DEA Window Analysis Efficiency Measurement of Selected Nigerian Bank

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Abstract
This study analyzes the performance efficiency of six selected banks in Nigeria for the period 2010 – 2016. DEA window analysis was employed to establish the performance efficiency of the selected banks. The analysis is based on panel data for the period under review. The result of the DEA window analysis for the reviewed period showed that the average efficiency scores under constant returns to scale ranged from 84% to 91%. Under the variable returns to scale, the average efficiency scores ranged from 91% to 95%. The average inefficiency of the selected Nigeria commercial banks under the constant returns to scale model was in the range 9 – 16%. This inefficiency could be attributed to the excess of customers deposits on the balance sheet of the selected banks. The average scale efficiency for the banks was 93%. Guaranty Trust Bank was the most efficient bank on all measures. United Bank for Africa was the most inefficient bank under constant returns to scale and variable returns to scale. It was however, more scale efficient than three other banks, an indication that its inefficiency cannot be attributed to inappropriate scale size.

Keywords: Data Envelopment Analysis, Window Analysis, Performance, Efficiency, Deposits, Nigerian Banks

Introduction

The Nigerian financial sector is characterized as bank-based, expectedly, banks play a leading role in the economy. Banking operations in Nigeria can be traced back to 1892 during the colonial rule when foreigners were in charge. Some Nigerians ventured into the sector by establishing their own banks as at 1945. The period 1939 – 1969 witnessed the first phase of consolidation in the industry to stem the tide of colossal failure which characterized the industry between 1953 – 1959 basically due to liquidity issues (Eriki and Osagie, 2014). The Central Bank of Nigeria (CBN) was established in 1959 as a regulatory and supervisory body for the banking institution. This brought some sanity in the banking sector by ensuring that banks were adequately capitalized to forestall avoidable failures (Olugbenga and Olankunle, 1998; Somoye,2008; Ekiri and Osagie, 2014).

The year 1986 brought in another challenge to the banking sector with the introduction of Structural Adjustment Programme (SAP) and liberalization of lending rates which led to intense competition among banks. Between 1986 and 1990, the number of banks increased from 42 to 107 due to deregulation of the financial sector. By 1992, the number had increased to 120. As a result of liquidation due to dwindling fortunes, the number reduced to 89 (Ekiri and Osagie, 2014). To further bring sanity to the banking sector, the consolidation exercise of 2006 reduced the number of banks to 25 by raising the minimum paid-up capital from ₦2 billion to ₦25 billion (Ekiri and Osagie, 2014).

The banking sector has experienced noticeable advancement globally due to innovations in the operating environment which has substantially impacted on how banking services are conducted. Globalization, financial innovation, deregulation as well as technological advancement have significantly impacted on the operational efficiency of banks (Dong *et al*., 2014; Fagge, 2019).

Efficiency and productivity measurements to assess the performance of banks are basic to their operational sustainability and economic growth. A good percentage of total output in the banking sector can be linked to their assets. Banks accept deposits, grant credits, and provide liquidity for a seamless payment system. Efficiency is key in the banking system for the entrenchment of sustainable economic growth and lively economic system. The benefit of enhanced economic efficiency is to minimize gaps between lending and deposit rates, thus allowing financial and real resources to flow easily to their highest-return uses (Karimzadeh, 2012; Fagge, 2019).

This study is therefore aimed at deploying the technique of Data Envelopment Analysis (DEA) Window Analysis on the data of selected Nigerian banks to assess their efficiency for the period 2010 to 2016. The analysis is based on panel data for the period from 2010 to 2016. DEA window analysis based on input oriented model will be used to measure the efficiency of the selected banks. The outcome will allow for an analysis of trends of the selected banks' efficiency. Furthermore, the technical efficiency will be analyzed sequentially using appropriate window width. Accordingly, the temporal influence on the bank technical efficiency will the captured and its short-run progress from one window to another will be seen in addition to the pure technical efficiency and scale efficiency.

The rest of the paper is structured as follows. Section 2 deals with literature review. Section 3 presents the methodology of DEA window analysis while section 4 describes the data and the input and output variables. Section 5 presents the results and section 6 concludes the paper.

Literature review

Efficiency measurement of the financial sector has become the focus of many studies in the recent past for both the developed (Fiordelisi, *et al*., 2011; Chortareas, *et al*., 2012; Chortareas, *et al*., 2013) and developing economies (Tecles and Tabak, 2010; Sufian and Majid, 2009; Shawtari, *et al*., 2017). These authors adopted different methods to measure efficiency, in particular, most of them utilized the conventional DEA to estimate the efficiency of banks world-wide.

Shawtari *et al*. (2017) utilized the data envelopment analysis in its windows version to estimate the efficiency scores reflecting the time variance and compares between banking models for Islamic and conventional banks. The findings indicate that pure technical efficiency (TE) is higher for conventional banks than Islamic banks. On the other hand, Islamic banks are more scale efficient (SE) than their conventional counterparts.

Fagge (2019) examined the technical, allocative and cost efficiency of Nigerian deposit money banks for the period 2010 to 2017 using data envelopment technique. The range covered the period of economic crisis and its effect on the banking system as well as the policy measures taken to address the issues. The study established that technical inefficiency was the major source of inefficiency, which calls for managerial improvement in order to scale up the efficiency levels.

Inefficiencies in Nigerian banks ranging from 36% in 2001 to 45% in 2002 were attributed to pure technical efficiency rather than scale efficiency. The specific sources were linked to low capital-to-asset ratio, high operating expense-to-income ratio, low returns on equity, market share, interest expense-to-deposit ratio, in addition to liquidity ratio (Nyong, 2017; Fagge, 2019).

Osuagwu *et al.*, (2018) estimated the technical efficiency and total factor productivity change in the Nigerian banking sector for the period 2005 – 2014. Their study covered the post-consolidation period and the banking reform era aimed at stabilizing the banking sector from the effects of financial crisis. The study applied Data Envelopment Analysis and Stochastic Frontier Analysis in addition to Productivity Index and error component production function to ascertain if any significant variation in efficiency exists on a sample of 12 banks in Nigeria. The findings of the study suggest that policy makers should be mindful of arbitrariness in bank's ability to earn free-based income to avoid high cost of banking services in the long run. A study by Assaf *et al.*, (2012) suggests that efficiency of Nigerian banks increased in the post-consolidation period to reach an average of 91.2% in 2007 using Bayesian stochastic frontier model.

Reisman *et al.*, (2003) applied Data Envelopment Analysis Window Analysis to examine the efficiency over time of a sample of banks in Tunisia and concluded that ownership plays a role in determining efficiency. Řepková (2014) utilized Data Envelopment Analysis Window Analysis to study the efficiency of the Czech banking sector and established that the larger banks are less efficient than small and other banks. This was due to the fact that larger banks hold enormous deposits in addition to inappropriate size of operations.

This study is a departure from the traditional use of Data Envelopment Analysis for efficiency measurement. It demonstrates that even when the number of DMUs is small, efficiency measurement could still be performed. Thus the difficulty that researchers usually face when sourcing for data, especially from Nigerian Banks, can be minimized by using Data Envelopment Analysis Window Analysis, which is the gap that this research seeks to fill.

Materials and Methods

The seminal paper of Farrell (1957) on efficient frontier defined a simple measure of a firm's efficiency that could account for multiple inputs. Leveraging on this, Charnes *et al.*, (1978) pioneered the work on data envelopment analysis. Data envelopment analysis is a linear programming based technique for measuring the relative performance of organizational units where the use of multiple inputs and multiple outputs make comparisons difficult. It involves constructing a non-parametric piecewise frontier over data so as to calculate efficiency relative to this frontier. Data envelopment analysis calculates the relative efficiency scores of various decision making units (DMU) in a particular sample (Eriki and Osagie, 2014). DEA requires that all DMUs lie on or under the efficiency frontier. DEA identifies for inefficient DMUs, the source and level of inefficiency for each of the inputs and outputs. The term DEA is derived from a theoretical efficient frontier which envelops all empirically-observed DMUs (Řepková, 2014).

The construction of DEA model could take the form of inputs minimization or outputs maximization. Input oriented objective aims at minimizing the inputs while maintaining the output levels, while an output oriented objective aims at maximizing the output levels without increasing the inputs.

There are two main forms of the DEA model: The Cooper, Charnes and Rhodes (CCR) model established by Charnes *et al.*, (1978) and the Banker, Cooper and Charnes (BCC) model. The BCC model is a modification of the CCR model established by Banker *et al.*, (1984). The basic DEA model is the CCR model which assumes that there is no significant relationship between the scale of operations and efficiency. It assumes constant returns to scale (CRS) and delivers overall technical efficiency (TE). This assumption is however, valid only if all DMUs are operating at an optimal scale. The BCC model is an extension of the CCR model, it assumes variable returns to scale (VRS) and delivers pure technical efficiency (PTE). Pure technical efficiency is the measurement of technical efficiency without the effects of scale efficiency (SE). The presence of scale inefficiency can be detected whenever there is a difference between TE and PTE scores for any DMU (Sufian, 2007; Řepková, 2014).

DEA has some limitations which include: inability to interpret results with confidence when data integrity is violated, the DMUs adjudged as efficient are only efficient relative to others in the sample. It is therefore possible for a unit outside the sample to have higher efficiency than the best practice DMU in the sample. DEA is done in only one period at a time, thereby hindering the measurement of efficiency changes when there is more than one period of time (Sathye, 2003; Řepková, 2014).

Window analysis operates on the idea of moving averages principles (Charnes, *et al*., 1995; Yue, 1992; Cooper *et al*., 2007). It is particularly applicable when the research interest is to trace the efficiency trends of a DMU over time (Kisielewska, *et al*., 2005; Shawtari, *et al*., 2017). Window analysis treats each DMU as if it were a different DMU in each period. It contrasts the efficiency scores of a DMU with its own in other periods as well as to other DMUs and subsequently helps to specify the best and worst DMUs and therefore the steadiness (Halkos and Tzeremes, 2009; Piyu, 1992; Shawtari, *et al*., 2017). Each DMU (i.e. bank) is treated as a different bank in a different period which can increase the number of data points. Thus, each DMU in a different period is treated as if it were a different DMU (Independently) but remain comparable in the same window (Řepková, 2014; Cooper, *et al*., 2011).Its discriminatory power is enhanced, especially in the case of small number of DMUs and large number of inputs and outputs, because it creates adequate observations and enhances the degree of freedom (Avkiran, 2004; Danijela, *et al*., 2012; Shawtari, *et al*., 2017).Thus, small sample sizes problems are solved (Řepková, 2014). Therefore, DEA window analysis offers the opportunity to contrast the performance of a bank in a period against themselves and against other banks over time (Řepková, 2014; Asmild, *et al*., 2004). Window analysis offers some evidence of the short-run progression of efficiency for a DMU over time.

Charnes *et al*. (1985) proposed DEA window analysis in order to measure efficiency in cross sectional and time changing data. Řepková (2014) and Paradi *et al*. (2001), explained that varying the window width (i.e. the number of time periods included in the analysis) means covering the range from contemporaneous analysis, which include only the observations from one-time period, to intertemporal analysis, which include observations from the whole study period.

From Asmild *et al*. (2004); Gu and Yue (2011) and Řepková (2014), let N DMUs (n = 1, 2, …, N) observed in T (t = 1, 2, …, T) periods using r inputs to produce s outputs. Let DMU_n^t represent a DMU_n in period t with an r dimensional input vector $x_n^t = (x_n^{1t}, x_n^{2t}, \ldots, x_n^{rt})^T$ and s dimensional output vector $y_n^t = (y_n^{1t}, y_n^{2t}, \ldots, y_n^{st})^T$. If a window starts at time $k(1 \leq k \leq T)$ with window width $w(1 \leq w \leq t-k)$, then the metric of inputs is given as follows:

$$x_{kw} = (x_1^k, x_2^k, \ldots, x_N^k, x_1^{k+1}, x_2^{k+1}, \ldots, x_N^{k+1}, x_1^{k+w}, x_2^{k+w}, \ldots, x_N^{k+w})^T \qquad (1)$$

The metric of outputs as:

$$y_{kw} = (y_1^k, y_2^k, \ldots, y_N^k, y_1^{k+1}, y_2^{k+1}, \ldots, y_N^{k+1}, y_1^{k+w}, y_2^{k+w}, \ldots, y_N^{k+w})^T \qquad (2)$$

The CCR formulation of the DEA window analysis problem for DMU_n^k is given by the linear program:

Objective function:

$$\min \theta \qquad (3)$$

Subject to:

$$\theta^T X_t - \lambda^T X_{kw} \geq 0 \qquad (4)$$

$$\lambda^T Y_{kw} - Y_t \geq 0 \qquad (5)$$

$$\lambda_j \geq 0 \; (j = 1, 2, \cdots, N \times w) \qquad (6)$$

Where θ represents the efficiency score of the decision making unit being investigated.

To obtain the BCC model formulation, add the restriction $\sum_{j=1}^{n}\lambda_j = 1$ (Banker *et al*., 1984; Řepková, 2014).

Objective function:

$$\min\theta \tag{7}$$

Subject to:

$$\theta^T X_t - \lambda^T X_{kw} \geq 0 \tag{8}$$

$$\lambda^T Y_{kw} - Y_t \geq 0 \tag{9}$$

$$\sum_{j=1}^{n}\lambda_j = 1 \tag{10}$$

$$\lambda_j \geq 0\ (j = 1, 2, \cdots, N \times w) \tag{11}$$

The choice of window width is guided by the consideration that there are no technical changes within each of the windows, since all DMUs in each window are compared and contrasted against each other and as such, a narrow window width is recommended (Asmild *et al*., 2004; Řepková, 2014). A window width, w = 3 or 4 established by Charnes *et al*. (1995), was found to yield the best balance of informativeness and stability of the efficiency scores. This study therefore considers a 3-year window (w =3).

Data and selection of input and output variables

The data for this study were collected from the annual reports of the six selected Nigerian banks for the 2010 – 2016 period. Three of the banks represent the old generation banks while the remaining three represent the new generation banks. Selection of input and output factors is guided by the formulation of appropriate theory of production that is applied to the banking industry. The approaches developed to define the input-output relationship in the financial institution behavior are intermediation, production, asset and profit approach. Intermediation is highly canversed in literature as it fits the nature of banking operations as financial intermediaries (Shawtari, *et al*., 2017). This study adopts the intermediation approach whose role is to channel the money of depositors to the borrowers through a combination of labour and capital. Five input variables (Employees (EMP), Wages and Salaries (WAS), Deposits from Customers (DFC), Operating Expenses (OE), and Investment Securities (IS)), and three output variables (Loans and Advances to Customers (LAC), Gross Earnings (GE), and Net Interest Income (NII)) are used in this study.

Results and Discussion

Table 1: Descriptive Statistics

	EMP	WAS	DFC	OE	IS	LAC	GE	NII
Max	10651	58298	2570719	244717	781902	2138132	478232	259567
Min	2589	11679	327351	29235	41006	136982	55623	21971
Average	5812.62	32660.1	1355488	95574.1	316569	844954	218510	108732
SD	2572.28	13053.5	686844	49482	192805	519766	112614	66319.4

Table 1 shows the maximum, minimum, average and standard deviation values for each of the input and output variables.

DEA window analysis was used to measure the efficiency of each of the six selected banks under the assumption of constant returns to scale and variable returns to scale. DEA-SOVLVER-LV8 software was used to conduct the analysis. The input-oriented constant returns to scale model as well as the output-oriented variable returns to scale model were used to estimate the DEA window analysis efficiencies for the banks. These two approaches were adopted because the assumption of constant returns to scale is feasible only in the event that all DMUs are operating at optimum size. In practice however, this assumption is hard to fulfill. To ameliorate this problem, it became necessary to calculate the variable returns to scale also (Stavárek and Řepková, 2012; (Řepková, 2014)). Panel data for the period 2010 – 2016 for six Nigerian commercial banks (Union Bank (UBN), Guaranty Trust Bank (GTB), Zenith Bank (ZENB), United Bank for Africa (UBA), Fidelity Bank (FIDB) and First Bank (FBN)) were used.

The constant returns to scale DEA window analysis efficiency scores, using a 3-year window width, are shown in Table 2. The average efficiency for the period 2010 – 2016, calculated under the constant returns to scale model, ranges from 84% to 91%. Based on this result, the banks are considered to be efficient on the average, with only minimal changes over time. Accordingly, the average inefficiency of the selected Nigeria commercial banks under the constant returns to scale model was in the range 9 – 16%. This inefficiency could be attributed to the excess of customers deposits on the balance sheet of the selected banks.

Table 2: CCR Input Oriented Model

DMU	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016	Average
UBN	0.9345	0.9262	0.9979	0.9979	0.9528	0.9619
GTB	1.0000	1.0000	1.0000	0.9790	0.9789	0.9916
ZENB	0.7469	0.8111	0.7748	1.0000	1.0000	0.8666
UBA	0.6929	0.6352	0.6227	0.6908	0.6762	0.6636
FIDB	0.7916	0.8329	0.8680	0.9109	0.8895	0.8586
FBN	0.9127	0.8423	0.8317	0.8592	0.9186	0.8729
Average	0.8464	0.8413	0.8492	0.9063	0.9027	

From Table 2, the most efficient bank is Guaranty Trust Bank, a new generation bank, with the highest average efficiency score of 0.9916. This is followed by Union Bank, with an average efficiency score of 0.9619, which is an old generation bank. The efficient banks are adopting best practices which should be understudied and emulated by the inefficient banks. On the other hand, the least efficient bank is United Bank for Africa, an old generation bank, with an average efficiency score of 0.6636. The reason for this inefficiency is that, being one of the mega banks, it has excess of customers deposits in balance sheet.

Table 3: BCC Input Oriented Model

DMU	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016	Average
UBN	0.9630	1.0000	1.0000	1.0000	1.0000	0.9926
GTB	1.0000	1.0000	1.0000	0.9992	0.9991	0.9997
ZENB	0.8241	0.9113	0.9615	1.0000	1.0000	0.9394
UBA	0.7262	0.6991	0.7110	0.7270	0.7021	0.7131
FIDB	0.9355	1.0000	1.0000	1.0000	0.9807	0.9832
FBN	1.0000	1.0000	1.0000	1.0000	0.9371	0.9874
Average	0.9081	0.9351	0.9454	0.9544	0.9365	

In Table 3, the efficiency of the selected Nigerian banks under the BCC input oriented variable returns to scale model is presented. The average efficiency scores for the period 2010 – 2016 ranges from 91% to 95%. The average inefficiency is in the range of 5% to 9%. The most efficient bank is Guaranty Trust Bank, followed by Union Bank. The most inefficient bank is United Bank for Africa.

In Table 4, we present the scale efficiency of the selected banks. Scale efficiency is obtained by dividing the technical efficiency arrived at under CRS by pure technical efficiency arrived at under VRS (Řepková, 2014).

Table 4: Efficiency of Selected Nigerian Banks

DMU	Technical Efficiency (CRS)	Pure Technical Efficiency (VRS)	Scale Efficiency
UBN	0.9619	0.9926	0.9691
GTB	0.9916	0.9997	0.9919
ZENB	0.8666	0.9394	0.9225
UBA	0.6636	0.7131	0.9306
FIDB	0.8586	0.9832	0.8733
FBN	0.8729	0.9874	0.8840
Average	0.8692	0.9359	0.9285

Examination of Table 4 shows that the results obtained through the BCC model are higher for each bank than the results obtained through the CCR model. The reason is because the BCC model decomposes inefficiency of production units into two components: pure technical inefficiency and the inefficiency due to scale. Thus the values of efficiency obtained by VRS attain higher values than efficiency obtained through CRS by eliminating the part of the inefficiency that is caused by lack of size of production units. The selected Nigerian banks reached a mean scale efficiency of 93% within the period 2010 – 2016. Guaranty Trust Bank achieved the highest scale efficiency within the period under review. Thus, it will be safe to say that Guaranty Trust Bank is the most efficient bank during the period under review. However, United Bank for Africa obtained a scale efficiency score higher than three other banks. This shows that the technical inefficiency and the pure technical inefficiency displayed by UBA cannot be attributed to choice of inappropriate size. All the other banks that are adjudged inefficient, can attain the same level of efficiency as GTB by understudying its mode of operation. This will make for a healthy banking sector which will in turn impact positively on the Nigerian economy.

Conclusion

Banks are very central to the growth process of Nigeria, making their efficiency measurement a worthy venture. A methodology that gives the opportunity to assess the efficiency of banks even when there is paucity of data should be carefully studied. The entrance of DEA window analysis for the measurement of the efficiency of Nigerian banks is therefore timely.

This study estimated the efficiency of selected Nigerian banks on the assumption of constant returns to scale and variable returns to scale. For the period 2010 – 2016, the analyzed banks attained average efficiency under constant returns to scale ranging from 84% to 91%. Under the variable returns to scale, the range was from 91% to 95%. The average scale efficiency for the analyzed banks was 93% within the period under review. The results show that Guaranty Trust Bank was the most efficient bank with the highest efficiency scores under CRS, VRS and SE. United Bank for Africa had the lowest efficiency scores under CRS and VRS, but beat three other banks on scale efficiency. Going by the average scale efficiency score, it can safely be said that the analyzed banks are not suffering from inappropriate scale size.

The explicit results for the CCR and BCC input oriented models for the DEA window analysis, for each bank, are presented in Appendices A and B respectively.

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