfin.2011.03.007

Kao, C., & Liu, S. T. (2009). Stochastic data envelopment analysis in measuring the efficiency of Taiwan commercial banks. *European Journal of Operational Research*, *196*(1), 312–322. https://doi.org/10.1016/j.ejor.2008.02.023

Liu, W. B., Sharp, J., & Wu, Z. M. (2006). Preference, production, and performance in data envelopment analysis. *Annals of Operations Research*, *145*(1), 105–127. https://doi.org/10.1007/s10479-006-0042-7

Liu, W. B., Meng, W., Li, X. X., & Zhang, D. Q. (2010). DEA models with undesirable inputs and outputs. *Annals of Operations Research*, *173*(1), 177–194. https://doi.org/10.1007/s10479-009-0587-3

Mohd Noor, N. H. H., Bakri, M. H., Wan Yusof, W. Y. R., Mohd Noor, N. R. A., & Zainal, N. (2020). The impact of bank regulation and supervision on the efficiency of Islamic banks. *Journal of Asian Finance, Economics, and Business*, *7*(11), 747–757. https://doi.org/10.13106/jafeb.2020.vol7.no 11.747.

Paradi, J. C., Asmild, M., & Simak, P. C. (2004). Using DEA and worst practice DEA in credit risk evaluation. *Journal of Productivity Analysis*, *21*(2), 153–165. https://doi.org/10.1023/B:PROD.0000016870.47060.0b

Paradi, J. C., Rouatt, S., & Zhu, H. (2012). Two-stage evaluation of bank branch efficiency using data envelopment analysis. *Omega*, *39*(1), 99–109. https://doi.org/10.1016/j.omega.2010.04.002

Stewart, C., Matousek, R., & Nguyen, T. N. (2016). Efficiency in the Vietnamese banking system: A DEA double bootstrap approach. *Research in International Business and Finance*, *36*(C), 96–111. https://doi.org/10.1016/j.ribaf.2015.09.006

To, T. H., & Le, P. T. (2020). An analysis of Vietnamese bank productivity change in the time of restructuring. *Journal of Asian Finance, Economics, and Business*, *7*(11), 779–788. https://doi.org/10.13106/jafeb.2020.vol7.no11.779

Vo, X. V., & Nguyen, H. H. (2018). Bank restructuring and bank efficiency—The case of Vietnam. *Cogent Economics and Finance*, *6*(1), 1, 1520423. https://doi.org/10.1080/23322039.2018.1520423

Appendix 1: The List of Vietnamese Commercial Banks in the Research

No.	Name of Commercial Bank	Abbreviated Name
1	Vietnam Joint Stock Commercial Bank for Industry and Trade	Vietinbank
2	Joint Stock Commercial Bank for Investment and Development of Vietnam	BIDV
3	Joint Stock Commercial Bank for Foreign Trade of Vietnam	VCB
4	Asia Commercial Joint Stock Bank	ACB
5	An Binh Commercial Joint Stock Bank	ABB
6	Viet Capital Commercial Joint Stock Bank	Viet Capital
7	Bac A Commercial Joint Stock Bank	BacA
8	Lien Viet Post Joint Stock Commercial Bank	LPB
9	Vietnam Public Joint Stock Commercial Bank	PVC
10	Southeast Asia Joint Stock Commercial Bank	SEA
11	Vietnam Maritime Commercial Joint Stock Bank	MSB
12	Kien Long Commercial Joint Stock Bank	KLB
13	Vietnam Technological and Commercial Joint Stock Bank	TCB
14	Nam A Commercial Joint Stock Bank	NamA
15	Orient Commercial Joint Stock Bank	OCB
16	Military Commercial Joint Stock Bank	MB
17	Vietnam International Commercial Joint Stock Bank	VIB
18	National Citizen Commercial Joint Stock Bank	NCB
19	Sai Gon Joint Stock Commercial Bank	SCB

Appendix 1: (Continued)

No.	Name of Commercial Bank	Abbreviated Name
20	Saigon Bank For Industry And Trade	SGB
21	Saigon – Hanoi Commercial Joint Stock Bank	SHB
22	Sai Gon Commercial Joint Stock Bank	Sacombank
23	Tien Phong Commercial Joint Stock Bank	TPB
24	Viet A Commercial Joint Stock Bank	VietA
25	Vietnam Prosperity Joint Stock Commercial Bank	VPB
26	Vietnam Thuong Tin Commercial Joint Stock Bank	VietB
27	Petrolimex Group Commercial Joint Stock Bank	PGB
28	Vietnam Export Import Commercial Joint Stock Bank	EXIM
29	Ho Chi Minh City Development Joint Stock Commercial Bank	HDB

Appendix 2: Equity of the Vietnamese Commercial Banks

No.	Bank	Equity (Million Vietnam Dong)				
		2016	2017	2018	2019	2020
1	VCB	47,052,404	51,289,563	60,788,651	79,342,806	92,188,196
2	Vietinbank	58,991,289	61,672,330	65,021,293	74,306,559	82,112,946
3	BIDV	41,827,253	44,384,033	49,586,732	72,635,858	74,234,747
4	TCB	18,394,046	24,970,394	49,290,063	57,954,499	68,721,466
5	MB	25,097,994	28,191,371	32,205,824	37,276,615	46,736,043
6	VPB	15,054,361	25,912,074	30,525,738	37,186,243	44,801,372
7	ACB	13,760,691	15,699,742	20,674,058	27,329,301	34,822,643
8	Sacombank	21,751,848	22,875,830	24,165,341	26,192,781	28,227,414
9	SHB	13,123,003	14,525,640	16,149,273	18,101,932	23,494,959
10	HDB	9,082,584	13,779,542	15,128,143	18,434,181	22,270,067
11	VIB	8,696,714	8,741,163	10,644,070	13,405,666	17,945,439
12	OCB	4,715,678	6,136,741	8,795,609	11,506,653	17,430,087
13	MSB	13,576,485	13,701,815	13,795,858	14,831,943	16,833,842
14	TPB	5,681,486	6,676,717	10,621,685	13,074,679	16,744,398
15	EXIM	13,414,472	14,211,589	14,822,245	15,674,811	16,729,618
16	SCB	15,251,872	15,302,877	16,332,227	16,395,260	16,328,525
17	LPB	8,331,885	9,383,258	10,200,892	12,579,800	14,231,726
18	SEA	5,848,530	6,135,568	8,270,152	10,953,036	13,813,455
19	PVC	9,926,585	10,131,197	10,101,101	10,195,846	10,262,083
20	ABB	5,802,880	6,078,994	6,824,691	7,767,646	8,810,843
21	BacA	5,817,631	6,368,278	7,076,037	7,805,595	8,351,550
22	NamA	3,409,018	3,640,553	4,202,172	4,931,875	6,570,260
23	VietA	4,005,688	4,103,389	4,219,314	4,446,898	5,727,536
24	VietB	3,066,820	3,329,275	4,506,780	5,018,384	5,277,720

Appendix 2: (Continued)

No.	Bank	Equity (Million Vietnam Dong)				
		2016	2017	2018	2019	2020
25	NCB	3,226,162	3,215,800	3,230,077	4,306,498	4,261,434
26	PGB	3,495,341	3,559,846	3,686,768	3,760,412	3,929,919
27	KLB	3,349,416	3,531,802	3,687,160	3,764,819	3,860,368
28	Viet Capital	3,278,198	3,308,698	3,405,306	3,702,169	3,857,447
29	SGB	3,514,518	3,416,913	3,434,544	3,560,879	3,620,982

Appendix 3: Total Assets of the Vietnamese Commercial Banks

No.	Bank	Total Assets (Million Vietnam Dong)				
		2016	2017	2018	2019	2020
1	BIDV	996,698,040	1,172,803,590	1,278,107,546	1,451,598,039	1,477,278,848
2	Vietinbank	944,364,085	1,088,073,001	1,154,647,795	1,228,542,264	1,327,921,008
3	VCB	785,990,897	1,032,313,058	1,071,299,131	1,219,158,483	1,320,802,577
4	SCB	360,836,655	443,226,369	508,165,061	566,834,276	632,647,595
5	Sacombank	329,187,491	364,016,293	401,862,887	449,097,153	486,520,422
6	MB	250,191,067	306,736,842	352,482,549	398,557,093	477,839,594
7	ACB	233,059,896	283,397,182	328,561,034	382,885,618	441,993,749
8	TCB	234,948,998	268,354,282	318,620,217	379,598,492	432,720,422
9	SHB	239,955,478	286,346,876	321,678,413	361,209,774	407,448,803
10	VPB	200,767,782	234,066,050	274,158,200	316,967,687	360,057,784
11	HDB	142,289,292	180,110,748	206,412,379	218,333,705	307,022,136
12	VIB	104,723,499	123,295,449	139,295,819	184,660,969	244,766,618
13	LPB	141,865,255	163,433,639	175,094,532	202,058,040	242,342,951
14	TPB	106,311,115	124,118,747	136,179,403	164,438,534	206,314,594
15	PVC	113,958,167	126,537,416	140,590,867	163,808,213	180,566,733
16	SEA	103,389,301	125,072,631	140,868,336	157,893,266	180,524,738
17	MSB	92,293,871	112,589,321	138,123,509	157,085,449	176,830,555
18	EXIM	129,679,511	150,252,537	153,530,229	167,759,787	160,689,663
19	OCB	63,815,088	84,352,903	100,046,572	118,234,668	152,670,865
20	NamA	42,847,904	54,493,218	75,095,575	94,657,366	134,348,942
21	BacA	75,952,304	91,859,805	97,115,077	107,976,122	117,302,424
22	ABB	74,431,564	84,724,294	90,237,337	102,486,813	116,267,442
23	VietB	36,701,696	41,537,358	51,676,057	68,946,502	91,525,490
24	NCB	69,048,305	71,907,133	72,480,307	80,405,111	89,711,960
25	VietA	61,459,220	64,413,978	71,314,799	76,520,013	86,647,635
26	Viet Capital	32,887,908	40,400,255	47,053,696	51,908,598	61,202,061
27	KLB	30,411,497	37,399,596	42,535,123	51,310,655	57,472,200
28	PGB	24,824,533	29,297,961	29,899,608	31,574,084	36,153,015
29	SGB	19,658,115	21,929,606	20,983,087	23,420,608	24,552,393