Assessing the Efficiency of Commercial Banks in Sierra Leone: A Data Envelopment Analysis Approach

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Abstract
Over the past decades, the Bank of Sierra Leone has implemented several reforms aimed at improving the efficiency of the banking sector. Despite these reforms, the banking sector is plagued by inefficiencies, evidenced by persistently high-interest rate spread and non-performing loans. To this end, this study utilised an output-oriented data envelopment analysis (DEA) technique to evaluate the efficiency of twelve commercial banks in Sierra Leone from 2012 to 2022. The study established that banks in Sierra Leone operate below optimal efficiency, with an average inefficiency score of 52.6%. Furthermore, the study revealed that pure technical inefficiency (41.9%) rather than scale inefficiency (14.8%) was the main driver of the overall inefficiency in the banking sector in Sierra Leone. The study also identified the inputs and output adjustments that the inefficient banks would have to make inorder to achieve efficiency. Finally, the inefficient banks were benchmarked against the most efficient banks to determine the appropriate input-output production mix that the inefficient banks should adopt. The findings from the study suggest that the top management of commercial banks in Sierra Leone should improve on their operational and managerial competencies if they are to operate efficiently. Specifically, banks in Sierra Leone should increase their efficiency and performance by reducing their operating expenses, increasing their deposit mobilisation strategy, and increasing their intermediation efforts.

Keywords: Banks; Data Envelopment Analysis; Technical Efficiency; and Sierra Leone.

Introduction
The financial sector is the backbone of a country's economy, driving growth and development through its interconnectedness with the real sector (Cikovic et al., 2021). Banks, being pivotal players, significantly influence the financial system's stability and efficiency, ultimately impacting the broader performance and prosperity in the economy. An efficient and stable banking system promotes economic growth, as investment is key to expanding the economy, and obtaining credit is essential for making investments. Consequently, assessing efficiency in

the banking sector, particularly in developing countries, has generated significant attention from academics, researchers, professionals, and regulators, particularly after the global financial crisis, which had a distortionary effect on the financial sector in general and the banking sector in particular (Obadire et al., 2022; Peša et al., 2021).

The financial system in Sierra Leone is mostly bank-based, with the banking sector accounting for more than 80 per cent of the total assets (Bangura et al., 2021). Based on its share of the financial sector, the banking sector plays a significant role in financing the country's economic activities. In response to the sector's critical role in supporting economic growth and the numerous challenges it faced, the Bank of Sierra Leone have over the past decades implemented a variety of reforms (Financial Sector Development Plan, 2009). The broad objective of these reforms was to promote the liberalisation of the financial system, thereby enhancing efficiency in the mobilisation and allocation of financial resources. These reforms specifically aimed to realign the banking system to support private sector-driven growth (Financial Sector Development Plan, 2009). The financial sector reform primarily targeted the removal of entry restrictions, the facilitation of foreign exchange operations, the liberalisation of interest rates, the enhancement of the legal and regulatory framework, the enhancement of market discipline and competition among commercial banks, and the reinforcement of the Bank of Sierra Leone's regulatory capacity to supervise the banking system (Johnson, 2011). The global financial crisis of 2008-2009 sparked further reforms that included increasing the minimum paid-up capital, introducing corporate governance guidelines, prudential reporting standards, credit reference bureaus, and enterprise risk management.

These reforms have produced significant progress in the banking sector through improved corporate governance and risk management practices, enhanced supervisory oversight from the Bank of Sierra Leone, the enactment of new banking laws and regulations, and improved human capacity in the banks. In addition, the banking sector has witnessed increased competition from new banks entering the banking space, as well as technological upgrades that facilitate the introduction of new products such as debit cards, automated teller machines, and point of sale, with significant advantages for financial inclusion. The aforementioned developments have resulted in improvements to most of the banking sector's indicators. For instance, the profit after tax, a measure of bank profitability, increased from Le 86.08 billion in 2012 to Le 381.76 billion in 2022. The banking system's total assets also grew to Le23.22 billion in 2022 from

Le3.62 billion in 2012. Similarly, the period 2012–2022 witnessed a significant increase in total deposits to Le16.94 billion from Le2.83 billion. Total intermediation levels increased from Le1.15 billion in 2012 to Le 3.14 billion in 2022 (Bank of Sierra Leone database, 2022).

Despite the gains achieved from the ongoing reforms, the banking sector continues to exhibit inefficiencies, which poses a threat to financial stability. For instance, the banking sector in Sierra Leone remains burdened with significant inefficiencies, as evidenced by high-interest rate spreads of an average of 11.95 per cent (WDI, 2023) and an average of 20 per cent in non-performing loans during the study period, surpassing the regulatory limit of 10 per cent (Bank of Sierra Leone database, 2022). Furthermore, the banking sector's income sources are less diversified, with an average income diversification ratio of approximately 3.19 per cent. This suggests that the banks get about 3 per cent of their income from non-interest sources and about 97 per cent from interest income, the bulk of which is derived from the holdings of government securities (Bank of Sierra Leone database, 2022). If the government shifts into a consolidation bias in its public financial management strategy, this income structure could pose potential risks to financial stability, thereby undermining the banks' efficiency (Financial Stability Report, 2018).

From the above discussions, it can be deduced that while the banking sector performed well when judged by certain metrics like profitability and growth in total assets, its performance based on non-performing loans, interest rate spreads, and income diversification was not encouraging. Thus, getting a comprehensive aggregate efficiency measure of the banking sector in Sierra Leone could prove challenging. The traditional single ratios, such as the capital adequacy ratio, return on equity ratio, liquidity ratio, etc., do not comprehensively capture the complexities of banks' operational environments (Yang, 2009). According to Arshinova (2011), ratio analysis only sheds light on a fraction of the banks' activities. In recent years, efficiency measurement techniques based on the frontier approach have been developed to offer a solution to this limitation by integrating multiple inputs and outputs.

Therefore, to address the computational challenges that comes with ratio analysis, this study adopted the data envelope analysis (DEA), a frontier technique that has been extensively used in the empirical literature to estimate bank efficiency in both developed and developing countries (Cvetkoska et al, 2021). The objective

of this study is to estimate the technical efficiency of commercial banks in Sierra Leone spanning the period 2012–2022. It also decomposed technical efficiency into pure technical and scale efficiency scores and further estimated targets for improvement for the inefficient banks. The empirical specification of the banks' production function was based on the intermediation approach, which assumes that the bank's main activity is to transfer funds between surplus and deficit economic agents.

To the best of our knowledge, there is only one known study (Mansaray et al., 2024) that have assessed the efficiency of banks in Sierra Leone using DEA technique. This study presents three novel contributions. Firstly, it introduces a new model to assess the slacks and targets. This approach is distinct from previous study by Mansaray et al. (2024). Secondly, this study identified peers for the inefficient banks. By identifying the peers, the inefficient banks can adopt the strategies and input-output mix of the efficient banks to make them efficient. Finally, this study distinguishes between pure and scale inefficiencies of Decision-Making Units (DMUs) in the Sierra Leone banking context. Following the introduction, Section 2 analyses the current empirical literature on bank efficiency. Section 3 discusses the methodology and data utilised in the study. The empirical findings are reported in section 4, and section 5 provides the conclusion.

Literature Review

Over the Past decades, there has been a plethora of empirical evidence on assessing the efficiency of commercial banks in both developed and developing countries. These studies have adopted both traditional and frontier approaches. However, the frontier techniques, especially the DEA modelling approach has been the most widely utilised in the bank efficiency literature (Cvetkoska et al., 2021).

For instance, Novickytė et al. (2018) utilised an input-oriented DEA approach to examine the efficiency of banks in Lithuania over the period 2012 to 2016. Based on both variable returns to scale and constant returns to scale assumptions, the authors established that local banks were relatively efficient under the variable returns to scale, while banks owned by Nordic parents and branches were found to be more efficient under the constant returns to scale.

Using the novel Window DEA technique, Kumar et al. (2020) investigated the efficiency of banks in India over the period 2005 to 2017. Using three-yearly window, the study showed that most of the banks are operating at close to optimal

levels, with an average efficiency score of 0.9. The results further demonstrated that banks with higher efficiency scores also exhibited higher variability in their scores, indicating increased risk exposure. Thus, this confirms the idea that higher efficiency is often accompanied by higher risk.

In a cross-country study, Cvetkoska et al. (2021) also employed the DEA technique to assess the efficiency of banks in North Macedonia, Serbia, and Croatia between 2015 and 2019.The authors found that banks in Macedonian were relatively more efficiency (91.1%) than banks in Croatian (90.9%) and Serbian (81.9%). The study also established the estimated targets that inefficient banks most achieve to make them efficient.

In a similar study for Western Balkan countries, Milenković et al. (2022) employed the two –stage DEA technique to assess the efficiency of banks over the period 2015 to 2019. The findings revealed banks in the Balkan exhibit variability in efficiency across countries and among the banks in each country. Furthermore, the results from the Tobit regression found that mergers and acquisitions and bank type impact efficiency negatively, while bank size has a positive effect on bank efficiency.

Horvat et al. (2023) also utilised the intermediation, operating and profitability approached within the DEA framework to estimate the efficiency scores of banks in Serbia during and after the COVID-19 pandemic. The authors found that the efficiency scores estimated through the intermediation approach was relatively higher than those from alternative approaches-profitability and operating approaches. Of the three approaches, the profitability approach estimated the lowest efficiency score. In addition, the study revealed that banks with modest market share exhibited the lowest efficiency across all approaches, thus, reinforcing the need for targeted strategies to enhance their performance.

Using bank-level data for 14 commercial banks in Sierra Leone, Mansaray et al. (2024) investigated the operational efficiency of banks in Sierra Leone from 2020 to 2022. The study mainly focused on technological adoption and its effects on the efficiency of the banks. Using DEA technique with the assumptions of both constant and variable returns to scale, they authors confirmed that there are varying levels of efficiency among the banks, with some performing well and others operating below their optimal levels.

In another study, Darko et al. (2024) investigated technical efficiency of 70 banks in 19 selected countries in Africa from 2009 to 2020. Using both CCR and BCC models within the DEA framework, the authors revealed that most of the banks sampled are operating at sub optimal levels, suggesting that there is an opportunity for improvements in their efficiency level. Furthermore, the study concluded that scale, economic, and allocative inefficiencies were mainly due to production scale mismatches.

Proaño-Rivera et al. (2024) examined technical efficiency of 24 financial institutions in Ecuador from 2015 to 2019. Utilising Data Envelopment Analysis (DEA), they authors found an average technical efficiency of 84.26% in the case of an output-oriented "Interest Income" and 73.22% with a case of output-oriented "Other Operating Income". Large banks exhibited higher efficiency levels, while medium and small banks showed room for improvement with 80% of Ecuadorian banks requiring potential improvements to increase efficiency

The reviewed literature provides evidence that there is a vast body of research on banking efficiency in developing economies that employs the non-parametric frontier DEA approach. The conclusions from the empirical literature have been mixed. While banks' efficiency has been consistently high in some countries, it has been largely inefficient in others. These studies collectively provide valuable insights into the efficiency of banks across diverse economies, offering implications for policymakers, bank managers, and stakeholders aiming to enhance banking sector performance and financial stability.

Research Methodology

The DEA which was developed by Charnes, Cooper and Rhodes (1978) and later modified by Banker, Charnes and Cooper (1984) has been widely used to assess the performance of homogenous decision-making units (DMUs), especially in the banking sector. The motivation for using the DEA as the preferred technique to evaluate the efficiency of banks, stems from its inherent advantages: first, it is most suited to handle multiple inputs and outputs ; second, specification of an explicit functional form is not required; third, the estimated efficiency scores can be decomposed into various components; fourth, it allows estimation with variables from different units without requiring standardisation; and finally, targets for the inputs and outputs can be determined and efficient peers for the inefficient DMUs identified (Milenković et al, 2022).

Following Tanwar et al. (2020), the output-oriented Charnes, Cooper and Rhodes (CCR) and Banker, Charnes and Rhodes (BCC) models are adopted in this study to evaluate the efficiency of commercial banks in Sierra Leone from 2012 to 2022. This allows for the decomposition of technical efficiency into pure technical efficiency (PTE) and scale efficiency (SE). The CCR and BCC model are specified below:

CCR output-oriented Model

$$\max \theta$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{i0} \qquad \text{i= 1, 2, 3 …….m}_j$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq \theta y_{r0} \qquad \textbf{r}\text{= 1, 2, 3 …….s}_j$$

$$\lambda_j \geq 0 \qquad j \neq 0$$

BCC output-oriented Model

$$\max \theta$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{i0}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq \theta y_{r0}$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

The CCR and BCC models are similar, except for a key constraint on input and output weights, which totals 1. This unity constraint suggests that the size of the DMU (Decision Making Unit) matters when calculating efficiency.

Where n is the number of DMUs in the sample and s is the number of output variables, while m is the number of input variables. Observed output and input values are y_r and x_i. Therefore, y_{rj} is the output r used by DMU_j while x_{ij} is the input i used by DMU j. λ is the weight of an entity (DMU) and θ is the efficiency score.

Scale efficiency can be calculated by comparing the technical efficiency (TE) of a firm using Constant Returns to Scale (CRS) technology to its technical efficiency using Variable Returns to Scale (VRS) technology. In other words, it is a measure of how well a firm is using its resources, relative to its optimal capacity, and can be quantified by dividing its CRS technical efficiency score by its VRS technical efficiency score.

$$SE_{dmu} = \frac{TE_{crs}}{TE_{vrs}} \quad (1)$$

Target values for the input and output variables were estimated to identify gaps in these factors. These predetermined targets serve as benchmarks, facilitating the identification of necessary improvements for enhancing efficiency among underperforming banks. In DEA literature, both the Farrell measure of technical efficiency and the presence of non-zero input and output slacks are recognised indicators of a bank's technical efficiency (Coelli et al., 2002). The established efficiency targets offer valuable insights into how the evaluated decision-making unit (DMU) can potentially reduce inputs while simultaneously increasing outputs. These target values for each bank are estimated using the formula below:

$$X_{i0} = \theta_i^* x_{i0} - s_i^{-*} \quad (2)$$

$$Y_{r0} = y_{r0} + s_r^{+*} \quad (3)$$

Where X_{i0} = the target input I for 0th bank;

Y_{r0} =target output r for 0th bank;

x_{i0} =actual input i for 0th bank;

y_{r0} =actual output r for 0th bank;

θ_i^* =Overall Technical efficiency score of 0th bank;

s_i^{-*} =optimal input slacks; and

s_i^{+*} =optimal output slacks.

To move the inefficient bank closer to the efficient frontier, the banks ~~we~~ must reduce the quantity of inputs by the discrepancy between the observed value (i.e. $\Delta x_{i0} = X_{i0} - x_{i0}$), and the desired value of inputs. Similarly, banks ~~we~~

should increase the quantity of output by the difference between the desired value and the observed value of output ($\Delta y_{r0} = Y_{r0} - y_{r0}$).

Finally, the study calculated the input reduction and the output addition using $\left(\frac{\Delta x_{i0}}{x_{i0}}\right)x100$ and $\left(\frac{\Delta y_{r0}}{y_{r0}}\right)x100$, respectively.

An analysis of slacks in the input and output variables was carried out to determine the magnitudes of improvement required for banks exhibiting relative inefficiency, thereby determining whether banks face excessive input or insufficient output. Additionally, a benchmark study was conducted using reference set analysis to identify benchmark banks and assess the frequency of utilising these relatively efficient banks as reference banks to enhance the performance of inefficient banks.

This study analysed data from 12 out of 14 commercial banks in Sierra Leone, covering the period from 2012 to 2022. The selection of this time frame was driven by the availability of data and the aim to assess the effects of financial sector reforms introduced by the Bank of Sierra Leone (BSL) following the global financial crisis. The data, obtained from annual balance sheets and income statements submitted by banks to the BSL, was used to calculate bank efficiency scores using the DEAP 2.1 software package

Selecting appropriate variables to measure banks' efficiency is an intricate process, complicated by the intangible nature of banking products and services (Akdeniz et al, 2023).The absence of a consensus on variable selection has led to the emergence of three predominant methodological approaches: the Production, Value-Added, and Intermediation approaches. In this study, the intermediation approach was used to choose the inputs and outputs of banks in Sierra Leone. The rationale for adopting the intermediation approach is based on the fact that commercial banks primarily function as intermediaries for capital. Consequently, loans and advances are used as an output variable, while deposits and operational expenses are the input variables. All the variables are measured in millions of Leones.

Presentation and Analysis of Results

To understand the performance gap between the banks, some exploratory data analysis on the input and output variables was conducted before determining the banks' efficiency scores in the sample. The results displayed in Table 1 indicate a significant gap in loan and advance performance, as evidenced by the difference between the lowest and highest loans and advances of Le39.60 million and Le671,940.36 million, respectively. Similar trends with the input variables—deposits and operating expenses were observed. Evidence from the exploratory data analysis suggests that there is a large performance gap between the sampled banks. The large standard deviations further confirmed the significant performance gap among the banks operating in Sierra Leone. Differences in bank size and available technology may explain the discrepancies in the output and input variables.

Table 1: Summary statistics of variables in Leones (million)

	Output	**Inputs**	
	Loans and Advances	**Deposits**	**Operating Expenses**
Mean	120,448.76	434,694.73	43,238.18
Median	72,800.90	326,869.90	38,869.60
Standard Deviation	130,069.04	405,585.80	37,495.87
Minimum	39.60	380.16	29.65
Maximum	671,940.36	2,097,990.10	209,483.10
Count	132	132	132

Source: *Authors' computation*

The reliability of a DEA model is highly dependent on the level of correlation between the inputs and outputs (Yang, 2009). Consequently, it is a recommended practice to examine if there is a significant positive relationship between the input and output variables. The correlation analysis shown in Table 2 indicates strong correlation coefficients between the input and output variables, confirming the appropriateness of the chosen input and output variables for efficiency evaluations.

Table 2: Correlation of Inputs and Outputs

	Loans and Advances	Deposits	Operating Expenses
Loans and Advances	1		
Deposits	0.7943	1	
Operating Expenses	0.7789	0.9583	1

Source*: Author's computation*

The DEA technique was utilised to assess the technical efficiency of commercial banks in Sierra Leone, taking into account both constant and variable returns to scale. The technical efficiency score was further decomposed into pure technical efficiency and scale efficiency. Table 3 displays the summary statistics of the efficiency scores produced by the DEA. The data shown in Table 3 demonstrates that, assuming constant returns to scale, commercial banks in Sierra Leone have achieved an average technical efficiency of 47.4 per cent between 2012 and 2022. This suggests that banks in Sierra Leone are inefficient since they have not reached a score of 100 per cent. Therefore, the typical commercial bank had a technological inefficiency level of 52.6 per cent. In terms of output orientation, it means that the sampled banks, on average, could have expanded their output (loans and advances) by 52.6 per cent given the existing level of inputs. Furthermore, the findings indicate that the technical efficiency scores vary from 0.0460 to 1, and the standard deviation of 0.3406 indicates a higher degree of variability in the technical efficiency scores across the banks included in the sample.

The pure technical efficiency scores, which assume variable returns to scale, indicated that commercial banks in Sierra Leone were highly efficient. The efficiency score of banks averaged 58.1 per cent, indicating the potential to boost their output (loans and advances) by 41.9 per cent while maintaining the same level of input (operating expenses and deposits). In addition, pure technical efficiency scores range between 0.0520 and 1, and the standard deviation of 0.3559, shows a greater dispersion in terms of pure technical efficiency among the commercial banks in Sierra Leone from 2012 to 2022.

Decomposing the technical efficiency scores into pure technical and scale efficiency reveals that scale efficiency, with an average efficiency score of 85.2 per cent, is the primary source of bank efficiency. This suggests that, on average, banks' efficiency level increases with the scale of operation and that the actual scale of production diverges from the most productive scale size by 14.8 per cent. These efficiency scores reveal significant room for commercial banks in Sierra Leone to enhance their output, given the current level of inputs. In other words, there was more scope for commercial banks to increase their output if they had operated at the same efficiency level as the most efficient bank in the sample.

Table 3: Descriptive Statistics of Efficiency Scores

	Technical Efficiency (TE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)
Mean	0.4740	0.5809	0.8523
Standard Error	0.0983	0.1027	0.0696
Median	0.4295	0.5005	0.9120
Standard Deviation	0.3406	0.3559	0.2412
Minimum	0.0460	0.0520	0.1180
Maximum	1.0000	1.0000	1.0000
Count	12	12	12

***Source**: Authors' computation*

The results presented in Table 4 suggest that under the constant returns to scale assumption, the banks used in this study achieved a mean technical efficiency of 47.4 per cent between 2012 and 2022. This implies that the banks, on average, are 52.6 per cent inefficient in utilising their inputs to generate output. Furthermore, the summary of bank means suggests that UTB and FBN were fully technically efficient banks, given the constant returns to scale assumption. UTB and FBN have an average technical efficiency score of 100 per cent for the entire period under consideration. The score indicates that UTB and FBN efficiently used their inputs—deposits and operating expenses—to produce output—loans and advances. In contrast, UBA is the least technically efficient bank on average, with a score of 4.6 per cent. This shows that on average, UBA is inefficient by 95.4 percent.

The pure technical efficiency scores of commercial banks in Sierra Leone, assuming variable returns to scale and output orientation show that commercial banks in Sierra Leone are 58.1 per cent efficient. The findings indicate that banks in Sierra Leone have the potential to increase their output, namely loans and advances, by 41.9 per cent while maintaining the same level of inputs to achieve maximum efficiency. During the study period, four banks (RCB, UTB, FBN, and SB) consistently demonstrated optimal technical efficiency and maintained their efficiency during the whole period. UBA has the most potential for boosting its production of loans and advances by up to 94.8 per cent

The mean scale efficiency score for commercial banks in Sierra Leone was estimated at 0.852, equivalent to 82.5 per cent. This indicates that the commercial banks' actual production scale differed from the most efficient scale size by 17.5 per cent. SB is the least scale-efficient bank, with a scale of operation that

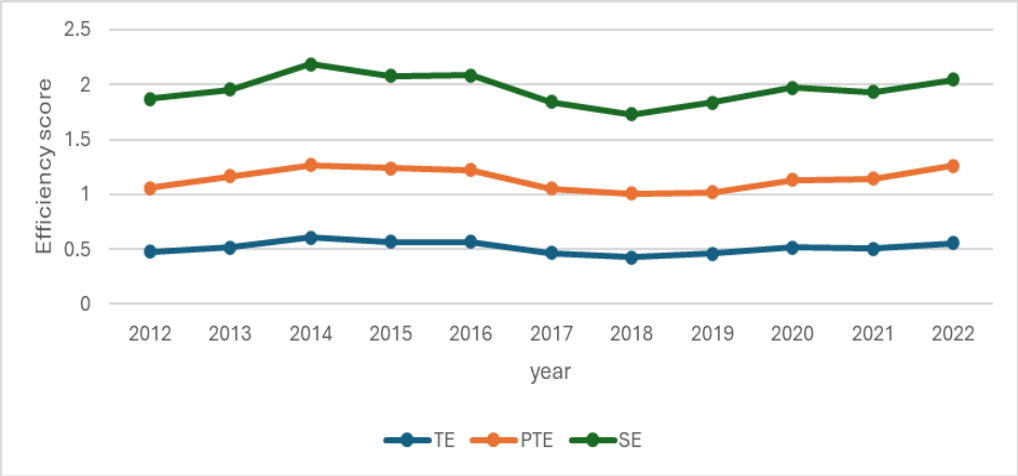
deviates from the optimal scale by 88.2 per cent. The results further validate that UTB and FBN exhibit the best scale efficiency, reaching a perfect score of 100 per cent. Furthermore, the findings indicated that most banks were operating at diminishing returns to scale. Based on the findings, eight banks were operating at decreasing returns to scale, three banks at increasing returns to scale, and one bank at constant returns to scale between 2012 and 2022. Consequently, most banks were functioning at a level lower than their maximum efficiency, indicating that they had the potential to increase their activities.

Table 4: Average Efficiency Score of Commercial Banks in Sierra Leone

Bank	Technical Efficiency (TE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)	
Standard Chartered Bank (SCB)	0.2250	0.2920	0.7700	drs
Rokel Commercial Bank (RCB)	0.8940	1.0000	0.8940	drs
Sierra Leone Commercial Bank (SLCB)	0.6400	0.7550	0.8470	drs
Union Trust Bank (UTB)	1.0000	1.0000	1.0000	-
Guarantee Trust Bank (GTB)	0.4910	0.5280	0.9300	drs
First International Bank (FIB)	0.4160	0.4290	0.9700	drs
First Bank Nigeria (FBN)	1.0000	1.0000	1.0000	drs
Ecobank (ECO)	0.4430	0.4730	0.9360	drs
Access Bank (ACB)	0.2090	0.2340	0.8910	irs
United Bank for Africa (UBA)	0.0460	0.0520	0.8800	drs
Skye (SB)	0.1180	1.0000	0.1180	irs
Zenith (ZEN)	0.2060	0.2080	0.9910	irs
Mean	0.4740	0.5810	0.8520	

Source*: Authors' computation*

Figure 1 displays the trajectory of technical, pure technical, and scale efficiencies from 2012 to 2022. Throughout the study period, the scale efficiency scores consistently exceeded the pure technical efficiency scores, indicating that the primary cause of technical inefficiency was pure technical inefficiency rather than scale inefficiency. The results show that all the banks demonstrated management inefficiencies throughout the entire study period. The result is supported by the fact that Sierra Leone, being a small developing nation, has less sophisticated technical capacity in its banking industry compared to the more advanced countries.



Source: *Author's computation using DEAP 2.1. TE =Technical efficiency, PTE =Pure technical efficiency, SE= Scale efficiency.*

Figure 1: Trend in average Efficiency Scores Commercial Banks in Sierra Leone 2012-2022

The target values represent the precise input and output levels that commercial banks must adopt to achieve Pareto efficiency. Table 5 illustrates the improvements in output and inputs in 2012, thereby compelling banks that operate inefficiently to reach efficiency levels along the most efficient frontier. The result demonstrates the initial values of inputs and outputs, as well as radial and slack movements, indicating that decision-making units must adjust the proportionality of input and output variables to approach the efficient frontier (Coelli, 2008; Cvetkoska et al., 2021). Finally, we provide the projected value for each input and output. The difference between the original value and the projected value represents the improvement required for each variable. Table 5 demonstrates the efficiency of banks 2, 4, 7, and 11. Hence, their projected values are equal to their original values.

For the remaining banks (SCB, SLCB, GTB, FIB, ECO, ACB, UBA, and ZEN), there is a need to make some adjustments to their inputs or outputs to reach the efficiency frontier. It is evident from Table 5 that SCB should increase its loan portfolio by Le159,701.52 million to achieve its efficient target of Le225,520.75 million. Reducing the original value of its operating expenses by Le11,018.59 can help achieve this target. To achieve an efficient target of Le321,793.63 million, SLCB needs to increase its loan portfolio by Le78,800.88 million. It can achieve efficient loan disbursement by reducing deposits by Le34, 375.99 million, to reach

a target of Le550, 406.36, and by reducing operating expenses by Le2, 629.90 million, to reach a target of Le50, 301.89. GTB can achieve its efficiency targets by increasing loans by Le100,529.22 million. Similar developments are observed in FIB, ECO, and ACB, where the loans are expected to increase by Le89,686.37 million, Le108,817.38 million, and Le47,456.22 million, respectively, to achieve efficient loan targets of Le156,932.60 million, Le206,417.86 million, and Le61,989.27 million. To achieve an efficient loan target of Le82,100.23 million, UBA would have to increase the original loan value by Le77,799.83 million. This can be achieved even when deposits are reduced by Le65, 153.65 million. Finally, ZEN needs to increase loans significantly by Le77, 593.56 million to achieve its efficient target of Le97, 941.49 million.

Table 5: Improvements in Inputs and Output in 2012

Bank	Variable	Original Value	Radial Movement	Slack Movement	Projected Target
SCB	Loans	65,819.22	159,701.52	-	225,520.75
	Deposits	319,837.90	-	-	319,837.90
	Opt. Exp.	47,633.83	-	(11,018.59)	36,615.23
RCB	Loans	321,793.63	-	-	321,793.63
	Deposits	550,406.36	-	-	550,406.36
	Opt. Exp.	50,301.89	-	-	50,301.89
SLCB	Loans	242,992.75	78,800.88	-	321,793.63
	Deposits	584,782.35	-	(34,376.00)	550,406.36
	Opt. Exp.	52,931.79	-	(2,629.90)	50,301.89
UTB	Loans	146,426.09	-	-	146,426.09
	Deposits	130,410.37	-	-	130,410.37
	Opt. Exp.	25,370.73	-	-	25,370.73
GTB	Loans	112,418.38	100,529.22	-	212,947.60
	Deposits	303,142.95	-	-	303,142.95
	Opt. Exp.	34,492.52	-	-	34,492.52
FIB	Loans	67,246.22	89,686.37	-	156,932.60
	Deposits	176,218.26	-	-	176,218.26
	Opt. Exp.	26,348.53	-	-	26,348.53
FBN	Loans	32,534.74	-	-	32,534.74
	Deposits	55,961.63	-	-	55,961.63
	Opt. Exp.	4,224.13	-	-	4,224.13
ECO	Loans	97,600.48	108,817.38	-	206,417.86
	Deposits	283,198.47	-	-	283,198.47
	Opt. Exp.	33,671.82	-	-	33,671.82
ACB	Loans	14,533.05	47,456.22	-	61,989.27
	Deposits	71,822.54	-	-	71,822.54
	Opt. Exp.	11,539.87	-	-	11,539.87
UBA	Loans	4,300.40	77,799.83	-	82,100.23
	Deposits	205,840.06	-	(65,153.65)	140,686.41
	Opt. Exp.	12,119.71	-	-	12,119.71
SB	Loans	3,251.01	-	-	3,251.01
	Deposits	24,461.55	-	-	24,461.55
	Opt. Exp.	5.51	-	-	5,513.33
ZEN	Loans	20,347.93	77,593.56	-	97,941.49
	Deposits	98,324.90	-	-	98,324.90
	Opt. Exp.	16,581.76	-	-	16,581.76

Source: *Authors' computation. Note: Opt. Exp means operating expenses*

The term "peer" denotes an efficient firm to follow, or a reference (Coelli, 2008). The efficient peers are the 100 per cent efficient DMUs with the most similar input mix in an output-oriented model to the assessed DMUs. This means that they have established a benchmark and are not required to adopt any other bank's production technology. Inefficient firms such as SCB, SLCB, GTB, FIB, ECO, ACB, UBA and ZEN could improve their efficiencies by adopting the practices used by their most efficient peers (Table 6). This means that they can follow the input-output mix of any of RCB, UTB, GTB, FIB, FBN and SB. Specifically, SCB can follow the input-output mix of RCB and UTB; SLCB can adopt the production technology of RCB, GTB can follow either FBN, RCB, or UTB, FIB can follow RCB, UTB, or FBN and FIB should adopt the practices of RCB, UTB, or FBN. ECO should follow RCB, UTB, and FBN; ACB should follow UTB, SB, or FBN; and UBA should adopt the production practices of FBN or RCB. Finally, ZEN can be efficient if it adopts the production practices of banks FBN, SB, or UTB.

Table 6: Results of Peers of the Least Efficient Banks

Bank	**Peers**		
SCB	RCB	UTB	-
RCB	RCB	-	-
SLCB	RCB	-	-
UTB	UTB	-	-
GTB	FBN	RCB	UTB
FIB	RCB	UTB	FBN
FBN	FBN	-	-
ECO	RCB	UTB	FBN
ACB	UTB	SB	FBN
UBA	FBN	RCB	-
SB	SB	-	-
ZEN	FBN	SB	UTB

Source: *Authors' computation.*

Conclusion and Policy Recommendations

The banking sector's dominance in Sierra Leone underscores the critical importance of its efficiency in ensuring financial stability. This study aims to assess the technical efficiency levels of commercial banks in Sierra Leone from 2012 to 2022 using a non-parametric approach, specifically data envelope analysis. We derived the efficiency scores from balanced panel data extracted from the returns of balance sheets and income statements submitted to the Bank of Sierra Leone by 12 out of the 14 commercial banks operating in Sierra Leone. To address the research questions, the output-oriented CCR and BCC models were

used, while the inputs and outputs for the banks were selected using the intermediation approach.

The findings show that the banking sector in Sierra Leone is not very efficient. Out of the twelve banks that were studied, only two (UTB and FBN) were considered to be at their most efficient under both the constant returns to scale (CCR Model) and variable returns to scale (BCC Model) assumptions during the study period. The average technical efficiency score of 47.4 per cent indicates a 52.6 per cent inefficiency in the banks. Decomposing technical efficiency into pure technical efficiency and scale efficiency, the results showed that pure technical inefficiency, with an average score of about 41.9 per cent and a scale inefficiency score with an average score of 14.8 per cent, primarily drove the inefficiencies observed in the banking system. Slacks and targets were also estimated to enable the evaluation of where the inefficient banks can make changes to their operations, specifically an improvement in the input-output mix that will bring less efficient banks up to the efficient frontier. Finally, the study identified banks that serve as benchmarks for inefficient banks to follow. This suggests that inefficient banks should emulate the production mix and operational practices of the efficient banks identified as their peers to operate effectively.

The findings of this study offer significant insights for policymakers, investors, and managers regarding the banking system in Sierra Leone. The study identified pure technical efficiency as the primary source of technical inefficiency in the country's banking sector, highlighting the significant need to improve the diffusion of technology and the managerial and operational aspects of the banking sector in Sierra Leone. Furthermore, less efficient banks could benefit from adopting the business strategies and modern technologies employed by their more efficient counterparts. Specifically, to approach the efficiency frontier, managers of inefficient banks should prioritise reducing the surplus utilisation of inputs. Finally, investors and customers can readily select from different banking sectors based on their efficiency scores.

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