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Article

Factor affecting technical efficiency of the banking sector: Evidence from Ethiopia

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FINANCIAL ECONOMICS | RESEARCH ARTICLE

Factor affecting technical efficiency of the banking sector: Evidence from Ethiopia

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Abstract: An efficient bank is more robust to shocks, fosters competitiveness, and promotes stability of the financial system. This study estimates Ethiopia's commercial banks' level of efficiency and its determinants during the period 2014–2020. Data Envelopment Analysis (DEA), Malmquist DEA, and Tobit regression were employed to analyze the data. The result indicated that the average efficiency score of banks in the constant returns to scale (CRS), variable returns to scale (VRS), and scale efficiency (SE) models were 95.5%, 99.85%, and 96.95%, respectively. Furthermore, in the VRS model, a state bank is more efficient than private banks. During the study period, the Total Factor Productivity (TFP) of Banks improved by 1%. According to the Tobit model, the efficiency of banks grows with an increment in the number of branches, bank size, and credit risk. However, when, liquidity risk and the log of the fixed asset increase, bank efficiency will decrease. The level of capitalization, log of GDP, and inflation, on the other hand, do not influence bank efficiency. Therefore, banks should pay close attention to aspects that influence technical efficiency.

Subjects: Public Finance; Corporate Finance; Banking

Keywords: Bank efficiency; DEA; CRS; VRS; SE; Malmquist Index; Tobit

JEL Classification: G21; G24; G32



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Salah Mohammed Abdulahi was born in 1988 in Harar, Ethiopia. He earned a Bachelor of Art in Economics from Jimma University in 2008 and a Master of Science in Development Economics from Dire Dawa University in 2018. He is currently a lecturer in the department of economics at Haramaya University, Ethiopia. His professional interests include measuring institutional productivity and efficiency, as well as assessing the impact of development programs. He published one paper entitled "The Three-Dimensional Impacts of Governance on Economic Growth: Panel Data Evidence From The Emerging Market" and currently he is leading a research project dealing with the impact of urban productive safety net program on poverty reduction in major cities of Eastern Ethiopia.

PUBLIC INTEREST STATEMENT

This paper measures factors affecting the technical efficiency of commercial banks of Ethiopia using the nonparametric frontier DEA and Tobit model. The paper also estimates the total factor productivity of the output using the Malmquist index. The result indicates that the number of branches, bank size, credit risk, fixed assets, and liquidity risk are the most important factors that must be considered in determining the technical efficiency of commercial banks in Ethiopia. On the contrary, the study reveals that capitalization, inflation, and GDP growth are not important to determine the technical efficiency of commercial banks in Ethiopia. Further, factor productivity of commercial banks has improved throughout the study period. Thus, decision-makers should take into account bank specific and macroeconomic variables to improve the efficiency of banks.

1. Introduction

In the economic growth and stability of a country, banks have an important role. They help in channelizing household savings to corporations and industries where it is optimally used for the development of the country. As financial institutions improve their efficiency and productivity in channelizing financial resources, they will bring value to the economy as a whole. Further, they should perform efficiently in converting their costly inputs into a variety of financial products and services to serve the aforementioned role effectively. According to Adusei and McMillan (2016), “Only strong technically efficient and profitable banks can promise a realistic return to their stakeholders and reduce the probability of bankruptcy.” As a result, it is important to investigate efficiency levels and identify factors determining bank performance. In Ethiopia, the financial market is developing and plays a key role in mobilizing funds. Moreover, banks dominate Ethiopia’s financial sector, with total banking capital of Birr 85.5 billion and fresh loan disbursements of Birr 271.2 billion, up 14.8% from a year before (National Bank of Ethiopia, 2020). Thus, with the increase in the number of commercial banks and rapid changes in the financial environment, assessing determinants of banking efficiency is a major issue.

DEA and Tobit models are common methods in the banking literature that are used to measure technical efficiency. Such studies include Sarsour and Daoud (2015), Karimu Tossa (2016), Hamid et al. (2017), R. Banya and Biekpe (2018), and Banna et al. (2019), and Jiménez-Hernández et al. (2019), and Cheriye (2020), and Jelassi and Delhoumi (2021).

Though there are many studies that examine the determinants of bank efficiency, little effort has been made to study the efficiency of banks in Ethiopia. Studies by Lelissa (2014), Tesfay (2016), Zenebe Lema (2017), and Dinberu and Wang (2018) have tried to measure the efficiency of commercial banks in Ethiopia. However, these articles are unable to incorporate relevant bank-specific explanatory variables like the number of branches and macro-specific variables like inflation and GDP in their efficiency model. Based on the findings of Jelassi and Delhoumi (2021), Ofori-Sasu et al. (Ofori-Sasu et al., 2019), and Trabelsi and Trad (2017) the aforementioned variables have a significant impact on determining the efficiency level of commercial banks.

Furthermore, previously conducted research did not measure factor productivity change on outputs of Ethiopian commercial banks. In addition, the data used in the aforementioned articles were too old for observing the current performance of banks in the dynamic financial world. In particular, Zenebe Lema (2017) made his analysis by using data from 2011 to 2014 and he failed to take into account the efficiency of three commercial banks, namely Enat Bank, Debub Global Bank, and Addis International Bank.

As a result, our study used the DEA and Tobit models to estimate the efficiency score and factor productivity changes and investigate factors that affect the technical efficiency of commercial banks in Ethiopia over the years 2014 to 2020. Therefore, this research could be crucial in understanding the technical efficiency score, changes in factor productivity, and variables affecting the technical efficiency score of commercial banks in Ethiopia. Furthermore, this study will be useful in providing a better foundation for bank managers, business professionals, and policymakers to improve the overall efficiency of the financial sector.

2. Literature review

Theoretical measurement of efficiency for decision-making units could be either parametric or nonparametric techniques. The parametric techniques such as the Stochastic Frontier Approach (SFA) or Distribution-Free Approach (DFA) were used to measure efficiency. The nonparametric technique includes mainly data envelopment analysis (DEA) and Free Disposal Hull Analysis (FDH). Empirically, a large volume of studies were conducted on the factors affecting the technical efficiency of commercial banks in various countries. For instance, Řepková (2015), R. Banya and Biekpe (2018), Goswami, Hussain, Kumar et al. (2019), Jiménez-Hernández et al. (2019), and Sultana and Rahman (2020), and Jelassi and Delhoumi (2021)

have examined both bank-specific and macroeconomic factors that determine technically the efficiency of banks. Bank-specific factors include those factors that are specific to banks or that are controlled by their management policy and decisions (Djalilov & Piesse, 2016). Macroeconomic factors, on the other hand, are the exogenous forces derived from the nation's economic environment and are not directly related to the internal banking policy (Ding et al., 2017).

Consequently, different literature on bank efficiency shows that the level of efficiency varies from country to country and the findings are inconsistent in terms of sign, size, and statistical significance of the coefficients of explanatory variables. In Ethiopia, studies (Yasin, 2018; Amene & Alemu, 2019; and Lemi et al., 2020) were conducted to investigate determinants of financial performance using ratio analysis. However, it is difficult to get comprehensive figures indicating the efficiencies of banks by only applying ratio analysis. Hence, this paper explores issues that influence the technical efficiency of commercial banks in Ethiopia using DEA and Tobit models.

2.1. Bank specific factors

2.1.1. Branches of bank

Literature on the effect of the number of bank branch on the technical efficiency of banks is limited. Bannour and Labidi (2013) found that the technical efficiency of commercial banks may not increase with the broadening of their distribution networks. Furthermore, Hirtle (2007) and Řepková (2015) found no significant effect on the number of branches. According to Liang et al. (2013), they found a positive impact on the technical efficiency of banks. This is because as banks get geographically closer to their clients, could enhance their number of clients, which in turn raise their performance. Based on the aforementioned, the study proposes the following hypothesis.

H₁: There is a direct relation between the number of branches and efficiency of banks.

2.1.2. Bank size

On the empirical front, the nexus between bank size and efficiency is an ongoing debate. Studies such as Karray and Eddine Chichti (2013), Anwar (2019), Otero et al. (2020), and Sakouvogui and Shaik (2020) establish that banks with higher assets record have higher efficiency in their operation. However, studies show that there is an inverse relationship between bank size and cost-efficiency literature (Ding & Sickles, 2018; Hadhek et al., 2018; R. M. Banya & Biekpe, 2017; Staněk, 2015). However, Ojeyinka and Akinlo (2021) found that larger banks do not enjoy any cost advantage over their smaller counterparts, hence, refereeing to the findings, the study proposes the following hypothesis.

H₂: The efficiency of banks is directly related to the size of banks as measured by total asset

2.1.3. Credit risk

Credit risk was found to be ambiguous. R. Banya and Biekpe (2018), Adusei and McMillan (2016), and Sharma et al. (2015) found that risk was positively related to technical efficiency. Whereas Salim et al. (2017), Hamza (2017), and Munangi and Bongani (2020) found that there is an inverse relationship between credit risk management and bank performance. Hence, the study predicts the following hypothesis.

H₃: Credit Risks are associated inversely with bank efficiency.

2.1.4. Liquidity risk

Empirical studies show that the impact of liquidity risk on bank efficiency is mixed. Some studies (Batir et al., 2017; Řepková, 2015; Tan et al., 2017) found that liquidity risk has a positive effect on bank efficiency. Others found a negative effect (Dahiyat, 2016; Marozva, 2015). Furthermore, R. Banya and Biekpe (2018) found that liquidity risk is insignificant to affect technical efficiency. Referring to these findings, we propose the following hypothesis:

H4: Liquidity Risk is inversely associated with efficiency.

2.1.5. Level of capitalization

Capitalization was found to be positively related to technical efficiency by most of the studies (Řepková, 2015; Ayadi, 2014; Blankson et al., 2022), except Batir et al. (2017), Adusei and McMillan (2016), and Adjei-Frimpong et al. (2014) who found a negative relationship between capitalization and technical efficiency. Based on the literature, the study hypothesised the following statement.

H5: Level of Capitalization directly influences the efficiency level of banks.

2.1.6. Fixed asset

Fixed asset investment is crucial for conducting business operations and also improves an organization's ability to deliver goods and services. The literature on the impact of fixed assets on bank efficiency is scanty. According to Olatunji and Adegbite (2014), fixed assets of banks significantly and positively affect bank efficiency. In contrast, Marian and Ikor (2017) found a negative impact of fixed assets on the performance of banks. Hence, our study proposes the following statement.

H6: Fixed asset directly related to bank efficiency

2.2. Macroeconomic factors

2.2.1. GDP Growth

A country's economic growth is traditionally measured by its Gross Domestic Product (GDP) and can have a significant impact on the performance of banks. Studies by Defung et al. (2016), Kamarudin (2015), and Trabelsi and Trad (2017) found that in time of favor of economic growth the demand for credit by household and company will rise up which in turn increases the efficiency of banks. However, Dell'Atti et al. (2015), Aiello and Bonanno (2016), and Goswami, Hussain, Kumar et al. (2019) showed that in periods of significant economic growth, they inversely affect the profitability of banks. This is due to the tendency to adjust their interest margins. Accordingly, we propose the following hypothesis to be tested

H7: There is a significant positive relationship between the country's GDP and the efficiency of banks

2.2.2. Inflation rate

Empirical literatures has found inconclusive features between the effect of inflation and the performance of the commercial bank. Most of the literature (Alhassan et al., 2016; Jelassi & Delhoumi, 2021; Seelanatha, 2012) found that there is a positive impact of inflation on bank efficiency. However, studies by Ofori-Sasu et al. (2019) and Karimu Tossa (2016) found a negative relation between inflation and the technical efficiency of banks. Based on the mixed result, the following hypothesis is posed.

H8: Inflation rate inversely associated with bank efficiency

3. Methodology

The study considered all 17 commercial banks in Ethiopia, which have audited financial statements over the period 2014 to 2020.

3.1. Variables definition and measurements

In the efficiency literature, there is no single rule for selecting input and output variables (Berger & Humphrey, 1997) and the variables are defined using the production approach, intermediation approach, value-added approach, and operating approach. Banks are assumed to be intermediaries between savers and borrowers in the intermediation approach, so the inputs are all types of funds and the outputs are all types of lending products. The production approach is used to study the efficiency of bank branches, while the intermediation approach is used for empirical studies at the bank or industry level (Mohd Noor. et al., 2020).

This study used a variant of the intermediation approach based on Sealey and Lindley's (1977) widely accepted intermediation approach. Furthermore, several studies Mohd Noor. et al., (2020); Mokhtar et al. (2008); Rahim et al. (2013); and Dharmendra and Bashir, 2015) used an intermediation approach to assess bank efficiency. Following the works of previous literature (Karimu Tossa, 2016; Ofori-Sasu et al., 2018; Tadesse 2017 and Lutfi and Suyatno 2019), this study used input variables such as fixed asset, deposit, and interest expense. Total loan and advances, interest income, and non-interest income as output variables as described in Table 1. Various studies considered labour as one of the input output variables in estimating commercial banks' technical efficiency. However, in this study, we did not consider labour as an input variable in the estimation process because the contribution of employee's number (physical labour) in the production process is less significant than effective (productive) labour. As explained by Marshall (1967), labour is the amount of physical, mental, and social effort required in an economy to produce goods and services. It also provides the knowledge, manpower, and services needed to convert raw materials into finished goods.

According to Jajri and Ismail (2010), effective labour differs from physical labour in that the former is computed by taking into account labour quality in terms of educational qualification, training received, or skill acquired. Furthermore, education and training have a significant impact on labour quality. In theory, when effective labour (labour quality) is used, output growth is

Table 1. Description of input-output variables (DEA model)

Variables		Description
Output Variables	Total loan and advances	Total loan and advance disbursed for customers
	Interest income	Interest on loans and advances, interest on deposits, and interest on Treasury and NBE bills are all added together.
	Non-interest income	Commissions, fees on letters of credit, letters of guarantee, and local transfers, as well as other sources of revenue
Input Variables	Fixed assets	Total fixed asset
	Deposits	The sum of demand, time, and saving deposit
	Interest expense	The sum of payment on fixed deposits, saving and demand deposits

Source: Based on the literature, 2021

enhanced and occurs at a faster rate than labour force growth (number of labour). This higher growth rate can be attributed to the productivity difference between physical labour and effective labour.

Therefore, in order to capture the full effect of labour in our study, we have to collect the disaggregated data about both the actual number of physical labour and effective labour. However, such disaggregated data were difficult to obtain uniformly from each commercial bank of Ethiopia for the study period. As a result, estimating bank efficiency mainly by the number of employees without taking into account the quality of labour will result in a biased estimation.

Therefore, we are unable to include labour as an input variable in our efficiency model. However, acknowledging the absence of labour as an input variable, we still hope to provide a useful framework for analysing the technical efficiency of commercial banks in Ethiopia.

Table 2 also outlines the expected characteristics that influence the efficiency of Ethiopian commercial banks. The following bank-specific and macroeconomic variables are utilized for the second stage of the DEA model. The selection of the variables is supported by various literatures (Zenebe Lema, 2017; Akmal & Saleem, 2008; Ayadi, 2014; Tesfay, 2016; Alrafadi et al., 2014; Soetanto, 2011; Jelassi & Delhoumi, 2021; Hassan & Jreisat, 2016; and Soetanto, T. V., 2011; Tecles & Tabak, 2010; Rosman et al., 2014; Řepková, 2015; Petria et al., 2015; Blankson et al., 2022; Dinberu & Wang, 2018) and availability of data. As a result, the study considered the number of branches, bank size, liquidity risk, capitalization level, log of fixed assets, credit risk, log of GDP, and inflation as factors affecting the technical efficiency of Ethiopian banks.

3.2. Methods of analysis

3.2.1. Data envelopment analysis (DEA)

In this study, the DEA model was used to assess the technical efficiency of commercial banks. DEA is a nonparametric linear programming technique that produces an efficiency frontier by

Table 2. Determinants of bank efficiency

Notation	Variable	Definition	Expected Sign
Dependent variable			
TE	Technical Efficiency	Efficiency scores of banks computed by applying VRS DEA method	
Independent variables			
NB	Number of Branches	Number	+
LQ	Liquidity Risk	The ratio of Total Loans to Total Deposits	-
CR	Credit risk	loan to asset ratio	+
SIZE	Bank size	The log of total Asset	+
LC	Level of Capitalization	The ratio of equity divided by total assets	+
LogFA	Fixed Asset	The logarithm of fixed asset	+
Log GDP	Log of GDP	The logarithm of GDP	+
INF	Inflation	Inflation rate measured by the consumer price index approach	-

Source, Own Computation, 2021

optimizing each provider's weighted output/input ratio. It is a method for comparing a company's or its components' performance by taking into account various inputs and outputs. By using Charnes et al. (1978)'s proposed model, the efficiency score based on a constant return to scale (CRS) is defined as follows:

$$Efficiency = \frac{\sum \text{of bank outputs, weighted}}{\sum \text{of bank inputs, weighted}} \quad (1)$$

If there are n banks, each with m bank inputs and s bank outputs, the relative efficiency score of one of them, P , can be obtained by solving the following model:

$$Efficiency = \max \frac{\sum_{r=1}^s U_r Y_{rp}}{\sum_{i=1}^m V_i X_{ip}} \quad (2)$$

$$s.t : \max \frac{\sum_{r=1}^s U_r Y_{rj}}{\sum_{i=1}^m V_i X_{ij}} \leq 1; j = 1, 2, \dots, n$$

$$U_r, V_i > 0; \quad r, i; r = 1, 2, \dots, s; i = 1, 2, \dots, m$$

Where:

X_{ij} = the amount of input utilized by the bank
 Y_{ij} = the amount of output produced by the bank
 U_r = weight given to output r
 V_i = weight given to input i

The functional programming model of equation (2) can be transformed to a linear programming model by adding the following constraint.

$\sum_{i=1}^m V_i X_{ip} = 1$ thus, the relative efficiency score of bank P can be obtained by solving the following equation

$$Max \text{ Efficiency}_P = \max_{U_r, V_i} \sum_{r=1}^s U_r Y_{rp}$$

$$s.t : \sum_{r=1}^s U_r Y_{rj} - \sum_{i=1}^m V_i X_{ij} \leq 0; \quad j = 1, 2, \dots, n$$

$$\sum_{i=1}^m V_i X_{ip} = 1, U_r, V_i > 0; \quad r, i \quad (3)$$

The first constraint requires that all banks need to be on or below boundaries, while the second stipulates that a bank's weighted sum of inputs must equal one. The technical and scale efficiency ratings are separated using the variable return to scale (VRS) methodology. Variable returns to scale cover the data more closely than the CRS model. As a result, the relative efficiency score of bank P can be calculated using the equation:

$$\text{Max Efficiency}_p = \text{Max}_{u_r, v_i} \sum_{r=1}^s U_r Y_{rp} + U_0$$

$$\text{s.t.} : \sum_{r=1}^s U_r Y_{rj} - \sum_{i=1}^m V_i X_{ij} + U_0 \leq 0; \quad i$$

$$\sum_{i=1}^m V_i X_{ip} = 1U_r, V_i > 0; \quad r, \quad i \quad (4)$$

Where;

The return to scale is determined by the sign of the convexity constraint, $U = 0$. If $U_0 = 0$, the returns to scale are constant; if $U_0 > 0$, the returns to scale are expanding; and if $U_0 < 0$, the returns to scale are increasing. The scale efficiency is derived as the ratio of the CRS and VRS models' efficiency scores (Coelli et al., 2005).

3.2.2. Malmquist indices of total factor productivity

The Malmquist index is used to calculate the change in total factor productivity. To assess the TFP change between two data points, the Malmquist Index evaluates the ratio of the distances between each data point compared to a common technology. According to Fare et al. (1989), an output-based Malmquist productivity change is defined as the geometric mean of two output-based Malmquist indices, as illustrated in the following equation:

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

Where M_0 measures production of the productivity point (x^{t+1}, y^{t+1}) relative to (x^t, y^t) ; D_0 stands for the distance from the frontier.

When M_0 is greater than one, the total factor productivity grew from period t to period $t + 1$, and when M_0 is less than one, the total factor productivity fell. The index in Equation (5) is a mixture of two indices. In one index, period t technology is employed, whereas in the other, period $t + 1$ technology is used.

3.2.3. Tobit regression model

The Tobit model was used to explore the elements that influence commercial bank efficiency. This model was chosen because it is designed to estimate linear correlations between variables when the dependent variable has either left- or right-censoring, and in our case the dependent variable (DEA VRS) has a range of 0 to 1. Furthermore, the Tobit model converts the dependent variable's observed response into a latent variable (Wooldridge, 2015). Similar studies on efficiency determinants have been conducted in many parts of the world using the same methodology (Zenebe Lema, 2017; Akmal & Saleem, 2008; Alrafadi et al., 2014; Soetanto, 2011).

Hence, the Tobit regression model is given by;

$$Y_{it}^* = X_{it}^* \beta + \epsilon_{it}$$

$$y_{it} = \begin{cases} L, & \text{if } y_{it}^* < L \\ y_{it}^*, & \text{if } L < y_{it}^* < U \\ U, & \text{if } y_{it}^* > U \end{cases} \quad (6)$$

Where y_{it} is the observed dependent variable and y_{it}^* is a vector of explanatory variables and are the parameters to be estimated, L is the lower limit, U is the upper limit, $I = 1, 2, \dots, N$ represents people, and $t = 1, 2, \dots, N$ represents time. The period is denoted by Tt , while the number of periods is denoted by Tt . An empirical regression model is specified as;

$$TE_{it} = \beta_0 + \beta_1 NB_{it} + \beta_2 LQ_{it} + \beta_3 CR_{it} + \beta_4 SIZE_{it} + \beta_5 LC_{it} + \beta_6 LogFA_{it} + \beta_7 LGDP_{it} + \beta_8 INF_{it} + \varepsilon_{it} \quad (7)$$

4. Results

4.1. Descriptive statistics

The summary statistics of input-output variables are reported in Table 3. Banks had an average total loan, interest income, and return on non-interest income of Birr 19.05 billion, 3.06 billion, and 833 million, respectively. In addition, banks in Ethiopia recorded a fixed asset, Deposit, and interest expense of 1.13 billion, 36.27 billion, and 1.23 billion Birr, respectively.

4.2. DEA Results

Table 4 shows the efficiency ratings of the DEA result, which may be used to measure the banking sector's productivity performance from 2014 to 2020.

Table 3. Descriptive Statistics

Variable	Observations	Mean	Standard. Deviation	Minimum	Maximum
Output variables					
Total loan and advances	119	19,054.18	38,925.62	270.00	234,030.00
Interest income	119	3,059.67	7,625.40	37.00	49,992.00
Total non-interest income	119	833.01	1,386.17	40.00	8,626.00
Input Variables					
Fixed assets	119	1,125.66	2,261.66	19.00	14,835.00
Deposits	119	36,274.39	94,212.49	500.00	591,107.00
Interest expense	119	1,229.09	3,101.63	12.00	21,340.00

Source: Own computation, 2021

Table 4. Summary of Efficiency Scores

	CRSTE	VRSTE	SCALE
Number of efficiency	7	14	7
Number of inefficiency	10	3	10
Maximum efficiency	100	100	100
Minimum efficiency	83	97	83
Average efficiency	96.5	99.6	96.9

Source: Own computation, 2021

Table 4 shows that under VRSTE assumptions, three are inefficient and 10 under CRSTE assumptions. In addition, 10 banks are SCALE inefficient. In contrast, under VRSTE, 14 efficient Banks, and under both CRSTE and SCALE efficiency assumptions, 7 banks are efficient. In the CRSTE, VRSTE, and SCALE models, the average efficiency score for banks from 2014 to 2020 is 96.5%, 99.6%, and 96.9%, respectively. This demonstrates that banks have the ability to increase the average technical efficiency by 3.5%, 0.4%, and 3.1% in each model, respectively.

4.3. Annual efficiency score of banks

The annual efficiency score for the year 2014 to 2020 is presented in Table 5 and Table 6. The result in Table 5 indicates that, for the year 2014, 8 (47%) banks registered efficiency scores of 100% and 9 (53%) are technically inefficient with a score below 100% in CRSTE. On the other hand, 11 (65%) banks were at their highest efficiency score (100%) in variable return to scale assumption and 6(35%) are inefficient. In addition, 7 (41%) banks are scale efficient and 10 (59%) banks are scale inefficient. In terms of bank return to scale, 6 (35%) were experiencing decreasing returns to scale, 2 (18%) were seeing increasing returns to scale, and 9 (47%) were at their optimal level of constant return to scale.

Bank's technical and scale efficiency for the years 2015 and 2016 revealed that 5 (29%) banks scored a CRS of 100%, whereas in the year 2016 there were 4 (24%) banks that registered an efficiency score of 100%. On the other hand, 12 (71%) and 13 (76%) banks become technically inefficient for the period 2015 and 2016, respectively. Furthermore, 12 (71%) of banks had a VRS technical efficiency score of 100%, whereas 5 (19%) of banks were inefficient (below 100%) in the periods. Moreover, 5 banks (29%) and 4 banks (24%) were scale efficient, while 12 (71%) and 13 (76%) banks registered scale efficiency score of below 100% for the years 2015 and 2016, respectively. In terms of returns to scale, 6 (35%) and 2 (12%) banks showed a rising return to scale over the course of the respective periods. However, 6 (35%) and 11 (65%) banks, respectively, showed falling returns to scale in the two decades. Furthermore, 5 (19%) and 4 (24%) banks operated at optimal CRS. Similarly, the result in Table 6 indicates that for the period 2017 and 2018, 8 (47%) banks scored CRS of 100% in both periods. On the other hand, 9(53%) of banks registered CRS technical efficiency scores of below 100% for both periods. Further, 12 (71%) banks and 11 (65%) banks were registered efficient, whereas 5(19%) and 4(24%) banks are inefficient for respective periods. Furthermore, 8 banks (47%) and 9(53%) banks were scale efficient, while the remaining 9(53%) and 8(47%) banks registered scale efficiency scores lower than 100% for the years 2017 and 2018, respectively. Three (18%) of banks and two (12%) of banks exhibited an increasing return. Nonetheless, 6(35%) banks exhibited decreasing returns to scale in both periods, while 4 (24%) of banks exhibited constant returns to scale were they operate at their optimal level.

Moreover, Table 6 show that for the period 2019 and 2020, 7(41%) and 9(53%) banks registered a CRSTE score of 100%, while 10(59%) and 8(47%) banks become technically inefficient for the CRS model for the respective period. On the other hand, 12(71%) and 13(76%) banks scored a variable return to scale of 100%, whereas 5(19%) and 4(24%) banks scored less than 100% for the respective periods. Moreover, 7 banks (41%) and 9 (53%) banks registered scale efficiency score 100%; however, 10(59%) banks and 8(47%) of banks are scale inefficient. Concerning return to scale of banks, only Addis International Bank exhibited increasing return to scale for the year 2019, while 9(53%) and 8(47%) banks showed decreasing returns to scale and the remaining 7(41%) and 9(53%) banks exhibited constant return to scale for respective periods.

4.4. Technical efficiency of banks based on ownership

The results in Table 7 indicate that in a VRSTE model, the state bank (commercial bank of Ethiopia) is efficient through periods as compared to private banks. Similarly, it is efficient for the first two periods in CRSTE. However, for the rest periods, domestic banks' efficiency scores become enhanced and showed better scores than state-owned banks, particularly in CRSTE and Scale efficiency assumptions.

Table 5. Banks' Technical and Scale Efficiency for 2014–2016

Banks	2014				2015				2016			
	CRSTE	VRSTE	scale	RTS	CRSTE	VRSTE	scale	RTS	CRSTE	VRSTE	scale	RTS
Commercial Bank of Ethiopia	1	1	1	crs	1	1	1	crs	0.928	1	0.928	drs
Awash International Bank	0.914	1	0.914	drs	0.828	1	0.828	drs	0.937	1	0.937	drs
Dashen Bank	0.814	1	0.814	drs	0.755	1	0.755	drs	0.786	1	0.786	drs
Bank of Abyssinia	0.959	1	0.959	drs	0.806	0.84	0.96	drs	0.831	0.881	0.943	drs
Wegagen Bank	0.936	1	0.936	drs	0.908	0.959	0.947	drs	0.957	1	0.957	drs
United Bank	0.91	1	0.91	drs	0.843	0.907	0.93	drs	0.969	1	0.969	drs
Nib International Bank	1	1	1	crs	0.954	1	0.954	drs	0.946	1	0.946	drs
Cooperative Bank of Oromia	1	1	1	crs	1	1	1	crs	1	1	1	crs
Lion International Bank	0.947	0.952	0.995	drs	1	1	1	crs	0.975	1	0.975	drs
Oromia International Bank	0.834	0.836	0.999	irs	0.733	0.755	0.97	irs	0.898	0.902	0.996	drs
Berhan International Bank	1	1	1	crs	0.985	1	0.985	irs	1	1	1	crs
Bunna International Bank S.c	1	1	1	crs	0.947	1	0.948	irs	0.99	0.993	0.997	irs
Zemen Bank Sc	0.971	0.971	0.999	crs	1	1	1	crs	0.946	1	0.946	drs
Aby Bank Sc	0.862	0.899	0.959	irs	0.826	0.861	0.959	irs	0.902	0.917	0.984	drs
Addis International Bank Sc	1	1	1	crs	1	1	1	crs	1	1	1	crs
Debub Global Bank S.c.	0.94	1	0.94	irs	0.938	1	0.938	irs	1	1	1	crs
Erat Bank S.c.	1	1	1	crs	0.845	1	0.845	irs	0.953	0.956	0.996	irs
Mean	0.946	0.98	0.966		0.904	0.96	0.942		0.942	0.979	0.962	

(Continued)

Table 5. (Continued)												
Banks	2014				2015				2016			
	CRSTE	VRSTE	scale	RTS	CRSTE	VRSTE	scale	RTS	CRSTE	VRSTE	scale	RTS
Sd	0.062	0.046	0.051		0.093	0.074	0.07		0.060	0.04	0.052	
Min	0.814	0.836	0.814		0.733	0.755	0.755		0.786	0.881	0.786	
Max	1	1	1		1	1	1		1	1	1	

Source: Own computation, 2021

Table 6. Banks' Technical and Scale Efficiency for 2017–2020

Banks	2017					2018					2019					2020				
	crste	vrste	scale	RTS	crste	vrste	scale	RTS	crste	vrste	scale	RTS	crste	vrste	scale	RTS	crste	vrste	scale	RTS
Commercial Bank of Ethiopia	0.873	1	0.873	drs	0.899	1	0.899	drs	0.933	1	0.933	drs	0.84	1	0.84	drs	0.84	1	0.84	drs
Awash International Bank	1	1	1	crs	1	1	1	crs	1	1	1	crs	1	1	1	crs	1	1	1	crs
Dashen Bank	0.907	1	0.907	drs	0.882	1	0.882	drs	0.921	0.932	0.988	drs	0.93	0.968	0.961	drs	0.93	0.968	0.961	drs
Bank of Abyssinia	0.937	0.942	0.995	drs	1	1	1	crs	0.941	1	0.941	drs	0.956	0.958	0.998	drs	0.956	0.958	0.998	drs
Wegagen Bank	1	1	1	crs	1	1	1	crs	0.893	0.969	0.921	drs	0.93	1	0.93	drs	0.93	1	0.93	drs
United Bank	1	1	1	crs	0.936	0.962	0.972	drs	0.951	0.999	0.952	drs	0.983	1	0.983	drs	0.983	1	0.983	drs
Nib International Bank	0.993	1	0.993	drs	0.911	0.912	0.999	irs	0.895	0.946	0.946	drs	0.939	0.961	0.977	drs	0.939	0.961	0.977	drs
Cooperative Bank of Oromia	1	1	1	crs	1	1	1	crs	1	1	1	crs	1	1	1	crs	1	1	1	crs
Lion International Bank	1	1	1	crs	1	1	1	crs	1	1	1	crs	0.896	0.941	0.952	drs	0.896	0.941	0.952	drs
Oromia International Bank	0.9	0.945	0.953	drs	1	1	1	crs	1	1	1	crs	1	1	1	crs	1	1	1	crs
Berhan International Bank	1	1	1	crs	0.998	1	0.998	drs	0.984	1	0.984	drs	1	1	1	crs	1	1	1	crs
Bunna International Bank S.c	0.995	0.997	0.998	irs	1	1	1	crs	1	1	1	crs	1	1	1	crs	1	1	1	crs
Zemen Bank Sc	0.852	1	0.852	drs	0.694	0.731	0.95	drs	0.864	0.873	0.989	drs	0.953	1	0.953	drs	0.953	1	0.953	drs
Abay Bank Sc	0.879	0.886	0.992	irs	0.905	0.999	0.906	drs	0.895	1	0.895	drs	1	1	1	crs	1	1	1	crs
Addis International Bank Sc	1	1	1	crs	0.961	0.966	0.995	irs	0.94	1	0.94	irs	1	1	1	crs	1	1	1	crs
Debub Global Bank S.c.	1	1	1	crs	1	1	1	crs	1	1	1	crs	1	1	1	crs	1	1	1	crs
Enat Bank S.c.	0.947	0.963	0.983	irs	0.962	0.962	1	crs	1	1	1	crs	1	1	1	crs	1	1	1	crs
Mean	0.958	0.984	0.973		0.950	0.972	0.977		0.954	0.983	0.97		0.966	0.99	0.976		0.966	0.99	0.976	

(Continued)

Table 6. (Continued)												
Banks	2017				2018				2019			
	crste	vrste	scale	RTS	crste	vrste	scale	RTS	crste	vrste	scale	RTS
Sd	0.055	0.032	0.048		0.079	0.067	0.041		0.048	0.035	0.035	
Min	0.852	0.886	0.852		0.694	0.731	0.882		0.864	0.873	0.895	
Max	1	1	1		1	1	1		1	1	1	

Table 7. Technical Efficiency (Mean)—Based on Ownership

	Private (Domestic) Banks							
	2014	2015	2016	2017	2018	2019	2020	Average
CRSTE	0.943	0.898	0.943	0.963	0.953	0.955	0.974	0.947
VRSTE	0.979	0.958	0.978	0.983	0.971	0.982	0.989	0.977
SCALE	0.964	0.939	0.965	0.980	0.981	0.972	0.985	0.969
	State-owned bank							
CRSTE	1	1	0.928	0.928	0.928	0.933	0.84	0.937
VRSTE	1	1	1	1	1	1	1	1.000
SCALE	1	1	0.928	0.928	0.928	0.933	0.84	0.937

Source: Own computation, 2021

4.5. Peer and Peer weights

Table 8 shows the peer and peer weights for banks generated from the VRS efficiency model for the recommended model. Inefficient banks might improve their performance by adopting the policies and organizational structure of their peers.

The result indicated that the peer group for Bank 4 (Bank of Abyssinia) is the bank (2, 5, 6, & 12) which entails that to become efficient, bank of Abyssinia should use an input–output combination of banks (Bunna International Bank, Wegagen Bank, Awash International Bank, and United Bank). The levels of the combination of the four banks are determined by peer weight.

4.6. Input and output slacks

Table 9 provides a summary of input and output slack movement (adjustment) for inefficient banks to become efficient. The results indicated that on average, the output side of inefficiency could be increased by Birr 76 million and Birr 25 million for total loan and interest income, respectively, without changing the current input level.

Furthermore, if inefficient banks could lower fixed assets by Birr 37 million in order to become more efficient while maintaining current output levels (See, Table 9 in the appendix).

4.7. Total factor productivity (TFP)

Table 10 presents a summary for Malmquist index of annual geometric means. It is shown that, on average, TFP increased to some extent by 1% over the period 2014–2020. This improvement in productivity of banks is mainly enhancement in technological changes (6%), where banks expand the use of ICT for different service provisions. In addition, banks also improved internal efficiency by 4%. Furthermore, the total productivity improvement is also contributed by 2% for both changes on pure and scale efficiencies.

Moreover, Table 11 provides a summary of TFP growth of banks' means. Accordingly, Abay Bank attains premier growth (6.2%) followed by Dashen Bank (6%) and United Bank (5.9%). All of this expansion is the result of technical advancements of banks by 3.6%, 3.7%, and 4.5%, respectively. While Commercial and Cooperative banks have shown the highest deterioration total factor productivity by (7.2%) and (7.8%), respectively (See, Table 11 in the appendix).

4.8. Factors affecting commercial banks of Ethiopia

4.8.1. Descriptive statistics of variables in the Tobit model

Table 12 presents the summary statistics of variables in the Tobit model. As it is shown, the banks under study recorded an average number of branches of 243. The number of branches varies from

Table 8. Peers and Peer Weight

DMUs(Banks)	peers:					peer	weights:		
1	1					1			
2	2					1			
3	3					1			
4	2	5	6	12		0.238	0.417	0.302	0.044
5	5					1			
6	6					1			
7	2	6	5			0.018	0.404	0.578	
8	8					1			
9	9					1			
10	12	8	2			0.497	0.431	0.072	
11	11					1			
12	12					1			
13	13					1			
14	14					1			
15	15					1			
16	16					1			
17	17					1			

Source: Own computation, 2021

Table 9. Input and output slacks

Banks	Output slacks			Input slacks		
	Total loan	Interest income	Interest income	Fixed assets	Deposit	Interest expense
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	188.434	415.551	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	160.076	0	227.183	168.428	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	1137.231	0	15.294	58.813	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
Mean	76.312	0	25.348	37.811		

Source: Own computation, 2021

Table 10. TFP Growth

Year	Eff	TE	PE	SE	TFP
2015	0.952	1.068	0.978	0.974	1.017
2016	1.046	0.991	1.022	1.023	1.036
2017	1.017	0.929	1.005	1.012	0.945
2018	0.99	1.027	0.986	1.004	1.017
2019	1.007	1.028	1.013	0.994	1.035
2020	1.013	0.999	1.007	1.006	1.012
Mean	1.004	1.006	1.002	1.002	1.01

Source: Own computation, 2021

Note that the abbreviations Eff, TEch, PE, SE, and TFP stood for efficiency change, technological efficiency change, pure efficiency change, scale efficiency change, and total factor productivity change, respectively.

4 to 1825 over the period. The average liquidity risk of the commercial banks in Ethiopia under study is determined to be 0.498 with the minimum and maximum liquidity risk of 0.29 and 0.65, respectively. The average credit risk of the commercial banks in Ethiopia under study is determined

Table 11. TFP Growth in the Banking Sector, 2014–2020

Banks	Eff	TE	PE	SE	TFP
Commercial Bank of Ethiopia	0.971	0.956	1	0.971	0.928
Awash International Bank	1.015	1.018	1	1.015	1.033
Dashen Bank	1.022	1.037	0.995	1.028	1.06
Bank of Abyssinia	0.999	1.048	0.993	1.007	1.048
Wegagen Bank	0.999	1.044	1	0.999	1.043
United Bank	1.013	1.045	1	1.013	1.059
Nib International Bank	0.99	1.06	0.993	0.996	1.049
Cooperative Bank of Oromia	1	0.922	1	1	0.922
Lion International Bank	0.991	1.001	0.998	0.993	0.992
Oromia International Bank	1.031	0.95	1.03	1	0.979
Berhan International Bank	1	0.983	1	1	0.983
Bunna International Bank S.c	1	1.028	1	1	1.028
Zemen Bank Sc	0.997	0.996	1.005	0.992	0.993
Abay Bank Sc	1.025	1.036	1.018	1.007	1.062
Addis International Bank Sc	1	1.011	1	1	1.011
Debub Global Bank S.c.	1.01	0.98	1	1.01	0.99
Enat Bank S.c.	1	1.003	1	1	1.003
Mean	1.004	1.006	1.002	1.002	1.01

Source: Own computation, 2021

to be 0.65 with the minimum and maximum liquidity risk of 0.39 and 0.91, respectively. Bank size as measured by the logarithm of total assets is found to have a mean value of 23.38 over the period under study. The summary statistics also indicate that the mean value of the logarithm of a fixed asset is 19.70 with the minimum and maximum values of 16.76 and 23.13, respectively.

4.8.2. The Tobit model result

Initially, the study selected 10 explanatory variables, which cover bank-specific variables (number of branches, number of employees, ownership, market share, liquidity risk, Credit Risk, Bank Size, Level of Capitalization, and Log of Fixed Asset) and macroeconomic variables (Log of Gross Domestic Product

Table 12. Descriptive statistics of variables in the Tobit model

Variable	Obs	Mean	Std. Dev.	Min	Max
Variables return to scale (VRTS)	119	0.9784958	0.0478753	0.731	1
Number of branch (NB)	116	243.931	299.3417	4	1825
Liquidity Risk (LIQ)	117	0.4982842	0.0772712	0.2963485	0.6547294
Credit Risk (CR)	117	0.6529392	0.0938615	0.3972224	0.9145538
Bank Size (LSIZE)	117	23.38352	1.302328	19.86681	27.29258
Level of capitalization (LC)	115	0.1442424	0.0424791	0.037171	0.2595156
Log of Fixed Asset (logFA)	118	19.70629	1.459709	16.762	23.13988
Log of GDP (logGDP)	119	25.09109	0.210051	24.74167	25.40211
Inflation (INF)	119	11.96714	4.650997	6.63	20.35

Source: Own computation, 2021

and Inflation) for the second-stage Tobit model. However, the number of employees, ownership, and market share are excluded from the model due to the perfect Multicollinearity problem (**See Appendix A**). Hence, the estimated technical efficiency scores are regressed against the remaining eight variables, as described in Table 13. In addition, we run the Breusch–Pagan test to detect the presence of heteroscedasticity and the result indicates the presence of heteroscedasticity (**see Appendix B**). As a result, the least-squares estimator is still a linear and unbiased estimator, but it is no longer best. That is, there is another estimator with a smaller variance. In addition, the standard errors computed for the least-squares estimators are incorrect. This can affect confidence intervals and hypothesis testing that use those standard errors, which could lead to misleading conclusions. Therefore, this study applied heteroskedasticity-consistent standard errors or simply robust standard errors to solve the affirmation problems (Gelfand, 2015).

The findings of Jathurika (2018), who examined the statistically significant and positive impact of the number of branches on the technical efficiency of commercial banks operating in Sri Lanka, are consistent with the results reported in Table 14. The results show that the coefficient of the number of branches (NB) is positive and statistically significant at 5%, indicating that banks with a large number of branches are more efficient than banks with a small number of branches. Thus, the technical efficiency of commercial banks operating in Ethiopia will increase by being more physically close to their clients by opening a lot of branches. To maintain a level at which an overall increase in technical efficiency is feasible, bank managers may want to re-evaluate their strategy for branch expansion. Similar studies on determinants of efficiency are also used in this method, including (Zenebe Lema, 2017; Akmal & Saleem, 2008; Alrafadi et al., 2014; Soetanto, 2011). The result indicated that the number of bank branches is positively and statistically significant in affecting bank efficiency. The outcome, however, contradicts Jelassi and Delhoumi's (2021) findings, which revealed a maximum average efficiency loss of 0.2% for each extra bank branch in Tunisia, and with the findings of Zenebe Lema (2017) that found the number of banks branches decreases the banks' technical efficiency.

Table 13. Robust Tobit regression result

variables	Coef.	Robust Std. Err.	t	P > t	[95% Conf. Interval]	
NB	.0003929**	.0002265	1.74	0.086	−.0000561	.000842
LIQ	−1.765412**	.6601163	−2.67	0.009	−3.074301	−.4565238
CR	.9339213**	.4890471	1.91	0.059	−.0357686	1.903611
SIZE	.1791463*	.0400813	4.47	0.000	.0996725	.2586201
LC	.9928821	.8155408	1.22	0.226	−.6241847	2.609949
logFA	−.1093701*	.0245961	−4.45	0.000	−.1581397	−.0606005
logGDP	.0958169	.1397498	0.69	0.494	−.1812812	.372915
INF	−.0049354	.0051613	−0.96	0.341	−.0151694	.0052986
_cons	−3.244561	3.540252	−0.92	0.362	−10.26423	3.775104
/Sigma	.0920702	0.0139934			.06 43,238	.11 98,166
0 left-censored observations						
34 uncensored observations						
79 right-censored observations at VRTS ≥1						
Level of significance: *(1%), **(5%),						
Source: Own computation, 2021						

The most dangerous risk to the bank is typically liquidity risk. It compromises not just the security of each commercial bank, but also that of the entire banking system (Eichberger & Summer, 2005). According to Table 14, the level of technical efficiency was significantly and negatively affected by the banks' level of liquidity risk, which is against the findings of Zenebe Lema (2017). The outcome is consistent with those of Lee & Kim (2013) and Bassey and Moses (2015), who find that liquidity risk and bank performance are negatively correlated in Asia and Africa, respectively.

The success of a bank's operations depends more than any other risk on the correct measurement and effective management of credit risk, which is by far the biggest threat to banks (Giesecke, 2004). Table 14 shows the statistically significant and favorable effect of credit risk on the technical effectiveness of Ethiopian commercial banks as assessed by loan-to-asset ratio. The outcome supports those of R. Banya and Biekpe (2018), Adusei and McMillan (2016), and Sharma et al. (2015) who discovered a statistically significant positive relationship between credit risk and technical efficiency.

Bank size, as defined by the logarithm of total assets, has a positive and statistically significant impact on the technical efficiency of commercial banks in Ethiopia, according to our estimates. These findings are in line with the findings of Hassan and Jreisat (2016), Soetanto (2011), and Karray and Eddine Chichti (2013) Anwar (2019), Otero et al. (2020), and Sakouvogui and Shaik (2020). However, this contradicts the findings of Staněk (2015), R. M. Banya and Biekpe (2017), Ding and Sickles (2018), and Hadhek et al. (2018).

The technical efficiency of Ethiopian commercial banks is negatively and statistically significantly impacted by the fixed asset logarithm, as shown in Table 14. According to Onyiriuba (2016), asset acquisition should be the major indicator of the owner's stake in the business is consistent with the outcome. However, the result contradicts the finding of Olatunji and Adegbite (2014) who found a strong and positive statistical impact of fixed assets on the efficiency of banks.

On the other hand, the level of capitalization is found to be statistically insignificant and has a positive impact on the level of technical efficiency. This result confirms the conclusion of Tecles and Tabak (2010), Rosman et al. (2014), Zenebe Lema (2017), and Řepková (2015). Furthermore, the two macroeconomic variables (log of GDP and inflation) were found to have a statistically insignificant impact on the technical efficiency of Ethiopian commercial banks. The finding is in line with Knezevic and Dobromirov (2016) who found no relationship between economic growth and bank efficiency.

5. Conclusion

This paper explores factors affecting the technical efficiency of commercial banks in Ethiopia. According to the DEA analysis, seven banks are technically efficient based on CRS assumptions. This implies that about 58.8% of the banks are technically inefficient. Furthermore, 14 banks are technically efficient in accordance with the VRS assumption. In other words, 17.6% of the banks are technically inefficient. The result shows that there is potential for improving the technical efficiency without requiring additional resources. That is, when inefficient banks enhance their performance on average by 3.5% and 0.4% on CRS and VRS assumptions, they can become efficient without the requirement of additional resources. On the other hand, the Malmquist DEA analysis shows that the average productivity of schools improved in the last seven years of operation by 1%. The improvement in productivity of banks is mainly due to technological changes and internal efficiency.

According to the Tobit regression results, out of the bank-specific variables, number of branches, credit risk, and bank size influence the technical efficiency of banks positively. However, fixed assets and liquidity risks are inversely related to banks. Furthermore, the level of capitalization is statistically insignificant to affect efficiency. Based on macroeconomic explanatory variables, both inflation rate and GDP are not significant to impact the technical efficiency of banks.

As a result, to enhance the overall efficiency of commercial banks of Ethiopia, they have to consider enhancing their branches in the different regions of the country. In other words, banks should raise their accessibility for customers. Moreover, banks should improve both bank size and credit risk to enhance efficiency. However, they have to reduce the liquidity risk and investment on fixed assets for improving their efficiency.

Further studies should focus on measuring the efficiency of commercial banks in Ethiopia by applying a more deterministic frontier technique, Stochastic Frontier Analysis (SFA). Besides, other efficiency estimations such as cost efficiency, super efficiency, and cross-efficiency model would be employed in the future research. One limitation of using the Tobit regression model was that the scores are not observable and unable to get a guaranteed statistical inference of the analysis. Hence, future research will employ a bootstrapped-truncated regression model in the second stage as recommended by Simar and Wilson (2007). Moreover, the study is unable to take into account labour as input variable in the first stage of efficiency estimation and explanatory variables, such as market concentration ratio, exchange rate, salary expense, and year of operation that could determine the efficiency of banks in the second stage of efficiency estimation.

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Appendix

Appendix A. Multicollinearity test result

Multicollinearity problem with MS, own, & NE			Multicollinearity problem without MS, own, & NE		
Variable	VIF	1/VIF	Variable	VIF	1/VIF
MS	80.36	0.012445	logTA	14.36	0.069622
own	76.06	0.013148	LIQ	12.52	0.079876
NE	40.88	0.024459	CR	8.76	0.114193
NB	32.73	0.030550	logFA	6.43	0.155579
logTA	16.41	0.060950	LC	6.23	0.160427
LIQ	15.52	0.064416	NB	6.06	0.165087
CR	9.30	0.107528	logGDP	4.96	0.201802
logFA	7.95	0.125802	INF	4.34	0.230639
LC	6.26	0.159680			
logGDP	5.35	0.186866			
INF	4.67	0.213932			
Mean VIF	26.86		Mean VIF	7.96	

Appendix B. Breusch–Pagan/Cook–Weisberg test for heteroscedasticity

Breusch–Pagan/Cook–Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of VRTS

$\chi^2(1) = 49.63$

Prob > $\chi^2 = 0.0000$



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