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Impact of technological innovation on performance of Vietnamese commercial banks

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Abstract

The purpose of this paper is to investigate the impact of technological innovation on the cost efficiency of Vietnamese commercial banks from 2009 to 2022. The paper uses the data envelopment analysis (DEA) method combined with the Tobit regression model to examine the impact of technological innovation on the cost efficiency of Vietnamese commercial banks. Using a sample of 35 commercial banks from 2009 to 2022, the findings indicate that technological innovation has a significant positive impact on cost efficiency, suggesting that banks investing in advanced technology tend to improve their operating performance. Furthermore, factors such as profitability, bank size, equity ratio, and economic growth contribute positively to cost efficiency. In contrast, bad debts and inflation are associated with negative impacts. The study concludes that to improve efficiency, commercial banks should continue to invest in technological advancements, strengthen financial capacity, and effectively manage bad debts. These findings provide practical implications for bank managers and policymakers, especially in the context of the ongoing digital transformation in the banking sector.

Keywords: Banking Efficiency, Technological Innovation, Tobit.

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1. Introduction

Technological innovation is booming globally, strongly affecting the development of the economy in general and the commercial banking system in particular in all countries around the world [1, 2]. Technological innovation has created multifaceted changes in the financial industry through financial technology innovation [3]. Technological innovation will replace existing models in the development of banking services by changing the way governance, business strategy, and the relationship between banks and customers operate, depending on the core elements of digital technology, which include artificial intelligence, the Internet of Things, and big data [3, 4].

In the world, in recent years, the banking industry has been significantly affected by the rapid development of financial Technology [5, 6]. Through Technological innovation, information processing and transmission at commercial banks are carried out quickly, customers can easily access banking products due to the expansion of the network of operations based on regional and global connections, thereby significantly increasing the efficiency of banking operations [3].

In Vietnam, Technological Innovation is a vital condition for the business operations of commercial banks. In fact, Vietnamese commercial banks are greatly affected by Technological Innovation in the context of the strong industrial revolution 4.0. However, there has been no empirical study quantifying the impact of Technological innovation on the cost efficiency of Vietnamese commercial banks. There are only a few studies on the effect of Technological innovation on profit efficiency [7, 8].

Therefore, from the academic and practical context in Vietnam, this paper is conducted with the expectation of making a new contribution to the approach of measuring technological innovation index to fill the research gap by providing empirical evidence on analyzing the effect of Technological innovation on the cost efficiency of Vietnamese commercial banks.

2. Literature Review

2.1. Technology Innovation

According to Khalil [9] stated that, Technology is the knowledge and application of products and processes, methods, tools, and systems that create or produce goods and services. Technological innovation is made up of system innovation, process innovation, personnel innovation, and working equipment in an organization [10]. According to Hilal [11] shown that, Technological innovation is a privileged means to improve the performance of banks. Technological innovation has a special ability to increase the competitive advantage of banks on the basis of allowing banks to offer products in the banking platform thanks to the superior banking system originating from stakeholders specializing in the production and trading of software copyrights and supporting a wide range of products and services [12, 13].

2.2. Bank efficiency

Bank efficiency assessment is of interest to academicians in the world [14-16]. This method can be divided into two groups: (i) Parametric method - Stochastic Frontier Approach (SFA) and (ii) Non-parametric method-Data envelopment approach (DEA) [17]. According to Svitalkova [18] and Wanke et al. [15] assert that the non-parametric method (DEA) is more suitable than parametric models to assess bank efficiency. Non-parametric methods are widely used to assess efficiency [19-21]. Although both methods have advantages and disadvantages in measuring efficiency, over time, researchers have advocated that DEA is a superior Technique than SFA in calculating overall efficiency scores across different industries [21, 22].

2.3. Technological innovation and banking efficiency

According to the theory of economic efficiency, banks should structure their output in a way that achieves the lowest possible cost per unit of production. This theory also states that high competition among banks will prevent excessive profit-seeking through raising prices too high compared to marginal costs [23, 24]. This means that banks have to look for alternative means to increase their competitiveness effectively by implementing Technological innovation. The economy in general and the lifting industry in particular are greatly affected by technological innovation [25]. Technological innovation is one of the main drivers of bank profitability and is a determinant of bank efficiency and competitiveness [25]. This means that banks must look for alternative means to compete effectively and thus increase profitability.

According to Wang et al. [26] asserted that the application of Technology in banking services is a good way to improve services. Technological innovation plays an important role in improving the efficiency of the banking industry as well as reducing the cost of banking transactions for customers [27]. Investment in information Technology innovation has a significant impact on the efficiency of the banking industry, Beccalli [28], and is a privileged means to improve bank productivity[11].

According to Angko [29] also concluded that one of the benefits of e-innovation in banking is cost savings for both banks and customers. This suggests that banks need to ensure that innovative products and services are priced appropriately to attract and satisfy customers. According to Ngugi and Karina [30] provide evidence that Technological innovation strategies (such as product repositioning, product substitution, and process innovation strategies such as regulatory compliance and cost reduction) has a positive impact on bank efficiency. Similarly, Yang and Huang [31] asserted that the application of FinTech innovation will increase the overall efficiency and competitiveness of the banking industry in Taiwan. From the above empirical evidence, it can be seen that Technological innovation has a positive impact on the efficiency of commercial banks. Therefore, Technological innovation is one of the most significant tools for improving efficiency and competitiveness in the banking industry.

2.4. Data, Model and Methodology

2.4.1. Data

The data sample is collected from 35 Vietnamese commercial banks from 2009 to 2022. The focus of this data allows us to analyze bank behavior in a more homogeneous environment. The research data is collected from many reliable sources, including Bankscope from 2009 to 2016 (because the bank data from Bankscope is homogeneous and stops at 2016), and Vietstock also sources the audited financial statements of each bank from 2017 to 2022.

2.4.2. Model

Efficiency measurement: The author uses the non-parametric data envelopment method, DEA to measure bank efficiency [15, 32]. According to Charnes et al. [33], estimating the cost efficiency function with multiple inputs and outputs using the non-parametric data envelopment method, DEA will provide an objective numerical efficiency value. DEA is derived from the fractional programming formula.

Suppose there are *nDMUs* to be evaluated. Each *DMU* absorbs a different amount of input *i* and produces different outputs *r*, i.e., *DMUs* absorb x_{ji} amounts of input to produce y_{jr} amounts of output. Assume that the x_{ji} inputs and y_{jr} outputs are non-negative and that each *DMU* has at least one positive
Input and output value. The productivity of the *DMU* can be written as:

$$h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$$

$$\max h_0(u,v) = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \qquad (1)$$

$$subjectto\ h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, j = 1, \dots, n \qquad (2)$$

$$u_r \ge 0, r = 1,2,\dots,s,$$
$$v_i \ge 0, i = 1,2,\dots,m, \qquad (3)$$

Where h_0 is the technical efficiency of the DMU_0 to be estimated, u_r and v_i are the weights to be optimized, y_{rj} is the observed output quantity of the r^{th} type for the j^{th} DMU, x_{ij} is the observed input quantity of the i^{th} type for the j^{th} *DMU*, *r* denotes *s* different outputs, *i* denotes m different inputs, and *j* denotes *n* different DMU_s. According to Yun [34], bank efficiency can be divided into two components: Technical efficiency (TE) and allocative efficiency (AE).
Cost efficiency (CE) = Technical efficiency (TE) * Allocative efficiency (AE)

Measuring the Technological Innovation Index: Similar to the research of Yun [34] and Cruz-Cázares et al. [35], the paper used the DEA method according to the Malmquist index approach to decompose the Technological Innovation Index to measure the Technological Innovation Index of 35 Vietnamese commercial banks.

According to Fare et al. [36], the Malmquist index is determined as follows:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t = \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \right) \left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)} \right) \right] \qquad (4)$$

Suppose that for each period $t=1,\dots, T$ there is a production Technology H^T that represents how all combinations of output y^t can be produced using input x^t. Suppose H^t satisfies certain criteria to determine the output gap function as follows:

$$D_0^t(x^t, y^t) = inf \left\{ \lambda : (x^t, \frac{y^t}{\lambda}) \epsilon H^t \right\}$$

From there, decompose (4) into the following components:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t = \left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \right) \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \right) \left(\frac{D_0^{t+1}(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right) \right]^{1/2} \qquad (5)$$

In which the ingredients $\left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \right) \left(\frac{D_0^{t+1}(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right) \right]$, represents the marginal Technological innovation between two periods *t* and *t+1*.

Variables in the efficiency estimation: According to Berger and Humphrey [37], the input variables are x_1, representing labor costs, x_2, representing total net fixed assets, and x_3, representing total capital mobilized from customers. The output variables are y_1, including interest income and interest equivalents, and y_2, including non-interest income and equivalents. The price variables of the inputs are also p_1 representing labor price determined by the ratio of labor costs to total labor, p_2 is the price of assets calculated by the ratio of asset costs to total net fixed assets, and p_3 is the price of mobilized capital calculated by the ratio of interest expenses and equivalents to total capital mobilized from customers.

Table 1.
Data Summary – Average per Bank over the Entire Sample Period.
(Billion VND)

Variable	Obs.	Mean (Time)	Std. Dev.	Min. (Time)	Max. (Time)
y_1	353	31.941	52.118	56.712	323.060
y_2	353	808.581	208.470	89.884	1,252.166
x_1	353	40.375	77.529	0.188	501.835
x_2	353	34.972	54.721	0.063	384.819
x_3	353	3,864.014	5,543.386	2.645	29,645.670
P_1	353	0.009	0.016	0.006	0.169
P_2	353	0.0325	0.053	0.021	0.0374
P_3	353	0.086	0.091	0.002	0.629

Model: Similar to the study of Sari and Saraswati [38] and Batir et al. [39], the study used the Tobit model for regression analysis for the case of the censored dependent variable [41]. The Tobit regression technique has the following form:

$$Y^* = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \sum_{j=1}^{n} \beta_j D_j + \delta_i,\ \delta_i \sim N(0, \sigma^2) v\acute{ơ}i\ 0 < Y^* < 1 \qquad (6)$$
$$\begin{cases} Y = Y^*, Y^* > 0 \\ Y = 0\,, Y^* < 0 \end{cases}$$

Where Y_i^* are dependent variables reflecting the cost efficiency of the bank estimated by the maximum likelihood method. Y_i is the dependent variable reflecting the cost efficiency of the bank measured by the DEA method. X_i is the independent variable; D_j are control variables; β_i, and β_j are estimated parameters; δ_i is the error according to the normal distribution. Table 2 is below, presents the definition of dependent, independent and control variables. It also supplies the significance of each variable.

Table 2.
Descriptive statistics of research variables in the proposed model.

Variable	Symbol	Proxies and Measurements	Expectations	Related research
Dependent variable				
Cost effective	CE	Estimated by DEA		Sari and Saraswati [38] and Batir, et al. [39]
Explanatory variables				
Technological innovation	TECH	Estimated by DEA based on the Malmquist index	+	Yun [34] and Cruz-Cázares, et al. [35]
Control variables				
Profitability	ROA	Net income/total assets	+	Sari and Saraswati [38] and Adjei-Frimpong et al. [40]
Non-Performing Loans	NPL	Nonperforming Loans/ total loans	-	Vu and Nahm [41]and Havrylchyk [42]
Bank size	SIZE	Natural logarithm of total Assets.	+	Vu and Nahm [41] and Sufian and Akbar Noor Mohamad Noor [43]
Capitalization	EA	Equity/ total assets	+	Vu and Nahm [41] and Ismail, et al. [44]
State ownership	SO	The dummy variable takes on the value of 1 if the bank has state investment capital and 0 otherwise	-	Vu and Nahm [41]
Restructuring	Dres	Dummy variable takes the value of 1 from 2011-2017[1] and 0 for the remaining years.	+	Author's recommendation
Economic growth	GDP	Annual GDP growth rate	+	Sahul Hamid and Ibrahim [45] and Vu and Nahm [41]
Inflationary	INF	Annual inflation rate	-	Carbó, et al. [46] and Vu and Nahm [41]

SOURCE: According to Nguyen [47].

According to Table 2, the Tobit regression technique analyzing the effect of Technological on the efficiency of Vietnamese banks is specifically rewritten according to the following equation:

$C = \beta_0 + \beta_1 TECH + \beta_2 ROA + \beta_3 NPL + \beta_4 SIZE + \beta_5 EA + \beta_6 Dres + \beta_7 GDP + \beta_8 INF + \delta i$ (6)

Accordingly, the study proposes hypothesis H: "Technological innovation has a positive effect on bank efficiency".

2.4.3. Methodology

The paper uses quantitative research methods to determine the impact of Technological innovation on the efficiency of Vietnamese commercial banks period 2009-2022. The study is conducted in two stages: (i) Using a non-parametric approach (Data Envelopment Analysis - DEA) to measure the efficiency and Technological innovation index of 35 Vietnamese banks in the period 2009-2022; (ii) Using the Tobit regression technique to estimate the affect of tenological innovation on the efficiency of Vietnamese commercial banks.

3. Empirical Findings and Discussion

Table 3 presents the descriptive statistics of the key variable in analyzing the impact of Technological innovation on banking efficiency.

Table 3.
Descriptive statistics of variables.
(Billion VND)

Variable	Obs.	Mean (Time)	Std. Dev.	Min. (Time)	Max. (Time)
CE	353	0.7664	0.2920	0.4593	0.9489
TECH	353	0.9850	0.4850	0.8110	1.0610
ROA	354	0.0349	0.0381	0.0097	0.1914
SIZE	354	23.8808	9.3408	14.3990	42.9890
EQUITY	485	0.0986	0.1002	0.0013	0.7810
NPL	354	0.0147	0.0462	0.0070	0.0310
GDP	484	0.0615	0.0110	0.0291	0.0780
IFR	485	0.0636	0.0444	0.0184	0.1940

The descriptive statistics in Table 3 show that, for the entire research period 2009-2022, the average cost efficiency is 0.766. With the same research period sample, this research result is similar to the result of the comparison with the average cost efficiency of commercial banks in Southeast Asian countries of 0.768 [47]. This shows that the cost management ability of Vietnamese commercial banks is gradually improving, along with regional banks. The results of the Malmquist index decomposition in DEA show that the average Technological innovation index (TECH) of Vietnamese commercial banks in the period 2009-2022 is at 0.985<1, reflecting that the level of Technological innovation of Vietnamese commercial banks is still not high. This can be explained by the fact that Technological progress has not been fully exploited during this period and many banks still lean towards labor-intensive Technologies. Thus, the factor of Technological change is of great importance in contributing to improving banking efficiency. With the same research sample, this result is similar to the results of Usman and Hammar [48] with a variable TECH of 0.693.

The mean net profit ratio to total assets is 0.034. The mean of the bank size is 23.881, while the mean of the equity ratio is 0.098. The mean of the Nonperforming Loans ratio is 0.014. The mean annual growth rate is 0.061, and the mean annual inflation rate is 0.063. During the research period, in general, the average efficiency of Vietnamese commercial banks decreased over time (Figure 1).

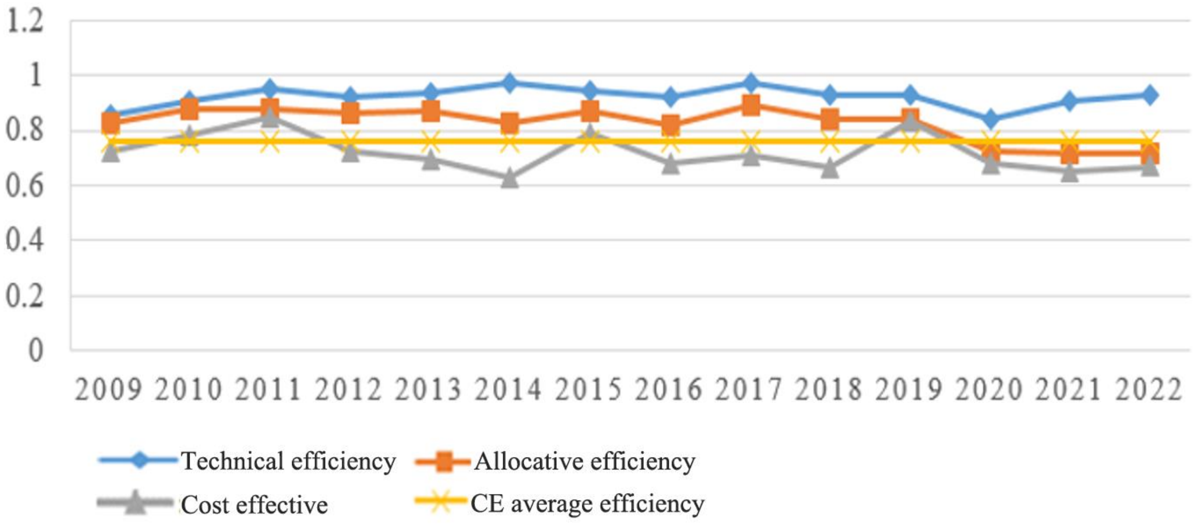


Figure 1.
Average Technical efficiency, allocative efficiency, and cost efficiency of Vietnamese commercial banks in the period 2009-2022.

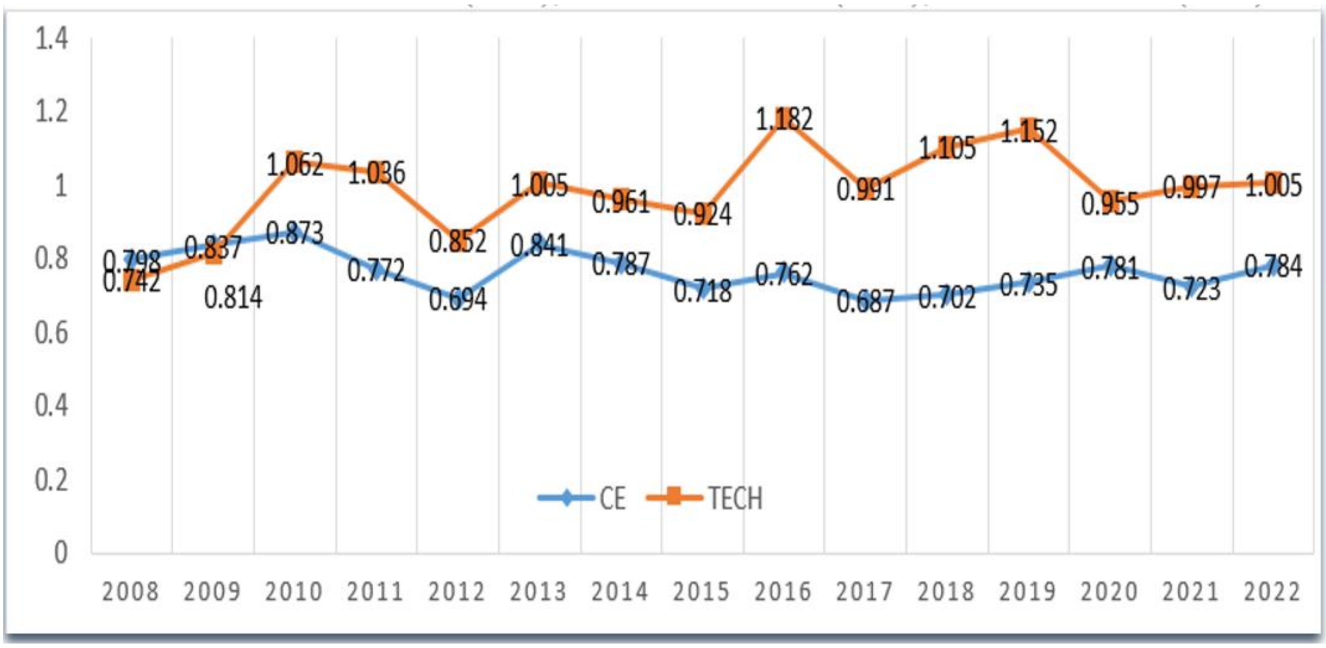
Table 4.
Regression results using the GMM estimation approach.

Variables	Coefficient	Standard deviation	z-Statistic
TECH	0.384***	0.38	10.08
ROA	0.394**	0.152	-2.59
SIZE	0.277***	0.359	7.72
EQUITY	0.499***	0.162	3.07
NPL	-0.765***	0.266	2.87
DRES	0.378	0.367	1.03
SO	0.417***	0.512	8.15
GDP	0.141***	-0.148	-0.95
IFR	-0.111**	0.302	-0.37
_cons	-0.691***	0.172	-4.00

The dependent variable is cost efficiency (CE). This table reports regression results on the impact of Technological innovation on cost efficiency. The sample represents 35 Vietnamese banks over the period 2009-2022. The key explanatory variable is the Technological innovation measure (TECH). Other explanatory variables include the Profitability (ROA), Nonperforming Loans (NPL), Bank Size (SIZE), Capitalization (EQUITY), Restructuring (DRES), State ownership (SO), Economic growth (GDP), and Inflationary (INF). The symbols *, **, and *** stand for significance at the 10%, 5%, and 1% level, respectively.

The results of the Tobit model estimation in Table 4 show that the speed of Technological innovation has a positive impact on the cost efficiency of Vietnamese banks at the 1% statistical significance level. This means that when the speed of Technological innovation increases, the cost efficiency of Vietnamese commercial banks will increase and vice versa. Figure 2 shows that in 2013, 2014, and 2015, when the speed of Technological innovation decreased continuously to the levels of 1.005, 0.961, and 0.924, the cost efficiency of Vietnamese commercial banks also decreased continuously to the levels of 0.841, 0.787, and 0.718, respectively. On the contrary, when the rate of Technological innovation increased continuously in 2017, 2018, and 2019, corresponding to the levels of 0.991, 1.105, and 1.152, the cost efficiency of Vietnamese commercial banks also increased continuously, corresponding to the levels of 0.687, 0.702, and 0.735. The research results accept the initial hypothesis are similar to the research results of Ndunga et al. [49]; Muigai and Gitau [50] and Wang et al. [51]. This finding implies that Technological innovation plays an important role in improving the efficiency of Vietnamese commercial banks.

In addition, Tobit regression technique also shows that, the control variables, including profitability, size, equity, state ownership, and economic growth, have a positive impact. While Nonperforming Loans and inflation have a negative impact on the cost efficiency of Vietnamese commercial banks at the statistical significance level of 1% and 5%. This result is similar to the research results of Sari and Saraswati [38], Vu and Nahm [41], and Abidin et al. [52].



Note: CE is cost efficiency, and TECH is Technological innovation.
Figure 2.
Technological innovation and cost efficiency of Vietnamese commercial banks in the period 2009-2022.

4. Conclusion

The objective of this research is to examine the impact of technological innovation on the efficiency of 35 Vietnamese commercial banks in the period 2009 to 2022. Using the DEA approach, the research first measures the efficiency and technological innovation index of Vietnamese commercial banks over the period 2009 to 2022. Then, the research uses the Tobit regression technique to examine the effect of technological innovation on the efficiency of Vietnamese commercial banks.

The average rate of Technological innovation in Vietnamese commercial banks is 0.985 < 1. Thus, Technological progress hasn't been promoted during this research period, and many banks still lean towards labor-intensive Technological practices. The average cost efficiency of commercial banks is 0.768, showing that Vietnamese commercial banks haven't yet fully utilized input resources. The results of the Tobit model provide that the Technological innovation index has a positive effect on the cost efficiency of Vietnamese banks. In addition, this study also shows that Profitability, Bank Size, Equity ratio, State Ownership, and Economic Growth have a positive impact. While the Nonperforming Loans and Inflation have a negative impact on the cost efficiency of Vietnamese commercial banks.

The study results provide a scientific basis for policy recommendation for policymakers and bank administrators. For improve cost effiency, Vietnamese banks need to continue to enhance Technological innovation by continuing to invest in and development digiatal Technological products, promote the deployment of technology application operation, and enhance the training of hight tech human resources.

In addition, to improve cost efficiency, commercial banks need to continue to improve their financial capacity and competitiveness by improving profitability, increasing economic growth and curbing inflation, stabilizing the system, reviewing, and promulgating policies, and creating a favorable legal environment for the operation of Vietnamese commercial banks.

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