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Performance Efficiency of Ethiopian Commercial Banks: Data Envelopment Analysis Approach

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ABSTRACT

The Ethiopian banking sector plays a pivotal role in resource allocation of the country with the absence of a securities market. The study aimed to evaluate financial performance of Ethiopian commercial banks during 2014 to 2020. Data from all of the 17 commercial banks in Ethiopia have been considered in the study which resulted in 119 observations. The classical Data Envelopment Analysis (DEA) models were employed to estimate the efficiency scores. Two input variables (non-interest expense and deposits), and three output variables (net interest income, non-interest income and loans and advances) were identified under intermediation approach. The efficiency scores of Ethiopian commercial banks vary among each banks and years. The highest ranked commercial banks based on the average relative efficiency score are the most stable and consistent banks in the industry. The public owned commercial bank is more efficient than private owned commercial banks in Ethiopia. Whereas, the smallest private owned commercial banks are more efficient than the largest one. Thus, bank managers should review and rescale their scope of operations to levels that guarantees both pure technical efficiency and scale efficiency. Future studies should evaluate the efficiency of Ethiopian commercial banks overtime using parametric analysis and identify factors affecting their financial performance.

KEY WORDS

DEA, efficiency, commercial banks, Ethiopia, CCR, BCC

1. Introduction

The banking sector in Ethiopia has economic significance through its contribution of about 3.1 percent to GDP in the last decade and it has been the second largest employer with over 90 thousand direct employees (Abbay, 2018; Cepheus Capital Research [CCR], 2019). There are eighteen banks in the Ethiopian banking industry which constitute one development bank and seventeen commercial banks (one public owned and sixteen private owned) (NBE, 2020, p. 38). The sector is highly dominated by the state owned bank (commercial bank of Ethiopia) which holds about two-third of the sector's assets (CCR, 2020, pp. 9–10; Geda et al., 2017).

The banking system in Ethiopia, with the absence of financial markets, is the most common instrument in exercising economic and monetary policy. Improving the resource allocation in the banking production process is a critical factor to ensure the health of these policies (Antunes et al., 2022, p. 1374). The Operating efficiency of commercial banks significantly affect national economy (Weiwei et al., 2021, p. 65). Evaluating the overall performance of commercial banks is, therefore, a

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matter of deep concern for stakeholders such as owners, investors, regulators, and policy makers (Bayeh et al., 2021; Kao, 2014; Nguyen & Pham, 2020, p. 209).

In this study we employ a Data Envelopment Analysis (DEA) to examine how Ethiopian commercial banks (here after ECBs) perform relative to each other, over time, and across ownership and size. DEA is a non-parametric technique that generates the comparative ratio of weighted output to weighted input known as relative efficiency score. The relative efficiency score, ranging from 0 to 1, indicates how efficiently or inefficiently a bank utilizes the measured inputs to generate the measured outputs.

We prefer DEA to other efficiency measurements because it can handle multiple inputs and outputs with different units of measurement (Antunes et al., 2022; Bhatia & Mahendru, 2019; Fernandes et al., 2018; Xie et al., 2021).

The purpose of this study is, therefore, to accurately measure the efficiency level of ECBs and examine whether the efficiency level of commercial banks differ with ownership and size by employing rigorous statistical tests.

We find that the efficiency of ECBs differ among banks and across the years. The public owned commercial bank is more efficient than private commercial banks. Among private owned commercial banks, the smaller banks are more efficient than the larger banks during the study period. This implies that larger private owned commercial banks are not working at their optimal scale size. This study, therefore, extends the bank efficiency literature in general and the Ethiopian commercial banking sector's efficiency in particular by exploring the effect of key bank characteristics, such as ownership and size, on banks performance measured with efficiency scores.

This paper is organized as follows. We review relevant literature in Section 2 and describe our methodology and research design in Section 3. In Section 4 we present and discuss the empirical results. Section 5 concludes.

2. Literature Review

Ethiopia is one of few major developing economies where stock or bond market is non-existent and banks dominate the financial market. Some studies of ECBs have employed the DEA model. They include Alemu (2016), Dinberu & Wang (2018), Garamu (2016), Ijara & Sharma (2020), Lelissa (2014), Lelissa & Kuhil (2016), Lema (2017), and Rao & Lakew (2012). We next review these studies in terms of the study period covered, samples taken, theories underlying the selection of input and output variables, and their major findings.

Rao & Lakew (2012) examine the cost efficiency and ownership structure of all ECBs using a non-parametric approach during 2000 to 2009. The study shows an average inefficiency of about 27% during the study period but concludes that ownership of ECBs has no statistically significant influence on the cost efficiency score. To the contrary, Lelissa & Kuhil (2016), using data from 18 banks during 1995 to 2015, show that state-owned banks are more efficient than their privately owned counterparts across the study period both technically and in terms of management capacity. They also document a wide variation in efficiency scores of Ethiopian commercial banks. The average technical inefficiency level of these banks (with CRS assumption) was about 16%. Lelissa (2014) evaluates the efficiency of all ECBs from 2008 to 2012. He employs an intermediary approach to select three input and three output variables. The study shows a modest average efficiency level for the Ethiopian banking industry. It finds that the government owned commercial banks outperformed the privately owned ones and were persistently on the efficiency frontier. Ijara & Sharma (2020) investigate the overall efficiencies of 17 ECBs during 2014 to 2018. They select input and output variables under intermediary approach. The study documents that the publicly owned commercial bank dominated the industry in efficiency during the study period. The average efficiency score indicates that the average Ethiopian commercial bank was inefficient while only two of the commercial banks were consistently efficient during the study period. They conclude that the main cause of inefficiency was managerial capacity rather than scale size.

However, a few other studies report evidence that privately owned Ethiopian banks are more efficient. Alemu (2016) examines the technical, pure and scale efficiency of 15 ECBs during the Growth and Transformation Plan (GTP) I period, 2011 to 2014. The results show that privately owned commercial banks outperformed the government-owned ones in most of the efficiency scores. Lema (2017) corroborates this result with data of the same period.

Two other research teams have studied Ethiopian banks' efficiency using the DEA method. Garamu (2016) examines the relative technical efficiency and productivity change of 10 purposively selected commercial banks during 2007-2011. He finds that on average ECBs were technically inefficient and the main cause of this inefficiency is scale inefficiency. Dinberu & Wang (2018) use data from 18 commercial banks during 2005 to 2016 to measure their technical, cost, revenue and profit efficiencies. They employ an intermediate approach to select three input and two output variables to estimate the technical efficiency scores under both input and output orientations. The study concludes that only four

commercial banks, one of which is publicly owned, were on the efficiency frontier during the study period.

Our review of the extant DEA literature reveals that researchers have not yet reached consensus on how ownership and size relate to bank performance in developing economies or in Ethiopia. Some studies find that publicly owned commercial banks are more efficient than privately owned ones (Ijara & Sharma, 2020; Lelissa, 2014; Lelissa & Kuhil, 2016; Tanwar et al., 2020; Zhu et al., 2020), others report opposite evidence (Chaluvadi et al., 2018; Gupta et al., 2020), whereas still others argue that ownership structure does not affect the efficiency level of banks (Rao & Lakew, 2012; Thomas, 2019). With regard to bank size, multiple studies show that big banks are more efficient than smaller ones (Czerwonka, 2019; Grmanová & Ivanová, 2018; Novickytė & Droždz, 2018; Weiwei et al., 2021). However, Henriques et al. (2018) find that smaller banks are more efficient than larger ones. In short, we still do not have a good understanding whether and how some key bank characteristics, such as ownership and size, affect their performance measured with efficiency scores. Moreover, few studies have attempted to identify the mechanisms through which these characteristics enhance or impede the bank's efficiency measured with DEA technique.

For the purpose of extending the bank performance literature in general and understanding the opportunities and constraints faced by the Ethiopian banking sector in particular, this study, therefore, aims to answer the following research questions:

1) How efficiently ECBs perform during the study period?
2) How consistent are the ECBs performance efficiency level?
3) Whether the efficiency levels of commercial banks differ with ownership and size when rigorous statistical tests are employed?

3. Research Design and Methods

3.1. Sample Size and Data

The Ethiopian banking industry consists of two fundamental functional types, namely, seventeen commercial banks and one state owned development bank (NBE, 2020). The commercial banks hold more than 99% of total assets in the Ethiopian banking industry. We examine the 17 commercial banks which had annual report as of June 30, 2020. The data is from 2014 to 2020, yielding 119 bank-year observations. The sources of the data are the income statements and statement of financial positions taken from Central Bank of Ethiopia. All the data are in millions of Ethiopian Birr.

3.2. Inputs and Outputs variable Specifications

In banking studies there are two approaches, namely, production and intermediary approaches, identified by the literature for the inputs and outputs measurement (Berger & Humphrey, 1997; Fethi & Pasiouras, 2010). The production approach treats a commercial bank as a unit which uses labor and capital to produce deposits and loans (Ar & Kurtaran, 2013; Rao & Lakew, 2012). Intermediation approach treats a commercial bank as a channel which relates savers and borrowers, channeling funds from the surplus units to the deficit ones (Sealey & Lindley, 1977; Yue, 1992).

We employed the intermediation approach to explore the role of ECBs in mobilizing funds from savers to investors in the Ethiopian financial system which has no capital market. We choose the intermediation approach because it is appropriate for organization level efficiency measurement (Berger & Humphrey, 1997; Fethi & Pasiouras, 2010).

The determination of appropriate number of input (m) and output (s) variables is dependent on the number of DMUs considered in this study. Most of the prior study recommends as rule of thumb, the sample size should be the maximum of the product of m and s or three times the sum of input and output variables. i.e., $n \geq \max\{m \times s; 3(m+s)\}$ (Avkiran, 2006; Cooper et al., 2011).
Considering the constraint from data availability, we identify two input variables and three output variables as indicated in Table 1 to measure the efficiency of commercial banks in Ethiopia following prior literature (see for example, Fernandes et al., 2018; Hsiao et al., 2010; Maghyereh & Awartani, 2012; Sharma et al., 2012; Ayadi et al., 1998; Yeh, 1996).

3.3.Model Specification

DEA is a non-parametric approach to efficiency measurement of similar organizational units called decision making units (DMUs). It measures the efficiency of DMUs relative to the other best performing DMUs (Ramanathan, 2003). This study applies the basic DEA models (i.e. Charnes– Cooper–Rhodes (CCR) model and Banker–Charnes– Cooper (BCC) model).

Table 1: The inputs and outputs variables used to measure the efficiency score, and partition variables

Variable name	Description
Input variables:	
Non-Interest expenses	Non-Interest expense of each commercial bank per year
Deposits	Total deposits to each commercial bank per year
Output variables:	
Net Interest income	Interest income minus interest expense of each commercial bank per year
Non-interest income	Non-Interest income of each commercial bank per year
Loans and advances	Loans and advances of each commercial bank per year
Partition Variables:	
Ownership	Public owned vs private owned commercial banks
Size	Average loan of each bank during the study period

All variables except ownership are in millions of birr.
Source: Authors compilation based on prior literature (2022)

CCR is the first DEA approach, developed by Charnes et al. (1978); it is named as CCR model after the first letter of the authors names. The CCR approach assumed that for every change in input, the output changes proportionally, that means it works under constant return to scale (CRS). On the other hand, the BCC which was developed by Banker et al. (1984), assumed that the proportional increase or decrease in input level may cause a proportionally more or less increase or decrease in the level of output, which implies a variable return to scale (VRS). Moreover, we compute the scale efficiency of DMU as the ratio of efficiency score using CCR to BCC.

Following the suggestions by recent studies (for instance, Bhatia & Mahendru, 2019; Henriques et al., 2020; Wasiaturrahma et al., 2020) and considering that Ethiopian commercial banks' managers have more control on input than output (Rao & Lakew, 2012), we adopted input oriented, intermediation approach to measure the efficiency of ECBs . The intermediation approach posits deposits as being converted into loans; thus, deposits are taken as one of the input variables in table 1 as suggested by prior studies (Henriques et al., 2018; Czerwonka, 2019; Tamatam et al., 2019; Mercan, 2020; and Say et al., 2020).

The DEA method generates a technical efficiency score, which is the ratio of output(s) (y) and input(s) (x). Where the DMUs consume more than one input and produce more than one output, the efficiency score is the linear weighted sum of outputs over linear weighted sum of all its inputs (Avkiran, 1999; Ramanathan, 2003).

Mathematically:

$$Efficiency(\theta) = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \quad \ldots\ldots 1$$

Where;

s = number of outputs;

u_r = weight (importance) attached to output r

y_{ro} = amount of output r produced by the DMU_0;

m = number of inputs;

v_i = weight (importance) attached to input i; and

x_{io} = amount of input i used by the DMU_0.

The x and y weights are found as a solution to a specially formulated linear programming problem (Ramanathan, 2003).

The following linear programming is modeled to compute the efficiency score, θ^*, of the target decision making unit (DMU_0), by minimizing θ subject to the constraint that the weighted sum of the inputs of all DMUs is less than the input of the DMU_0, and that the weighted sum of the outputs of all DMUs is greater than or equal to the output of the DMU_0.

Mathematically, this can be written as:

Input Oriented CCR Model	Input Oriented BCC Model
$\theta^* = Min\theta$ (2)	$\theta^* = Min\theta$ (3)
Subject to:	Subject to:
$\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{i0}; i = 1,2,\cdots,m;$	$\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{i0}; i = 1,2,\cdots,m;$
$\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{r0}; r = 1,2,\cdots,s;$	$\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{r0}; r = 1,2,\cdots,s;$
$\lambda_j \ge 0; j = 1,2,\cdots,n;$	$\sum_{j=1}^{n} \lambda_j = 1$
	$\lambda_j \ge 0; j = 1,2,\cdots,n;$

Where;

θ^* is the input oriented efficiency score of DMUs;

x_{ij} and y_{rj} are the value of the i[th] input consumed and the value of the r[th] output generated by the j[th] bank respectively; thus, x_{i0} and y_{r0} are the i[th] input and the r[th] output of DMU$_0$ respectively;

n – the number of bank observations;
m- number of inputs;
s- number of outputs
λ - constant.

The best performing DMU(s) is assigned an efficiency score of 1 or 100%, and the other DMUs' score ranges from 0 to 100 percent relative to the best performer (Avkiran, 2006, p. 3; Ramanathan, 2003). If the efficiency score under model 1 and model 2 are not equal, there exists scale inefficiency. Scale efficiency (SE) expresses how close the firm is to the optimal scale size; the larger the scale efficiency, the closer the firm is to optimal scale (Avkiran, 2006, p. 28).

The DEA model's results are generated using the Stata 13 application. We ran the DEA models (CCR and BCC) separately for each year using input- orientation.

4. Data Analysis, Findings and Discussion

In this section we analyze the data collected and summarize the findings.

Table 2: Summary Statistics of input-output variables (in millions of Birr*)

Variables	N	Mean	Median	Sd	Min	Max
Non-Interest Expense	119	1,477.97	602.88	3,330.89	47.31	25,602.52
Deposits	119	36,774.62	11,118.17	94,337.61	500.23	593,000.00
Non-Interest Income	119	882.50	448.19	1,633.40	40.23	11,469.49
Loan and –Advances	119	19,205.54	7,191.45	39,791.50	270.40	252,000.00
Net-Interest Income	119	1,874.04	594.78	4,583.97	25.56	29,089.68

*Birr is the home currency of Ethiopia, 1 USD = 34.9822 Birr (NBE, 2021, p. 2)
Source: Authors own calculation, 2022

Table 2 above shows the descriptive statistics for input variables and output variables used in the computation of the efficiencies of commercial banks in Ethiopia during the study period. On an average, ECBs mobilized 36.775 billion Birr deposits in the range of the Birr 500.2 million and 593.041 billion, with a standard deviation of Br. 94.338 billion. The range of loans and advances was within 270.4 million birr and 251.995 billion birr, with a large size of standard deviation of 39.792 billion. The average non-interest expenses during the study period were 1.478 billion Birr. The average values of the net-interest income and non-interest income are Birr 1.874 billion and Birr 882.5 million, respectively. There was a huge variation in the deposits and loans and advances of ECBs during the study period.

Table 3: Matrix of correlations between input and output variables

Variables	(1)	(2)	(3)	(4)	(5)
(1) Non-interest expense	1.000				
(2) Deposits	0.978	1.000			
(3) Net-interest income	0.981	0.997	1.000		
(4) Non-interest Income	0.898	0.908	0.903	1.000	
(5) Loan and Advances	0.975	0.992	0.995	0.925	1.000

Source: Authors own calculation, 2022

Table 3 indicates that there are strong to perfect correlations between among the variables used to estimate the efficiency score of Ethiopian commercial banks. The result of correlation analysis indicated a strong association between input and output variables used in the DEA analysis. The minimum correlation coefficient was 0.898 between non-interest income and non-interest expense; and the maximum of 0.997 was registered between net interest income and banks deposits. These statistically significant and positive correlations among the variables provide further support for the appropriateness of the selected variables in the DEA models in this research (Mercan, 2020; Say et al., 2020).

4.1. Relative Efficiency scores of Ethiopian commercial banks (2014-2020)

We first compute the technical efficiency (TE), pure technical efficiency (PTE) and scale efficiency (SE) of each of the 17 commercial banks in Ethiopia during the study period. We decompose TE into PTE and SE to get insight for the source of inefficiencies and to determine whether the DMUs operating at optimal scale size (Avkiran, 1999, p. 211).

4.1.1. Technical Efficiency of Ethiopian Commercial Banks (2014-2020)

TE is an efficiency that ignores the impact of scale size by comparing one bank to another with similar scale.

As indicated in Table 4, most of the ECBs were scored a technical efficiency of less than 1 and inefficient. This reveals that the sample commercial banks' efficiency has been fluctuating during the study period. Only ZB had scored an efficiency score of 1 and found to be technical efficient during each of the study period.

The average efficiency score of the 17 commercial banks was 0.942. It means that an average bank can reduce an input proportionally by about 5.8% [1-0.942] to produce the same amount of output. Alternatively, it is possible for an average ECB to produce 1.062 times (i.e., 1/0.9416) as much outputs, i.e. income and loans, from the same level of inputs during the study period.

Table 4: Technical Efficiency of Ethiopian Commercial Banks (2014-2020)

DMU	2014	2015	2016	2017	2018	2019	2020	Average
AB	0.861	0.889	0.907	0.873	0.946	0.936	0.936	**0.907**
AIB	0.952	1.000	1.000	1.000	1.000	1.000	1.000	**0.993**
AdIB	1.000	1.000	1.000	1.000	0.970	0.912	0.956	**0.977**
BOA	0.909	0.835	0.855	0.926	0.991	0.933	0.959	**0.915**
BrIB	0.904	0.901	1.000	1.000	0.963	0.874	0.967	**0.944**
BuIB	0.987	0.943	0.967	0.958	0.987	1.000	1.000	**0.977**
CBE	1.000	1.000	1.000	1.000	1.000	0.930	0.767	**0.957**
CBO	1.000	1.000	1.000	0.947	0.806	0.773	0.811	**0.905**
DB	0.969	0.885	0.861	0.830	0.812	0.823	0.830	**0.858**
DGB	0.908	0.758	1.000	1.000	1.000	1.000	1.000	**0.952**
EB	0.832	1.000	1.000	1.000	1.000	1.000	0.992	**0.975**
LIB	0.878	0.897	0.974	0.993	1.000	0.917	0.946	**0.943**
NIB	1.000	1.000	1.000	1.000	0.911	0.928	1.000	**0.977**
OIB	0.816	0.852	0.888	0.754	1.000	0.848	0.941	**0.871**
UB	0.880	0.812	0.927	0.984	0.902	0.942	0.953	**0.914**
WB	0.907	0.879	0.972	1.000	1.000	0.887	0.945	**0.941**
ZB	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
Average	**0.929**	**0.921**	**0.962**	**0.957**	**0.958**	**0.924**	**0.941**	**0.942**
minimum	**0.816**	**0.758**	**0.855**	**0.754**	**0.806**	**0.773**	**0.767**	
maximum	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	
Standard deviation	**0.064**	**0.079**	**0.053**	**0.073**	**0.064**	**0.067**	**0.071**	

Source: Authors own calculation, 2022

The 17 commercial banks in Ethiopia have minimum efficiency score of 0.754 by OIB in 2017 followed by scores of 0.758 and 0.767 by DGB (in 2015), and CBE (in 2020) respectively. These numbers suggest that the banks in question had larger room for efficiency improvement in these years. Taking the banking industry as a whole we observe that the three maximum average TEs were 95.7% (in 2017), 95.8% (in 2018) and 96.2% (in 2016) in ascending order. It indicates that the industry performed more efficiently in the period from 2016 to 2018 than the years before or after.

We next examine the pure technical efficiency of ECBs which measures TE without scale efficiency and purely reflects the managerial performance to organize the inputs in the production process. The main aim here is to identify the source of inefficiencies of ECBs.

4.1.2. Pure Technical Efficiency of Ethiopian Commercial Banks

Table 5: Pure Technical Efficiency of Ethiopian Commercial Banks (2014-2020)

Year	2014	2015	2016	2017	2018	2019	2020	**Average**
AB	0.871	0.892	0.910	0.899	0.950	1.000	0.943	**0.923**
AIB	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
AdIB	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
BOA	0.912	0.836	0.867	0.926	0.992	0.934	0.959	**0.918**
BrIB	0.967	0.909	1.000	1.000	0.970	0.890	1.000	**0.962**
BuIB	1.000	1.000	0.967	0.979	1.000	1.000	1.000	**0.992**
CBE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
CBO	1.000	1.000	1.000	0.948	0.807	0.775	0.934	**0.923**
DB	1.000	1.000	1.000	1.000	1.000	0.833	0.943	**0.968**
DGB	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
EB	0.847	1.000	1.000	1.000	1.000	1.000	1.000	**0.978**
LIB	0.933	1.000	1.000	1.000	1.000	0.942	0.955	**0.976**
NIB	1.000	1.000	1.000	1.000	0.961	0.978	1.000	**0.991**
OIB	0.836	0.852	0.888	0.768	1.000	0.854	0.957	**0.879**
UB	0.880	0.812	0.955	1.000	0.904	0.948	0.962	**0.923**
WB	0.945	0.881	1.000	1.000	1.000	0.897	0.963	**0.955**
ZB	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
Average	**0.952**	**0.952**	**0.976**	**0.972**	**0.976**	**0.944**	**0.977**	**0.964**
Minimum	**0.836**	**0.812**	**0.867**	**0.768**	**0.807**	**0.775**	**0.934**	
Maximum	**1**	**1**	**1**	**1**	**1**	**1**	**1**	
Standard deviation	**0.061**	**0.07**	**0.044**	**0.06**	**0.051**	**0.071**	**0.026**	

Source: Authors own calculation (2022)

From table 5 we can observe that the pure technical efficiency of ECBs is unstable during the study period with standard deviation ranging from 0.026 to 0.071. On average, the entire sector performed more efficiently after than before 2016, except for a dip in 2019. The average score was more than 0.97 in 2016, 2017, 2018, and 2020. In contrast, it was 0.952 before 2016 and even lower in 2019. This longitudinal pattern is more or less consistent with what reveals in Table 4. There was a system-wide improvement in banking efficiency since 2016 that was somehow arrested in 2019.

ECBs have scored an average efficiency score of 0.964 during the study period; which implies that the ECBs were operating at a marginal inefficiency of 4.6%.

Out of the 17 commercial banks, five of them scored an average efficiency score of 1 during the study period. The least pure technical efficiency score of 0.768 by OiB in 2017 was registered to be the minimum one followed by 0.775 and 0.807 by CBO in 2019 and 2018 respectively. Relatively large number of commercial banks scored pure technical efficiency of 1, opposite to the technical efficiency score presented in table 4. This implies that the source of inefficiencies of Ethiopian commercial banks were more of on setting the appropriate size of operation than the input-output configuration. Thus, one can infer the overall managerial success of ECBs at utilizing the inputs in the production process of financial services.

4.1.3. Scale Efficiency of Ethiopian Commercial Banks

The scale efficiency measures the ability of the management to choose the optimum size of resources. We examine which of the ECBs was operating at wrong scale of operations.

Table 6 indicated the scale efficiency which is computed as a quotient of TE and PTE; and showed how close or far the size of the ECB is from its optimal size. The 17 commercial banks scored an average scale efficiency of 0.977. It implies that an average Ethiopian commercial bank should reduce its input consumption by about 2.3% by adopting the optimal size or volume of operation. The

average scale efficiency score of ECBs for the recent year 2020 was 0.963. This implies that, an average bank could increase their relative efficiency on average by 3.7% if they adopted optimal scale size or volume of activities. Only one of the 17 commercial banks in Ethiopia, ZB, had the scale efficiency of 1 and said to have an optimal size and volume of activities. Based on average loan size during the study period ZB has found in a small group with average loan size of Birr 4,884.68 million where the average loans of all ECBs during the study period was birr 10,165.05. This implies that all other ECBs are too large to take full advantage of scale and has supra optimum scale size. Thus, ECBs should reduce their size to be as efficient as of the ZB and should follow the decreasing return to scale (DRS).

Table 6: Scale Efficiency of Ethiopian Commercial Banks (2014-2020)

Year	2014	2015	2016	2017	2018	2019	2020	**Average**
AB	0.988	0.997	0.997	0.971	0.996	0.936	0.993	**0.983**
AIB	0.952	1	1	1	1	1	1	**0.993**
AdIB	1	1	1	1	0.97	0.912	0.956	**0.977**
BOA	0.997	0.999	0.986	1	0.998	0.999	1	**0.997**
BrIB	0.934	0.992	1	1	0.992	0.982	0.967	**0.981**
BuIB	0.987	0.943	1	0.978	0.987	1	1	**0.985**
CBE	1	1	1	1	1	0.93	0.767	**0.957**
CBO	1	1	1	0.999	0.999	0.997	0.868	**0.980**
DB	0.968	0.885	0.861	0.83	0.812	0.988	0.88	**0.889**
DGB	0.908	0.758	1	1	1	1	1	**0.952**
EB	0.982	1	1	1	1	1	0.992	**0.996**
LIB	0.941	0.897	0.974	0.992	1	0.973	0.99	**0.967**
NIB	1	1	1	1	0.948	0.949	1	**0.985**
OIB	0.976	1	1	0.982	1	0.992	0.984	**0.990**
UB	1	1	0.971	0.995	0.998	0.994	0.99	**0.993**
WB	0.959	0.998	0.972	1	1	0.989	0.981	**0.985**
ZB	1	1	1	1	1	1	1	**1**
Average	**0.976**	**0.969**	**0.986**	**0.985**	**0.982**	**0.979**	**0.963**	**0.977**
Minimum	**0.908**	**0.758**	**0.861**	**0.83**	**0.812**	**0.912**	**0.767**	
Maximum	**1**	**1**	**1**	**1**	**1**	**1**	**1**	
Standard deviation	**0.028**	**0.066**	**0.034**	**0.041**	**0.046**	**0.029**	**0.064**	

Source: Authors own calculation, 2022

4.2. Relative variability of Ethiopian commercial banks' efficiency and rankings

In this section we employed the coefficient of variation (CV), a method recommended by Chaudhary & Arora (2022), to measure the relative variability of the data sets on a ratio scale and rank the ECBs. The CV indicates the consistency in the efficiency pattern of ECBs. A lower CV indicates less variation in the data and vice-versa.

Consequently, Table 7 indicates the ranking of ECBs based on their average efficiency score, standard deviations and the CV. The top three banks, ZB, AIB and BuIB, based on the average relative efficient score are also consistently ranked one to three in terms of the standard deviation and CV. This witnessed that those banks have the most stable relative efficiency scores. However, the least three efficient commercial banks based on their mean efficiency scores, namely DB, OIB and CBO, are the most unstable banks in terms of their relative efficiency scores. From this analysis we can infer that ZB is the most strong, stable and consistent bank in Ethiopian banking industry followed by AIB and BuIB.

Table 7: Coefficient of variation and ranking of banks by mean, standard deviation (S.D.) and Coefficient of variations (CV)

DMU*	Average	Rank by Mean	S.D.	Rank by S.D.	CV	Rank by CV
AB	0.907	14	0.034	5	3.74%	5
AdIB	0.977	5	0.034	4	3.46%	4
AIB	0.993	2	0.018	2	1.81%	2
BOA	0.915	12	0.055	11	5.99%	10
BrIB	0.944	9	0.051	8	5.39%	8
BuIB	0.977	3	0.022	3	2.25%	3
CBE	0.957	7	0.088	15	9.16%	14
CBO	0.905	15	0.104	17	11.50%	17
DB	0.858	17	0.055	10	6.36%	12
DGB	0.952	8	0.092	16	9.69%	16
EB	0.975	6	0.063	13	6.49%	13
LIB	0.943	10	0.048	7	5.07%	7
NIB	0.977	4	0.040	6	4.05%	6
OIB	0.871	16	0.081	14	9.31%	15
UB	0.914	13	0.056	12	6.17%	11
WB	0.941	11	0.052	9	5.48%	9
ZB	1.000	1	0.000	1	0.00%	1

Note: *DMU ordered in alphabetic order; S.D.= standard deviation; CV = coefficient of variation
Source: Authors computation (2022)

4.3. Ethiopian Commercial banks efficiency score by ownership

Out of the 17 sample commercial banks, only one bank is publicly owned and the remaining 16 banks are privately owned. The public owned bank has dominated the banking industry. For example, during the study period of 2014 to 2020, it holds an average of more than 61% and 50% of the total deposits and loans in the banking sectors, respectively. In this section, we explore whether the efficiency score of ECBs differ based on the ownership.

The average efficiency score per year for public commercial bank is greater than the private commercial banks during most of the study period except TE for 2020, and SE for 2019 and 2020. Consequently, the overall average efficiency score of public owned commercial banks, that is, TE = 0.9567; PTE = 1.000 are greater than the private owned commercial banks, which are 0.941 and 0.962 for TE and PTE respectively.

Table 8: Descriptive Statistics of Performance Efficiency of ECBs by ownership per study period

	Av_TE		Av_PTE		Av_SE	
Year	**Private**	**Public**	**Private**	**Public**	**Private**	**Public**
2014	0.92503	1	0.94943	1	0.97455	1
2015	0.91564	1	0.94882	1	0.96673	1
2016	0.9594	1	0.97418	1	0.985	1
2017	0.95397	1	0.96936	1	0.98412	1
2018	0.95544	1	0.97401	1	0.98125	1

2019	0.92322	0.92966	0.94067	1	0.98192	0.92966
2020	0.95211	0.76702	0.97598	1	0.975	0.76702
Average	**0.94069**	**0.95667**	**0.96178**	**1**	**0.97837**	**0.95667**
Standard Deviation	**0.06686**	**0.08764**	**0.05780**	**0**	**0.04237**	**0.08764**
Minimum	**0.75418**	**0.76702**	**0.76834**	**1**	**0.75792**	**0.76702**
Maximum	**1**	**1**	**1**	**1**	**1**	**1**

Note: Av_TE = Mean score of Technical efficiency; Av_PTE = Mean score of Pure efficiency and Av_SE = Mean score of Scale efficiency
Source: Authors computation (2022)

However, on average private commercial banks are scale efficient than publicly owned commercial bank. In the recent two years, the relative efficiency performance of public owned commercial bank was dwindling. For example, the TE and SE of public owned commercial bank become lower than private owned commercial banks in the year 2020. It suggests that the public bank, though exhibiting excellent pure technical efficiency throughout the sample period, started to show inefficiency due to its large size.

We have tested whether these differences are statistical significant. The test results showed that the PTE score has statistically significant difference between private and public owned commercial banks at 5% (Z= -2.170, p=0.03). This implies that public owned commercial bank in Ethiopia is more efficient than the private owned commercial banks in terms of PTE. However, the mean rank for TE and SE between the state owned and private owned commercial banks is statistically insignificant difference at even 10%. This finding is similar to prior studies (Ijara & Sharma, 2020; Lelissa, 2014; Lelissa & Kuhil, 2016; Tanwar et al., 2020; Zhu et al., 2020).

4.4. Ethiopian Commercial banks efficiency score based on size

In this section, we test if the efficiency of private ECBs differ on size. The publicly owned commercial bank is dropped from the analysis because it is a giant compared to any of the private banks. Bank loans, one of the output variables and the major source of income for commercial banks, is used to measure the size of private banks. Following the work of Chen et al. (2015, p.348) private owned commercial banks are categorized as large scale banks and small scale banks based on their loan size. All private commercial banks registered average loans of birr 10.17 billion during the study period. Thus, a large-scale bank is one in which its average loan during the study period is larger than the average loan of private commercial banks. A small scale bank is one in which the average amount of its loan during the study period is smaller than birr 10.17 billion. Table 10 presents the average efficiency scores, standard deviation, minimum and maximum scores of private commercial banks during the study period on the basis of size.

Table 10: Performance Efficiency of private commercial banks categorized by size

	TE		**PTE**		**SE**	
Statistics	**Small**	**Large**	**Small**	**Large**	**Small**	**Large**
Average	0.950	0.929	0.968	0.954	0.981	0.975
Standard Deviation	0.063	0.070	0.054	0.062	0.038	0.048
Minimum	0.754	0.773	0.768	0.775	0.758	0.812
Maximum	1.000	1.000	1.000	1.000	1.000	1.000

Note: TE = Technical efficiency, PTE = Pure efficiency and SE = Mean score of Scale efficiency
Source: Authors' computation (2022)

Table 10 shows the efficiency score of ECBs by their size. In all the three efficiency measurements, TE, PTE and SE, the smaller private commercial banks scored higher average efficiency than the larger private commercial banks. However, the differences are not statistically significant based on Mann-Whitney U-test.

Therefore, to further investigate whether performance efficiency varies with bank size, we categorize private commercial banks into three groups based on their loan size and compare the top 1/3rd (largest 5) with the lowest 1/3rd (the smallest 5) commercial banks. The Mann-Whitney U test shows statistically significant difference in the efficiency scores of small and large private

commercial banks during the study period. More specifically, the average TE and PTE of smaller commercial banks had statistically significant difference with large group banks with z = -2.937, p = 0.003 and z = -2.928, p = 0.003, respectively. The SE also shows marginally significant statistical difference between the two groups at 10% significance level.

From these two analyses, we infer that when the ownership factor is controlled and the middle size commercial banks are excluded, smaller commercial banks operate more efficiently than the larger ones. This implies that private commercial banks should operate at diseconomies of scale.

Table 11: The Mann-Whitney U-test result

Efficiency Measure	Bank Size	N	Average rank*	Sum rank	z	p-value
TE	Small	35	28.64	1002.5	-2.937	0.0033
	Large	35	42.36	1482.5		
	Total	70		2485		
PTE	Small	35	29.26	1024	-2.928	0.0034
	Large	35	41.74	1461		
	Total	70		2485		
SE	Small	35	30.99	1084.5	1.933	0.0532
	Large	35	40.01	1400.5		
	Total	70		2485		

Source: Authors own computation (2022)

5. Summary and Conclusion

This study evaluates the performance of 17 commercial banks during the year 2014 to 2020. We employ the DEA technique to assess the technical efficiency (TE), Pure-Technical efficiency (PTE), and scale efficiency (SE) of the sample banks. The inputs and outputs are chosen through intermediation approach. The noninterest expense and deposits are used as input variables while net interest income, non-interest income, and loans and advances serve as output variables. The CCR model and the BCC model are used to estimate the efficiency scores. We find that on average, the commercial banks in Ethiopia operated during the study period at 94.2%, 96.4%, and 97.7% in terms of TE, PTE, and, SE, respectively. The top three efficient commercial banks, based on the average efficiency scores, appear to be also the most stable ones, experiencing least variation over the sample period in their efficiency scores. When ownership of the banks is considered, the public commercial bank outperformed private ones in average PTE over the study period but experienced inferior scale efficiency in later years. When the ownership factor is controlled and the middle size commercial banks are excluded, smaller commercial banks appear to be more efficient than the larger ones in all the efficiency dimensions.

The results found in this study have implications for both bank managers and policy makers. The relative efficiency score provides bank managers useful benchmarks to improve their operations. For example, we find that among private banks larger ones (based on the amount of loans) were not as efficient as smaller ones. It suggests that focusing on growing assets by extending loans may not be the best strategy for large private banks. Similarly, the public bank's deterioration in scale efficiency suggests that it might have become too large on the Ethiopian banking market.

The major limitation of this study, as common to DEA model, is on the selection of input and output variables. The inference about efficiency is only valid to the extent that the inputs and outputs are representative of the banks' business model. The DEA technique measures the relative efficiency and not the absolute efficiency level of commercial banks, thus we cannot indicate whether the efficiency of the ECBs improved or worsened overtime. Thus, we recommend parametric analysis, for example the Malmquist index, in order to identify how the efficiency level of each banks have changed overtime.

Moreover, this study only explores how bank efficiency differs with ownership and size. Banks' performance may be affected by various macro-economic, industry and organization level factors. Thus, future studies could use

multilevel models such as two stages DEA model to identify the impact of those factors on the efficiency scores of ECBs.

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