International Journal of Multidisciplinary Research and Growth Evaluation
ISSN: 2582-7138
Received: 22-06-2021; Accepted: 07-07-2021
www.allmultidisciplinaryjournal.com
Volume 2; Issue 4; July-August 2021; Page No. 514-520

An application of Super-SBM model to evaluate the efficiency of Vietnamese commercial banks

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Abstract
Purpose: Global economic development has increasingly widened banking operations worldwide. The banking industry in Vietnam has shown great development to serve its booming economy. The purpose of this paper is to provide an assessment of business performance in Vietnamese banks from early 2019 until the earlier 6 months of 2020 by means of a Super Slacks-Based-Measure (SBM) model using the Data Envelopment Analysis (DEA) method.
Methodology: Three of input variables are identified including total assets, operating expenses, capital and funds; and, two output variables are determined including net interest income, and profit after tax. Data related to twelve Vietnamese banks was chosen in accordance with the given criteria to measure banking efficiency based on the principles shown in the DEA method.
Findings: Analysis results identified relative periods of efficiency, relative periods of inefficiency, and the banks' rankings throughout each period. Based on the principle of slacks of the super-SBM model, a feasible solution was recommended to deal with inefficient periods in particular.
Value: The final empirical result exhibited an overall picture of the operational process of Vietnamese bank industry before and within the COVID-19 pandemic.

Keywords: Super Slacks-Based-Measure (SBM) model, Data Envelopment Analysis (DEA) method, Vietnamese bank, efficiency

1. Introduction
A bank is a financial institution providing opportunities for credit, savings, payment services and other financial functions, and it plays a key role in the development of any country. The first bank in the world was established in Italy in the 14th century (Hoggson, 1926) [13]. In Vietnam, according to the Vietnam National Bank (1951), the first bank was established by Decree No. 15 / SL on May 6, 1951. Over time, Vietnam's banking industry has grown exponentially. In the early period of establishment, Vietnam's banking industry faced many significant challenges and possessed only 1.25 million Dong Phuong at opening. Currently, according to the Vietnam National Bank (2020), the total assets of the banking sector have reached 12,831,052 billion VND as of 31/07/2020. Through difficult years of wartime and recovery, the banking industry has constantly strived to leverage Vietnam's economic development to the mutual benefit of the people.
Since the beginning of 2020, the world in general, and Vietnam in particular, have been seriously affected by the COVID-19 pandemic. All fields of business have been in an economic downturn, including the financial services industry. In order to understand the process of economic recession, this study analyses the effectiveness of banking operations in Vietnam from the beginning of 2019 to the second quarter of 2020 through the Super-SBM model using the DEA method. The super-SBM model is used to measure the efficiency of every bank separately and determine their positions every period because this model can calculate the maximum performance (Fang *et al*., 2013) [16] and different scores (Andersen and Petersen, 1993) [1]; hence, it is a good and high effective methodology to rank the position.
The aim of this paper is to determine the business performance of twelve banks in Vietnam and the ranking of each bank in every period of endeavor. Based on the research objectives, the latest data of twelve banks listed on the stock market, as published on Vietstock (2020) [24], is used to analyze and then to evaluate the process of banking operations in Vietnam via the super-SBM model. The finding results recaptured the operational variation of Vietnamese bank industry from the early 2019 to Q2/2020.
The rest of this study is arranged as follows: Section 1 gives the objective, scope, and methodology. Section 2 reviews the theoretical banking industry, efficiency, and super-SBM model in DEA. Section 3 sets up the equation of the super-SBM model, cites the data source and studied input and output variables. Section 4 shows the empirical results of business and market efficiencies including efficient and inefficient scores for these two cases, and then determining their position in every period.

Section 5 recaptures the main finding results and gives further research.

2. Literature review

A commercial bank is a financial institution which does banking business to earn profit by borrowing and lending, i.e., deposit creation (Eugene, 1980; Douglas, 1986), money loans (Goodfriend, 1990) [12]. Therefore, the bank is a central finance (Dean and Martha, 2002) that manages the flow of money, many papers have demanded in their researches. For instance, Dana and Alexander (2013) [5] showed banking business and factors affecting financial stability of economics via the real development of the banking business sector in Slovakia. Ismail and Sheriff (2017) [14] investigated and indicated a positive impact of factors that have the influence of internal marketing on organizational commitment of 407 banks in Yemen. Pampurini and Quaranta (2018) [20] conducted the efficiency level of European banking market after the global crisis based on the period 2011-2016 via the Stochastic Frontier approach. Chen *et al.*, (2019) [3] used the pooled regression model to seek out the interactive role of bank competition and foreign bank entry based on the cross-country data for the banking sector from 2000 to 2016, the finding results revealed policy implications for foreign investors and regulatory authorities. Rudi and Auliya (2020) [21] analyzed influences between internal banking and macroeconomic variables on system risk in Indonesia and found out a positive relationship between macroeconomics variables and economic situation.

Banking industry plays an important role to growth the global economy. Vietnam is a developing country with a direction of international trade so that the banking industry is developing sharply. To evaluate the level of performance level of banking companies which are operating in Vietnam, this study used the super-SBM model in DEA with the function of measurement that can provide the maximum value, different scores, and different positions as well.

Efficiency is a measure of an operation process of a production or service establishment that is determined by the ratio between the outputs and the inputs. Analysis of production efficiency or business performance provides a closer view into operational expenses, which is a ratio between the outcome and the initial costs. Any production or service business with different products will have different operating processes. All of these institutions have to build a business strategy and to adapt it to market economic conditions with the aim of achieving optimal efficiency. In order to make an evaluation on the performance of the operation of the institution, this paper utilizes the indicators located in financial statements. These statements reveal the cost of implementing and promoting overall operations, thus giving important implications related to the business or production activities.

Several concepts of efficiency have been introduced in the past. Farell (1957) stated a unit is considered to be efficient when the output has reached its maximum taken in consideration with the input. Coelli *et al.*, (2005) [4] offered a firm is efficient when the output is achieved at a fixed level with the minimum amount of input. Jennifer (2009) [15] suggested that efficiency is a technical assessment that is used specifically after job completion or the operations of a unit. The findings reveal the relationship existing between the output variables and the input variables. Although each previous study has its own way of defining efficiency, they all share a common argument: the efficiency of a unit determined by a mathematical method and then described as the ratio of the output values and input values.

The data envelopment analysis (DEA) method provides models to evaluate the production and performance efficiency of a unit based on both the calculation of inputs and outputs. Charnes *et al.*, (1978) [2] were the first researchers to lay the foundations for DEA. In the initial research, researchers proposed a firm size theory using research taken from traditional CCR models. Over 40 years of development, DEA has expanded and provided theories on changing business sizes along with many different models such as EBM, SBM, Super-SBM, etc among which the super-SBM model offers the feature of unit efficiency evaluations with unlimited scores.

The super-efficiency model was first introduced by Anderson and Peterson (1993), who introduced an AP model that uses the super-efficiency to help rank units by efficiency in the operation of production and sales. However, this model had remaining limitations as its solutions are neither viable nor stable, and it could only solve the problem of determining constant return-to-scale. To solve this problem related to DEA, Tone (2002) [23] proposed the super-SBM model. In the SBM model, Tone (2001) [22] provided a solution to the mathematical problems of output and input variables with a measure of efficiency ranging from 0 to 1. This model did not achieve optimal results in determining the ranking of unit's efficiency because the maximum score is only 1. From this limitation based on the efficiency measurements available from the traditional models, Tone (2002) [23] built the super-SBM model with unlimited efficiency score calculation ability, offering insights into the output shortage, and input excess of inefficient units.

In general, the super-SBM model is meant to offer boundless results for effective units. In addition, this model is proposed as a solution to the output variables' shortage and the excess in the input variables necessary to improve future efficiency ratings. Thus, many previous studies utilized the super-SBM model to measure the performance with various different aspects. For example, the environmental efficiency in China was exhibited particularly based on the value of effect factors from 1991 to 2001 (Li *et al.*, 2013) [16]. Emília (2014) [8] explored the performance and position of banks in Slovakia via the super-SBM model. The performance of the logistics companies in Vietnam were conducted and determined the efficient and inefficient companies, and their ranks in every year (Wang *et al.*, 2018) [25]. Wang and Chen (2020) indicated the level of impact factors to China's public culture services. Li and Liu (2019) [17] measured the innovative performance of China's high-end manufacturing industry and pointed out a trend of gradual optimization, stepping into the middle and high-end levels. In this study, we continue to apply the super-SBM model to measure the performance of Vietnamese banking industry.

3. Research method and materials

3.1 Super-SBM model

Traditional models in DEA including BCC, CCR, and SBM models only calculate technically efficiency. It means that the decision-making units in the efficient case will have a similar score. Thus, the Super-SBM model, created by Tone (2002) [23], facilitates calculation and offers unlimited efficiency scores. This model was created based on an efficiency measuring method that Tone (2001) [22] presented. For the

purpose of ranking, the super-SBM model was used to conduct the score in this study. Setting up the banking companies as *n* units (DMUs) with inputs are *a* and outputs are *b*, the original possibility of each unit is defined as:

$$P = (a,b) / a > 0, b > 0 \quad (1)$$

The business efficiency score of DMUs is determined based on the equation of Tone (2001) [22]:

$$\min p = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / a_{i0}}{1 + \frac{1}{s}\sum_{r=1}^{s} s_r^- / b_{r0}} \quad (2)$$

$(s^- > 0; s^+ > 0)$

Based on Tone (2002) [23], the super-efficiency of each bank in the business operating process and market process is calculated by:

$$\min p = \frac{\frac{1}{m}\sum_{i=1}^{m} \overline{a_i} / a_{i0}}{\frac{1}{s}\sum_{r=1}^{s} \overline{b_r} / b_{r0}} \quad (3)$$

Whereas,

$$\overline{a} \geq \sum_{k}^{n} \lambda_k a_k b_k; \overline{b} \leq \sum_{k}^{n} \lambda_k b_k$$

From the equation (3), the optimal solution of each value is set up accordingly; thus, the DMU is defined the performance based on the optimal solution under the condition $\rho^* \geq 1; s^{-*} = 0; s^{+*} = 0$. In this case, there are no input excess and no output shortfall. Therefore, the DMU will have efficiency if the score is equal or higher than 1. When the score of the DMU is lower than 1, it does not have efficiency; thus, the input variables can occur excess and the output variables can occur shortage.

In the case, the reduction of inputs and enlargement of outputs, set up inputs and outputs of the DMU as $(\alpha a_o, \beta b_o)$, the super-efficiency of $(\alpha a_o, \beta b_o)$ will be lower than (a_o, b_o). The super-efficiency score of $(\alpha a_o, \beta b_o)$ is estimated by:

$$\min p = \frac{\frac{1}{m}\sum_{i=1}^{m} a_i / (\alpha a_{i0})}{\frac{1}{s}\sum_{r=1}^{s} b_r / (\beta b_{r0})} = \frac{\beta}{\alpha}\frac{\frac{1}{m}\sum_{i=1}^{m} a_i / a_{i0}}{\frac{1}{s}\sum_{r=1}^{s} b_r / b_{r0}} \quad (4)$$

Whereas,

$$a \geq \sum_{k}^{n} \lambda_k a_k b_k; \hat{b} \leq \sum_{k}^{n} \lambda_k b_k; a \geq \alpha a_0; 0 \leq \hat{b} \leq \beta b_0; \lambda \geq 0$$

After the reduction of inputs and enlargement of outputs, the new efficiency will be estimated. The adjustment of inputs and outputs is a feasible suggestion to improve the inefficient cases, these banking companies can use this analysis result to determine and give a future development direction.

In generally, the super-SBM model has useful functions of different scores with the different efficiency scores and ranking that other models cannot do it.

3.2 Data source

With the development of industrialization and modernization, the financial organization is a currency exchange center. In the context of international commerce, Vietnamese commercial banks are growing sharply. Therefore, this study investigates the business and market performances of these banks, the data used in this study was obtained from the financial statements of banks listed on the website: https://vietstock.vn/ (Vietstock, 2020) [24]. The list of Vietnamese banks used to measure performance is shown in Table 1.

Table 1: List of banks

Code	Name of the bank
ACB	Asia Commercial Joint Stock Bank
BID	The Joint Stock Commercial Bank for Investment and Development of Vietnam
CTG	Vietnam Joint Stock Commercial Bank for Industry and Trade
HDB	Ho Chi Minh City Development Joint Stock Commercial Bank
MBB	Military Commercial Joint Stock Bank
NVB	National Citizen Commercial Joint Stock Bank
SHB	Sai Gon - Hanoi Commercial Joint Stock Bank
STB	Saigon Thuong Tin Commercial Joint Stock Bank
TCB	Vietnam Technological and Commercial Joint- stock Bank
TPB	Tien Phong Commercial Joint Stock Bank
VCB	Joint Stock Commercial Bank for Foreign Trade of Vietnam
VPB	Vietnam Prosperity Joint-Stock Commercial Bank

Source: Vietstock (2020) [24]

Based on the Super-SBM model, input and output variables that were selected are:

Input variables

Total assets (TAS): All assets of the bank including machinery, office equipment, etc.…

Operating expenses (OES): The costs that a bank must spend in the period to perform the business.

Capital and funds (OEY): Contributed capital and monetary funds of the bank.

Output variables

Net interest income (NII): The outcome of money trading with the inputs, mobilization and loan outputs.

Profit after tax (PAT): The remaining profit after total revenue minus total operating expenses and taxes.

According to the super-SBM model, the input and output variables need to be represented in positive values. Table 2 indicates that the minimum value of TAS, OES, OEY, NII, and PAT is 69371893; 178681; 3243417; 173861; and 2550, respectively. Thus, the statistical data in Table 2 show that all values used to measure performance are positive in nature variables.

Table 2: Data analysis

Index	Period	TAS	OES	OEY	NII	PAT
Max	2019/Q1	1342938577	4383645	72991878	8545052	4710901
Min		69371893	178681	3243417	173861	10651
Ave		508356304	2011159	35265128	4118988	1591450
SD		407865166	1157475	22253440	2902667	1177903
Max	2019/Q2	1400186022	4219335	77336868	9138082	4364807
Min		70695838	210731	4279977	258315	5796
Ave		531444869	2177114	36554091	4295350	1534304
SD		423344691	1275144	23163727	3036138	1129858
Max	2019/Q3	1425398552	4182440	81390894	8859286	5051595
Min		70793796	183814	4282534	241988	2550
Ave		542991457	2172588	38195332	4542756	1751576
SD		431532547	1213947	24136166	2968696	1291025
Max	2019/Q4	1490104755	6551168	85753348	9596941	4400374
Min		80394022	258736	4306672	453623	24138
Ave		567039972	2724064	41177486	4684785	1901393
SD		450116083	1686006	26704457	3086371	1223318
Max	2020/Q1	1446044081	4910290	85071986	9148651	4182655
Min		70458265	195705	4318651	235912	11979
Ave		558258636	2332585	42500731	4693385	1616173
SD		429720262	1231379	26827235	3026685	1074169
Max	2020/Q2	1446353871	3961792	89578031	8076890	4615185
Min		71386396	183394	4325028	244411	6377
Ave		571115213	1998020	44321927	4328520	1962647
SD		433290112	1068788	27491548	2559279	1329808

Source: Vietstock (2020) [24]

Note: Max (maximum), min (minimum), Ave (average), and SD (standard deviation)

4. Results and discussions

To compute the efficiency of banking industry in Vietnam, the historical data of 12 banking companies from Q1/2019 to Q2/2020 was used to calculate the efficiency score via the super-SBM model in DEA. According to the principle of the DEA method, besides the requirements that the values used must be positive, they also need to be tested for correlation coefficients among input variables, among output variables and between input and output variables. This is done to ensure that isotonic relationships exist between variables. The calculated correlation coefficients must always be between -1 and +1. If the correlation coefficient between the variables is close to -1 and +1, the variables have an absolute relationship. On contrary, the correlation coefficient between the variables does not have significant, thus the selected variables must remove and reselect. Table 3 shows the correlation coefficients between the variables including input and input; input and output; output and output are from 0.5712 to 1, so the variables possess good correlations to one another. Thus, the values are suitable for analyzing the financial performance of the 12 exhibit banks using the Super-SBM model.

Table 3: Correlational Coefficients

Variables	Period	TAS	OES	OEY	NII	PAT
TAS	2019/Q1	1.0000	0.8051	0.8467	0.8806	0.7198
OES		0.8051	1.0000	0.8796	0.9450	0.8804
OEY		0.8467	0.8796	1.0000	0.8972	0.8987
NII		0.8806	0.9450	0.8972	1.0000	0.8036
PAT		0.7198	0.8804	0.8987	0.8036	1.0000
TAS	2019/Q2	1.0000	0.8927	0.8462	0.8736	0.5747
OES		0.8927	1.0000	0.8568	0.9561	0.7023
OEY		0.8462	0.8568	1.0000	0.8646	0.8348
NII		0.8736	0.9561	0.8646	1.0000	0.7313
PAT		0.5747	0.7023	0.8348	0.7313	1.0000
TAS	2019/Q3	1.0000	0.8560	0.8395	0.8548	0.6269
OES		0.8560	1.0000	0.8943	0.9619	0.8131
OEY		0.8395	0.8943	1.0000	0.8759	0.8896
NII		0.8548	0.9619	0.8759	1.0000	0.7810
PAT		0.6269	0.8131	0.8896	0.7810	1.0000
TAS	2019/Q4	1.0000	0.8830	0.8929	0.8560	0.7165

OES		0.8830	1.0000	0.8157	0.8670	0.6393
OEY		0.8929	0.8157	1.0000	0.8898	0.9216
NII		0.8560	0.8670	0.8898	1.0000	0.8423
PAT		0.7165	0.6393	0.9216	0.8423	1.0000
TAS	2020/Q1	1.0000	0.7994	0.8845	0.8568	0.5712
OES		0.7994	1.0000	0.8697	0.9221	0.8600
OEY		0.8845	0.8697	1.0000	0.9112	0.8291
NII		0.8568	0.9221	0.9112	1.0000	0.7823
PAT		0.5712	0.8600	0.8291	0.7823	1.0000
TAS	2020/Q2	1.0000	0.8968	0.8760	0.7992	0.6482
OES		0.8968	1.0000	0.8807	0.9086	0.7294
OEY		0.8760	0.8807	1.0000	0.8909	0.8896
NII		0.7992	0.9086	0.8909	1.0000	0.8894
PAT		0.6482	0.7294	0.8896	0.8894	1.0000

With the positive selected data, after the data have been carefully tested for their correlation coefficients, values are applied to measure the performance scores of banks from Q1/2019 to Q2/2020, with the results shown in Table 4. Each banking company was measured and given the different performance in every period based on the super-SBM model.

Table 4: Banking activities' efficiency

DMU	2019/Q1	2019/Q2	2019/Q3	2019/Q4	2020/Q1	2020/Q2
ACB	1.0394	1.0632	1.0383	0.6466	0.8695	0.7111
BID	1.2502	1.1143	1.1714	1.0058	1.1609	0.4596
CTG	0.9074	0.7851	0.7491	0.7654	1.0434	0.7373
HDB	0.9694	0.8927	0.9203	0.9457	0.8885	1.0137
MBB	1.0327	1.0075	1.032	0.7228	1.0152	0.8413
NVB	3.5138	2.8238	2.9725	2.9833	3.7724	3.7648
SHB	0.7241	1.1329	0.6958	0.6719	0.6446	0.6934
STB	0.5775	0.4032	0.5108	0.3432	0.5108	0.5025
TCB	1.6867	1.7128	1.6257	1.4409	1.5524	1.5375
TPB	1.1749	1.1319	1.0926	1.3649	1.1579	1.1192
VCB	1.0228	1.0429	1.0129	1.4245	1.0228	1.0328
VPB	1.7443	1.8171	1.9319	1.9231	1.8165	1.9106

Based on the calculated data seen above in Table 4, it is shown that the given business performance of banks fluctuates continuously. According to the data calculated by the Super-SBM model, there are 5 banks including NVB, TCB, TPB, VCB and VPB, which have always achieved a high efficiency rating during operations so that the measured score is always greater than 1. NVB is considered to be the most effective bank as its scores are always the highest in the period Q1/2019 to Q2/2020, with scores ranging from 2.8238 to 3.7724. By contrast to NVB and other efficient banks, STB had a relatively low performance as its score was always below 1 and remained consistently low (from 0.3432 to 0.5775) throughout Q1/2019 to Q2/2020. The remaining six banks whose efficiency scores fluctuated continuously experienced intermittent periods of efficiency in some quarters. Specifically, in the first 3 quarters of 2019, ACB always achieved operational efficiency, but from the fourth quarter of 2019 to the second quarter of 2020, the operational process fell sharply and dropped below the expected efficiency level. BID has had a relatively good level of operational efficiency, but in Q2 - 2020, BID's efficiency rating dropped dramatically down to 0.4596. Although CTG attempted improvement, it was only able to achieve efficiency during its operations in the first quarter of 2020. HDB was able to make gradual positive changes since the beginning of 2019 until the first quarter of 2020, and it finally achieved an acceptable efficiency score in second quarter of 2020 with the result of 1.0137. MBB has had 4 out of 6 quarters of business performance rated as efficient, however the analysis shows a reduction of efficiency in operating activities in both the last quarter of 2019 and the second quarter of 2020. SHB achieved an efficiency business score only in the second quarter of 2019, while its performance efficiency dropped and then remained below 1 (between 0.6447 and 0.7241) during other periods.

The above analysis shows that most banks were directly affected in some measure by the COVID pandemic, thus affecting their overall performances in the first two quarters of 2020, since the stated appearance of COVID, thus showing a declining trend. This decline affected not only these 12 banks, it also caused hardships for every other bank in Vietnam. Based on the performance scores of the 12 banks in each given period, the ranking positions of these banks were determined concretely as shown in Figure 1.

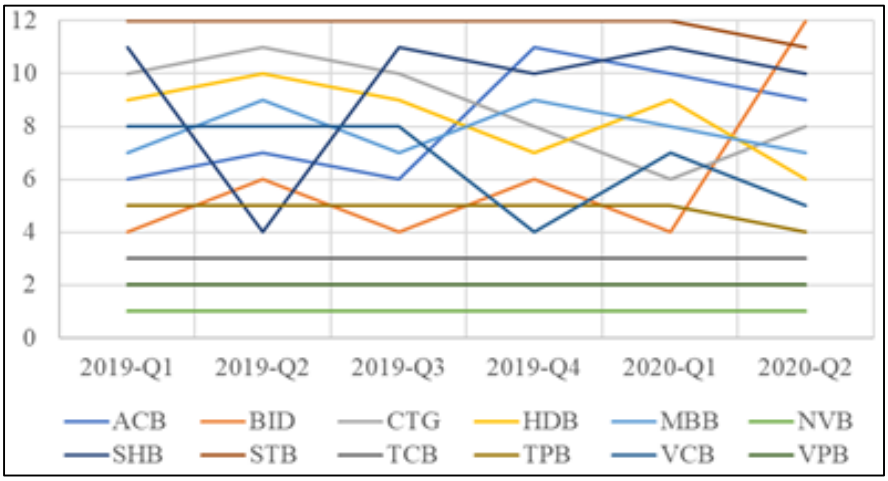

Figure 1: Ranking banks

Figure 1 shows that the ranking positions of three banks, NVB, VPB and TCB remained unchanged during the rated period, as first, second and third respectively. Thus, with good performance results, these banks have remained in a higher and more stable position from the beginning of 2019 to the end of the second quarter of 2020. TPB has remained relatively stable, remaining at number 5 in the rankings from the beginning of 2019 to the first quarter of the year. In addition, by 2020, with the best efforts in the second quarter of 2020, TPB has risen to 4th place. STB, which took the last place during the period from the beginning of 2019 to the end of Q1/2020, moved up in rank to 11th place in Q2/2020 after considerable effort. BID is a bank with relatively good performance, holding the positions between 4th and 6th place from early 2019 to Q1/2020. However, BID fell to last position in the second quarter of 2020. Other banks have constantly experienced changes in their positions due to operational concerns.

5. Conclusion

With its usefulness in evaluating efficiency and in ranking units, the highly efficient model in data bag analysis has been widely applied in many different areas such as in the transportation, industry, etc. In continuance of previous studies, this research paper offers an application of the high efficiency assessment model to the banking industry in Vietnam. The results of the analysis have identified performance scores and specific positions for each bank in the twelfth bank cohort located in Vietnam. NVB has been found to be the most efficient bank, and it has consistently ranked at the top from early 2019 through the end of 2nd quarter of 2020 while other inefficient banks were also revealed. Further, these results offer insights into possible ways for these banks to look at the structure of their investment capital. The banks need to consider an adjustment and reformation of their capital sources to improve operational efficiency. In addition to the obtained results, the study also has limitations regarding data sources since there are also banks that have not listed their data on the financial tables.

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