DOES BANK SIZE AFFECT EFFICIENCY? EVIDENCE FROM COMMERCIAL BANKS IN NIGERIA

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Abstract

This paper examines the cost efficiency of 15 commercial banks in Nigeria in the post-consolidation period extending from 2006 to 2018. As a first step, efficiency scores are generated using the stochastic frontier approach. As a second step, the effect of bank size on cost efficiency is examined using the robust standard errors of Driscoll and Kraay (1998) and the dynamic generalised method of moments (GMM) to control for cross-sectional dependence and endogeneity issues respectively in the model. The findings of the study show that the overall mean cost efficiency for Nigerian commercial banks is 78%. This suggests that approximately 22% of input resources are being wasted in the sector. The findings from the frontier analysis further reveal that larger banks do not enjoy cost advantage over their smaller counterparts. In the second stage of the analysis, the study finds that bank size does not affect cost efficiency within the study period. Other internal factors such as capitalisation ratio, loan-to-deposit ratio, operating expenses and loan to total asset are found to be major drivers of cost efficiency. The study therefore advises banks to place less emphasis on size by closing down inefficient branches to reduce their operating expenses and stimulate cost efficiency.

Keywords: Bank size, Cost efficiency, Cross-sectional dependence, Stochastic frontier analysis

JEL Classification: G2; G21

Introduction

Every business entity strives to produce optimum output at the lowest possible cost. The banking industry is not an exemption, as it is the desire of every bank to provide maximum return to its fund providers, otherwise called shareholders. Producing maximum return at the lowest possible cost is termed 'efficiency'. A firm is efficient if it can maximise output given the cost of production or minimize cost given the level of output. The issue of efficiency among deposit money banks occupies a central focus due to their role in the financial intermediation of the economy. A study on bank efficiency is particularly relevant in an economy like Nigeria, where the real sector development depends on the stability of the financial sector.

For more than two decades, the Nigerian banking sector has undergone notable fundamental changes in a bid to reposition the sector as the hub of economic development in the country. Before 2005, there were more than 89 banks in the country that were highly undercapitalised, distressed and grossly inefficient with a high percentage of nonperforming loans. In 2005, the Central Bank of Nigeria (CBN) mandated all the commercial banks to increase their minimum capital base from ₦2billion to ₦25billion (Bolarinwa & Obembe, 2019). One major objective of this exercise was to make the banking sector highly capitalised, stronger and more cost efficient (Kolapo, Ajayi & Aluko, 2016; Nyong, 2017). The recapitalisation exercise forced many banks into a series of mergers and acquisitions. After 2005, only 25 banks emerged as commercial banks in the country. Besides, the recapitalisation exercise produced the emergence of large banks in terms of asset base as well as wider coverage.

It is expected that through the consolidation process, the sector would rebound, produce large banks that could favourably compete with their counterparts in other countries, achieve better cost structure, and hence, benefit from economies of scale, resulting in an improvement in the efficiency level (Enyi, 2007; Karray & Chichti, 2013). The question then is, does the increase in bank size due to recapitalisation bring about corresponding increase in the cost efficiency score of the banking sector? This paper attempts to answer this question by examining the effect of the increase in size of Nigerian commercial banks after the 2005 bank consolidation on their cost efficiency.

Cost efficiency has not been given serious attention in the developing countries and most especially in Nigeria. In fact, existing studies in Nigeria such as Babalola (2013), Owoputi, Olawale and Adeyefa (2014), Abdulazeez, Suleiman and Yahaya (2016), Kolapo, Ajayi and Aluko (2016), and Bolarinwa and Obembe (2017) focus on profitability using the return on assets (ROA) and return on equity (ROE) as measures of bank performance. However, as documented by Berger *et al.* (1993) and Leykun (2018), these ratios might be misleading due to their failure to account for product mix and their inability to consider multiple inputs and outputs. Similarly, the few studies that consider cost efficiency among commercial banks in Nigeria employ the nonparametric approach of data envelope analysis (DEA) to compute the efficiency score (see Oke & Poloamina, 2012; Eriki & Osifo, 2015; Nyong, 2017; Fagge, 2019; Worimegbe, Oladimeji & Eze, 2019). Again, DEA has been criticized for its failure to account for random error and other measurement errors (Otero *et al.,* 2020).

The discussion on cost efficiency in the banking sector thus cannot be overemphasized, especially in an emerging economy such as Nigeria, whose financial sector is still at the formative stage. This is premised on the fact that the achievement of financial stability and higher productivity in the economy strongly depends on the efficiency of the financial sector in performing its traditional role of financial intermediation. Similarly, the growth and development of the real sector and the economy as a whole are contingent on the degree of efficiency of the banking sector (Adejei-Frimpong, Gan & Hu, 2014; Nitoi & Spulbar, 2015; Kashian, Lin & Xue, 2019). Therefore, there is a need to examine the cost efficiency of the Nigerian banking sector and investigate whether the increase in bank size actually enhanced cost efficiency among the commercial banks in Nigeria.

Looking into the empirics, however, the debate on the size-efficiency nexus is far from being conclusive. For instance, Berger and Mester (1997), Bikker (1999), Sathye (2001), Hassan and Marton (2003), Halkos and Salamouris (2004), Kamu (2011), Karray and Chichti (2013), Oluitan, Ashamu and Ogunkenu (2015), and Anwar (2018) argue that bank size promotes efficiency. These studies conclude that banks with larger assets record better cost efficiency in their operations. Conversely, other studies such as Kaparakis *et al.* (1994), Darrat and Yusuf (2002), Isik and Hassan (2002), Drake and Hull (2003), Kamberoglou *et al.* (2004), Leong and Dollar (2004), Alhassan (2015), Stanek (2015), Banya and Biekpe (2018), and Ding and Sickles (2018) contend that bank size has a negative and substantial impact on cost efficiency. These authors argue that larger banks are complex and costly to manage, resulting in increased cost of operation. Despite this ongoing debate, Adjei-Frimpong, Gan and Hu (2014), Okorie and Agu (2015), Hadhek, Frifita and Hmida (2018), and Goswani, Husain and Kumar (2019) find no evidence of a significant relationship between size and cost efficiency among the deposit money banks in Ghana, Nigeria and India respectively.

This current study contributes to the body of knowledge on bank efficiency literature in five major ways. First, it adopts cost efficiency as a better measure of the performance of banks in the Nigerian banking sector. Second, it generates cost efficiency scores through a stochastic frontier analysis (SFA) that is robust to uncertainty and other measurement errors. Third, it analyses the impact of bank size and other bank-specific factors on cost efficiency, especially after the consolidation that gave birth to the emergence of large banks. Fourth, unlike previous studies in the cost efficiency literature, which assume that the disturbances in a panel model are cross-sectionally independent (Nitoi & Spulbar, 2015; Bolarinwa, Obembe & Olaniyi; 2019; Kashian, Lin & Xue, 2019; Bolarinwa Adegboye 2020), the study adopts the robust standard errors technique to account for cross-sectional dependence inherent in the model. Apart from the fact that the approach adequately deals with heteroscedasticity, it is also appropriate for panel models with cross-sectional and temporal dependence (Le & Tran-Nam, 2018; Le, Le & Taghizadeh-Hesary, 2020, Olaoye & Aderajo, 2020; Olaniyi, 2021). Lastly, this study also adds to the body of literature on the size-efficiency nexus among commercial banks in Nigeria by classifying the commercial banks into three broad groups based on their total asset to control for size differentials.

The remaining parts of the study are sectioned as follows; section 2 presents the literature review, section 3 provides the methodology and techniques of analysis, section 4 discusses the findings, while section 5 concludes the study.

Literature Review

In the literature, there are two broad techniques to measure the performance of commercial banks; these are the financial ratios and frontier approaches. Financial ratios involve the use of return on assets (ROA) and return on equity (ROE). However, this method has been criticized for its limitation in scope and failure to provide information on long-term bank performance. Besides, the ROA and ROE ignore the managerial ability of banks to transform inputs to outputs. On the other hand, the frontier approach uses efficiency to measure performance by comparing a bank's efficiency score to the best bank on the efficiency frontier (Leykun, 2018).

Two methods have been identified in the cost efficiency literature; they are the parametric and nonparametric methods. The parametric approach uses the econometric method to generate the efficiency score, while the nonparametric approach relies on linear programming techniques to estimate the efficiency score. Of all the parametric techniques, the stochastic frontier analysis (SFA) is the most widely adopted in generating efficiency score. This is basically due to its advantages over other parametric methods. According to the pioneer study by Aigner, Lovell and Schmidt (1977), the SFA approach to efficiency helps to observe the influence of disturbance on the efficiency level. The authors identify two different components of the error term. The first component is the random error which captures measurement and specification errors. The second component is the inefficiency term which captures the deviation of actual cost from the stochastic frontier[1]. In the nonparametric approach, the data envelope analysis (DEA) is the most recognised method of computing efficiency score. It has however been subjected to some criticisms. For instance, it assumes that there is no statistical measurement error. It also considers only technical inefficiency and not allocative inefficiency because prices are ignored. Lastly, it focuses on technological rather than economic optimisation (Kaparakis *et al.,* 1994; Berger & Mester, 1997). This current study adopts the SFA due to its advantages over other measures of efficiency as it ranks firms with the lowest cost of production as the most efficient.

On the empirical front, the nexus between bank size and efficiency is an ongoing debate. Studies such as Sathye (2001), Hassan and Marton (2003), Halkos and Salamouris (2004), Karray and Chichti (2013), Anwar (2018), Otero *et al*. (2019), and Sakouvogui and Shaik (2020) establish that banks with higher assets record higher efficiency in their operation. Berger and Meyer (1997) likewise find cost efficiency to improve with bank size among US banks. The authors link this outcome to strong competition among US banks. Their finding is validated by the recent study of Sakouvogui and Shaik (2020) where the value of total asset is found to influence the improvement of cost efficiency in US commercial banks. Also, a study by Karray and Chichti (2013) explores the effect of bank size on the technical efficiency of 402 commercial banks in developing countries and concludes that the overall technical efficiency improves as bank size increases. Similar findings are obtained by Gunes and Yildirm (2016) for Turkish banks. Additionally, Anwar (2018) examines the factors that affect the efficiency of 111 deposit money banks in Indonesia. Adopting the Battese and Coelli (1992) SFA and standard pooled estimation techniques to generate the

[1] For a comprehensive discussion of Stochastic Frontier Analysis, consult Green (2005) and Erkoc (2012).

efficiency score, the study shows the banking sector's efficiency level to be on the increase within the study period of 2002-2010 with an average efficiency index ranging between 66% and 86% for all the countries examined. It is also revealed that large banks are more efficient than smaller ones. More recently, Otero *et al.* (2019) explore the efficiency of the banking sector in MENA countries between 2005 and 2012, and find that cost efficiency among commercial banks in MENA countries improved from 70% in 2005 to 76% in 2012. The authors also observe a positive relationship between bank size and cost efficiency for all the banks examined.

The aforementioned studies conclude that larger banks record better and higher cost efficiency score and thus enjoy the benefit of economies of scale as propounded by the microeconomic theorists. However, a strand of studies has documented an inverse relationship between bank size and cost efficiency in the literature (Stanek, 2015; Banya & Biekpe, 2018; Ding & Sickles, 2018; Hadhek, Frifita & Hmida, 2018). These studies confirm that there is gross inefficiency with larger banks due to lack of coordination, complex management and huge overhead expenses. For instance, Drake and Hall (2003) conclude that technical efficiency deteriorates as size increases. Ncube (2009) analyses the cost efficiency and profit efficiency among South African banks between 2000 and 2005, and reveals that bank efficiency declines with increasing size. In a recent study conducted by Adusei (2016), the determinants of bank technical efficiency of rural and community banks in Ghana are investigated using the DEA method, and only 20 rural and community banks out of 101 banks examined are found to be technically efficient. It is thus concluded that technical efficiency deteriorates with increase in bank size. Also, Banya and Biekpe (2018) analyse bank efficiency and its determinants among 10 African countries between 2008 and 2012. Major findings from the study reveal an improvement in cost efficiency in all the countries investigated, with Botswana, South Africa and Tanzania having an average efficiency of 72%, 67% and 66% respectively. Yet another group of studies suggests that bank size has no impact on cost efficiency (Girardone *et al.*, 2004; Stuab *et al.*, 2010; Adjei-Frimpong *et al*., 2014; Fernando & Nimal, 2014; Stanek, 2015; Dharmendr & Bashir, 2015).

In Nigeria, Nyong (2017) analyses the efficiency of Nigerian banks between 2001 and 2009 using DEA and finds an increase in technical efficiency from 64% in 2001 to 66% in 2009. Using a similar approach and extending the study period, Fagge (2019) examines the technical, allocative and cost efficiency of banks in Nigeria between 2010 and 2017. In line with the findings of Nyong (2017), the author notes an improvement in technical efficiency from 72.6% in 2010 to 81.8% in 2017. To the best of the knowledge of the authors of this paper, the few studies that examine the cost efficiency of Nigerian banks within the SFA framework include Idialu and Yumere (2010) which focuses on the pre-consolidation period, Bolarinwa, Obembe and Olaniyi (2019), and Bolarinwa and Adegboye (2020). However, none of these studies examine the size-efficiency nexus of commercial banks in Nigeria. Besides, these studies fail to test for cross-sectional dependence among the banks examined. This current study stands out from previous works on commercial banks in Nigeria by analysing the cost efficiency of 15 commercial banks, using the parametric SFA technique on data from the selected Nigerian banks in the post-consolidation period stretching from 2006 to 2018. The paper also fills a major lacuna in the literature by accounting for cross-sectional dependence in the nexus between bank size and cost efficiency.

Methodology

Theoretical model

In microeconomic theory, a cost function describes the relationship between cost and its determinants, which include prices of the inputs and output level. Hence, the cost function can be modelled as a function of input prices and output level. This study adopts the stochastic frontier analysis proposed by Aigner *et al.* (1977) in modelling the evolution of cost efficiency of commercial banks in Nigeria.

Following the work of Aigner *et al.* (1977), the stochastic cost frontier is specified as:

$$y_{it} = x_{it}^{/}\beta + \varepsilon_{it}; \quad i = 1,..., N, \; t = 1,..., T \tag{1}$$

Where $\varepsilon_{it} = v_{it} + u_i$ (2)

From equation (1), y_i represents the logarithm of cost of the ith bank, x_i is vector of the independent variables which are the inputs and quantities produced, and β is the vector of unknown parameters associated with output and input variables, while ε_{it} is the composite error term. As presented in equation (2), the ε_{it} is decomposed into the measurement error (v_{it}) and the inefficiency term (u_i). In econometric term, it is assumed that both (u_i) and (v_{it}) are independently and identically distributed across observations. In the SFA literature, the distribution assumption and identification of the inefficiency term (u_i) is important as these will guide in the use of the appropriate technique to estimate the cost frontier model. It must be acknowledged that different distribution assumptions have been advanced in the literature for the inefficiency component, and these include half-normal distribution (Aigner *et al.,* 1977), exponential distribution (Meeusen & Van den Broeck, 1977), truncated normal distribution (Stevenson, 1980) and gamma distribution (Green, 1980).

In linear form, equation (1) can be re-presented as:

$$\ln y_{it} = \delta_0 + \beta \ln x_{it} + v_{it} + u_i \tag{3}$$

In exponential form and following Bolarinwa *et al.* (2019), equation (3) can be rewritten as:

$$y_{it} = \exp(\; \delta_0 + \beta \ln x_{it} + v_{it} + u_i) \tag{4}$$

Alternatively, the right hand side of equation (4) can be decomposed into two parts as presented below:

$$y_{it} = \exp(\delta_0 + \beta \ln x_{it}) \text{ x } \exp(v_{it}) \exp(u_i) \tag{5}$$

The idea behind the estimation of SFA is to compare the observed total cost of a particular bank to the cost-efficient frontier—the best practice cost frontier (Manlagnit, 2010). Hence, the overall cost efficiency of the ith bank in the tth year of observation is derived as the ratio of cost-efficient frontier to the bank's actual observed cost as presented below:

$$CE_{It} = \frac{\exp(x^{/}\beta + v_{it})}{y_{it}} = \frac{\exp(x^{/}\beta + v_{it})}{\exp(x^{/}\beta + v_{it} + u_{it})}^{/} = \exp(-u_{it}) \tag{6}$$

From the representation in equation (6), it can be inferred that cost efficiency ranges between zero (0) and 1 ($0 \leq CE_i \leq 1$). If the cost efficiency score for a bank is 1, it implies that the bank is fully efficient; if otherwise, the actual cost for the bank exceeds the minimum cost. Therefore, the closer a bank's efficiency score is to 1, the more efficient the bank is, and vice-versa.

Determination of input and output variables

One major source of controversy among existing studies is how to identify the inputs and outputs of a typical bank. The bone of contention in the literature is whether the deposit should be treated as input or output. This has led to two major approaches in the empirical literature, namely: the intermediation and production approaches. The intermediation approach suggests that bank deposit should be treated as an input. Adherents of this idea perceive banks as financial intermediaries engaging in the conversion of inputs, such as deposit, labour and capital, to generate outputs in form of loans and other interest-earning assets (Sealey & Lindley, 1997). The production approach, on the other hand, conceives deposit as an output variable. Proponents of this approach define banks activity as the production of services that involve the use of inputs, such as labour and capital to produce deposits and loans. Following the studies of Favero and

Papi (1995) and Omar *et al.* (2006), this study adopts the intermediation approach to bank activities, and hence, treats deposit as input in the production process. Three inputs and one output are identified to generate the efficiency score. The outputs are loans and advances, while price of fund, price of labour and price of capital constitute the input variables. Information on inputs and outputs employed in the study is provided in Table 1.

Table 1:Output and input Variables

Variables	Description	Measurement
Dependent	Total cost	The sume of finance expenses and operating expenses
Independent Variables		
Output	Total loan and advances	Loan and advances to customers
Input-1	Price of labour	The ratio of personnel expenses to total asset
Input -2	Price of funds	The ratio of interest expenses to total deposit
Input-3	Price of capital	The ratio of non - interest expenses to the fixed asset.

Note: non –interest expenses is total expenses minus interest expenses minus personnel expenses
Source: Authors' compilations.

Model Estimation

Total cost function

In the literature, cost function can be presented in different forms. However, the most widely accepted approach is the transcedential logarithm function often called the translog cost function. Drawing from empirical studies such as Manlagnit (2011) and Anwar (2018), this study adopts the translog cost function due to its flexibility in estimating the frontier function (see Berger & Mester, 1997; Manlagnit, 2011). The translog cost function expresses total cost as a function of output and input prices. As presented above, the study employs one output—loans and advances to customers—and three inputs—price of labour, price of capital and price of funds. The adopted translog cost function is presented below:

$$\ln TC_i = \alpha + \sum_{k=1}^{k} \beta \ln w_{ik} + \frac{1}{2}\sum_{k=1}^{k}\sum_{l=1}^{k} \delta_{kl} \ln w_{ik} w_{il} + \sum_{m=1}^{m} \gamma \ln q_{im} + \frac{1}{2}\sum_{m=1}^{m}\sum_{r=1}^{m} \phi_{mr} \ln q_{im} \ln q_{ir} + \sum_{m=1}^{m}\sum_{k=1}^{k} \lambda_{mk} \ln q_{im} \ln w_{ik} + v_i + u_i \qquad (7)$$

Where TC is total cost of bank i, w is input prices and q is output. As defined earlier, v and u are idiosyncracy error term and inefficiency term respectively. In line with Manlagnit (2011), the price of funds is used to normalise the total cost and other input prices to impose linear homogeneity into the model.

Modelling size-efficiency nexus

As documented by Ariff and Can (2008) and Adjei-Frimpong *et al*. (2014), some well-known bank-specific factors influencing cost efficiency are bank size, profitability, capitalization, loan to asset and loan to total asset, while inflation and gross domestic products are incorporated in the model to capture the effect of the Nigerian macroeconomic environment on bank efficiency. This study follows the model of Adjei-Frimpong *et al.* (2014) with little modification to determine the impact of bank size on efficiency in Nigeria. Hence, the following model is specified:

$$CE_{it} = \alpha_1 + \alpha_2 ASSET_{it} + \alpha_3 ROA_{it} + \alpha_4 CAR_{it} + \alpha_5 LTA_{it} + \alpha_6 LDR_{it} + \alpha_7 OPEXTA_{it} + \alpha_8 GDPGR_{it} + \alpha_9 INF_t + \mu_{it} \qquad (8)$$

Where CE_{it} is the cost efficiency for the bank i at time t generated from the SFA model, $ASSET_{it}$ is bank size proxied with the natural log of total assets, ROA_{it} is return on assets, and is a measure of bank profitability. CAR_{it} is capital adequacy ratio and a measure of capitalization ratio defined as a ratio of total shareholders' equity to total assets, while LTA_{it} represents loan to total asset and this represents a measure of credit risk. LDR_{it} is the ratio of loan to total deposit which is regarded as a measure of liquidity risk, $OPEXTA_{it}$ represents operating expenses as a percentage of total asset, INF_{it} is inflation rate to capture the level uncertainty in the economy, while $GDPGR_{it}$ is GDP growth as a proxy for the level of economic activity in Nigeria and μ_{it} captures the error term.

In terms of apriori expectation, the estimate of asset (α_2) can be positive or negative, depending on whether an increase in bank size enhances or reduces bank efficiency. Similarly, it is expected that $\alpha_3 > 0, \alpha_4 > 0, \alpha_5 < 0, \alpha_6 > 0$ because an increase in return on assets suggests that the bank is efficient in its operation. It is likewise expected that $\alpha_7 < 0$ based on the fact that an increase in operating expenses will increase the cost of production and thus reduce efficiency. On the magnitude of the macroeconomic variables, α_8 is expected to be positive because an increase in GDP is expected to enhance efficiency, while α_9 is expected to be negative since a rise in the general price would lead to an increase in the cost of production which might erode bank efficiency.

Estimation technique

As presented above, the study employs the SFA to generate the efficiency score based on equations 1 and 2. In the second stage of the analysis, the cost efficiency obtained from the SFA is regressed on bank size, other bank-specific variables and two macroeconomic variables as presented in equation 8. Unlike previous studies on cost efficiency literature, the study tests for the presence of cross-sectional dependence in the model. The outcomes of the test validate a strong evidence of cross-sectional dependence in the panel model. Having established cross-sectional dependence among the banks in the panel, the usage of conventional panel estimation techniques such as the pooled ordinary least squares (OLS), and fixed and random effects will produce consistent but inefficient estimates as these methods fail to account for cross-sectional dependence in the panel framework (Hoechle, 2007). Besides, the standard error of the estimates provided by such conventional approaches are biased (Hoyos & Sarafidis, 2006).

A superior approach is to employ the technique proposed by Driscoll and Kraay (1998), known as the robust standard error for panel models with cross-sectional dependence. To estimate the model, this study uses the xtscc command proposed by Hoechle (2007) which produces the Driscoll and Kraay (1998) standard error for panel models. It has been argued that the xtscc command performs well with both balanced and unbalanced panels (Le & Tran-Nam, 2018; Le, Le & Taghizadeh-Hesary, 2020). To ensure the robustness of the estimates, the study also employs dynamic system generalised method of moments (GMM) technique based on its potency to address the endogeneity problem inherent in the model. Lastly, to account for the effect of different bank sizes on cost efficiency, the study estimates four different models, one of which is for all the banks, while the remaining three models estimate the size-efficiency nexus for large, medium and small bank categories in this study.

Data and sources

As noted in the first section, there were 25 banks in Nigeria after the consolidation exercise of 2005. However, as of December 2018, only 16 of those banks were in operation, while the remaining 9 had either been merged, nationalised, acquired or taken over by another bank. Hence, the sample for this study comprises of 15 commercial banks in Nigeria over the study period, 2006-2018. The selected banks accounted for more than 95% of the sector's total assets as at 2018. In addition, all the selected banks have consistently maintained and retained their names within the study period. Data for the analysis are obtained from the selected banks' financial statements from 2006 to 2018. Similarly, data on macroeconomic variables such as inflation and GDP growth rate are sourced from the World Bank Indicators (WDI) 2018 edition. Using average total assets within the study period, the 15 banks are grouped into three categories—small, middle and large banks. The grouping also conforms to the Central Bank of Nigeria's classification of commercial banks. 7 banks are classified as large, 5 banks as medium, and 3 as small based on their total asset. Table A1 in the Appendix provides information on the banks in the sample based on their size, while the descriptions and measurement of variables are provided in Table A2 in the Appendix. All the variables are in their logarithmic forms.

Results and discussion of findings

The first step in any econometric analysis is to examine the characteristics of the variables in the study. To do this, the mean, median, minimum and maximum values, as well as the standard deviations are examined.

Table 2: Summary of Descriptive Statistics

	CE	ASSET	ROA	CAR	LDR	OPEXTA	LTA	GDPGR	INF
Mean	77.940	1.320	2.145	9.155	62.084	5.948	11.027	4.75	11.027
Median	84.426	0.851	1.825	14.388	58.121	5.191	11.538	6.059	11.538
Max	95.540	11.400	50.065	290.057	624.928	48.406	16.523	8.037	16.524
Min	10.157	0.011	-43.841	-1547.5	1.838	1.61	5.382	-1.617	5.382
Std. Dev.	0.147	1.52	5.963	115.924	45.679	4.756	3.061	2.858	3.062
Obs	195	195	195	195	195	195	195	195	195

Note: All the variables are in percentage (%) except Asset whick is measured in N'billion
Source: Authors' Computation

Table 2 presents the synopsis of descriptive statistics. A quick look at the result shows an average cost efficiency score of 78% for the entire banks indicating that cost efficiency of the banks is above average. Further revelation from Table 2 shows that average total assets between 2006 and 2018 for the entire banks is ₦1.320 trillion while the average return on asset is 2.15% over the study period. The average loan to deposit ratio is 62.08% suggesting that more than half of customers' deposit is given out as loan to customers by the Nigerian banks. Since loan to deposit ratio (LDR) is taken as a measure of bank's liquidity, the LDR ratio of 62.08% indicates that commercial banks in Nigeria are exposed to liquidity problem should there be any unforeseen fund requirement. On the macroeconomic variables, the economy records an average growth of 4.75% compared with the mean inflation rate of 11%. This implies that the economy experiences an impressive performance within the study period albeit with rising inflation. Generally, further evidence from Table 2 reveals that all the variables except CAR show a high degree of consistency as the values of mean and median are very close. Also, the values of mean and median lie within the minimum and maximum values.

Correlation analysis

To prevent multicollinearity among the explanatory variables, the study uses the threshold of 0.7 proposed by Kennedy (2008) as benchmark.

Table 3:Correlation

VAR	ASSET	ROA	CAR	LDR	OPEXTA	LTA	GDPGR	INF
ASSET	1.000							
ROA	-0.313	1.000						
CAR	-0.461	0.458	1.000					
LDR	0.333	-0.167	-0.021	1.000				
OPEXTA	-0.356	0.163	0.447	0.042	1.000			
LTA	-0.013	0.053	0.407	0.645	0.523	1.000		
GDPGR	-0.376	0.183	0.171	-0.194	0.041	-0.121	1.000	
INF	0.307	-0.057	0.004	0.199	0.003	0.127	-0.499	1.000

Source: Authors' Computation

Table 3 displays the output of the correlation analysis. Insight from the table reveals that the level of association among the explanatory variables is moderate. Hence, the results of correlation analysis suggest no evidence of multicollinearity among the variables of interest since there is no correlation coefficient that is above the threshold value of 0.7.

Analysing the cost efficiency of the Nigerian commercial banks

The cost efficiency of all the banks (full sample) and across different categories (sub-samples) is presented in Table 4. The cost efficiency of all the banks rose from 74% in 2006 to 83% in 2009. The improved efficiency within these periods might be directly credited to the 2005 consolidation exercise witnessed in the sector.

Table 4:Average Efficiency Scores from SFA

Size/Year	Small	Medium	Big	All
2006	0.855	0.717	0.713	0.743
2007	0.779	0.768	0.69	0.734
2008	0.656	0.813	0.746	0.75
2009	0.862	0.802	0.842	0.833
2010	0.802	0.788	0.858	0.823
2011	0.561	0.756	0.825	0.749
2012	0.828	0.754	0.767	0.775
2013	0.813	0.757	0.797	0.787
2014	0.867	0.838	0.843	0.846
2015	0.868	0.825	0.826	0.834
2016	0.904	0.751	0.836	0.821
2017	0.61	0.844	0.787	0.77
2018	0.716	0.697	0.617	0.664
Average	0.779	0.778	0.781	0.779

Source: Authors' Computation

This suggests that increase in the capital base of the banking sector improves their cost efficiency. Additionally, this impressive performance may be associated with the consistent increase in economic growth experienced between 2006 and 2009. For example, the economy grew from 6.06% in 2006 to 8.03% in 2009. However, there is a marginal decline in cost efficiency score of all the banks from 83% in 2009 to 66% in 2018. Again, the decline in the cost efficiency score can be linked to the economic turbulence recorded in the country over the period. Between 2009 and 2018, Nigeria experienced a persistent fall in growth rate, while the inflation rate remained double digits. A major implication of double-digit inflation rate is the increase in the cost of production with adverse effect on cost efficiency of commercial banks. In fact, following the collapse of oil price at the world oil market in 2014, the Nigerian economy entered into a recession with an average growth rate of -1.6% and inflation rate of 15.6% in 2016. Overall, the mean efficiency score for all the banks over the sample period is 78%, which suggests that the industry as a whole is not doing badly in managing its cost of operation. Specifically, the cost efficiency score obtained implies that the sector as a whole could reduce its cost of production by approximately 22% to generate its current output. This further implies that Nigerian banks are relatively more efficient when compared with their counterparts in other African countries. For instance, Banya and Biekpe (2018) record an average efficiency score of 72% and 67% for banks in Botswana and South Africa respectively. However, the overall cost efficiency obtained in the current study is lower than that of Israel, Egypt and Tunisia which are 86%, 87% and 82% respectively (Otero *et al*., 2019).

Looking at the cost efficiency score for the three sub-samples, the trend in the efficiency score reflects that of the entire industry as the three groups experience improved performance in their cost efficiency score from 2006 to 2017. It can however be inferred from the finding that there is no significant difference in the cost efficiency score across different bank categories with an average cost efficiency score of approximately 78% for the three groups. Alternatively, the three groups could reduce their total cost with approximately 22% compared to the performance of the most efficient bank on the frontier level. In summary, the evidence obtained from the analysis reveals an improvement in the performance of the banking sector after the consolidation exercise of 2005. This suggests that the recapitalisation exercise of 2005 has significantly promoted the cost efficiency of commercial banks in Nigeria.

Unit root tests and cross sectional dependence test

In panel data analysis, several tests have been proposed in the literature to examine the stationarity properties of variables. To obtain consistent results, this study employs four different unit root tests to examine the order of integration of variables in the model. These are the Levin, Lin and Chu (LLC, 2002), Im Pesaran and Shin (IPS, 2003) and Fisher-based test using ADF and PP tests (Maddala & Wu, 1999; Choi, 2001). For all these tests, the null hypothesis is that individual series contain unit roots and are therefore not stationary. It is important to state that the LLC test assumes a common unit root process, while the IPS, PP-Fisher and ADF-Fisher assume individual unit root process. The results of these tests are presented in Table 5. It is clear from the table that the null hypothesis of unit roots is rejected for all the variables in the model by at least three tests. Hence, all the series are integrated of order zero, suggesting that the series in the model are stationary at level.

Table 5: Panel Unit Root Test Result

	LLC	IPS	ADF-Fisher	PP-Fisher	order
Variable	t-stat	w-stat	$\chi 2$	$\chi 2$	
CE	-9.760**	-2.839***	132.756***	123.845***	I(0)
	(0.011)	(0.000)	(0.004)	(0.000)	
ASSET	-3.604***	-0.622	41.742*	99.859***	I(0)
	(0.000)	(0.267)	(0.075)	(0.000)	
ROA	-1.836**	-2.380***	43.566***	95.708***	I(0)
	(0.033)	(0.009)	(0.009)	(0.000)	
CAR	-12.865***	-4.984***	87.899***	83.397***	I(0)
	(0.000)	(0.000)	(0.000)	(0.000)	
LDR	-4.082***	-3.624***	66.236***	76.331***	I(0)
	(0.000)	(0.000)	(0.000)	(0.000)	
OPEXTA	-0.495	-1.917**	48.217**	128.153***	I(0)
	(0.310)	(0.028)	(0.019)	(0.000)	
LTA	-4.808***	-2.334**	56.754***	83.909***	I(0)
	(0.000)	(0.010)	(0.002)	(0.000)	
GDPGR	-9.745***	-4.964***	72.724***	84.376***	I(0)
	(0.000)	(0.000)	(0.000)	(0.000)	
INF	-4.729***	-2.847***	48.060**	46.441**	I(0)
	(0.000)	(0.002)	(0.020)	(0.028)	

*Notes: ***, ** and * denoted 1%, 5% and 10% level of significance respectively*
Values in parenthesis are probability values.
Source: Authors' Computation

One major weakness of the first-generation unit root tests is that they assume that disturbances in the panel are independent of one another; that is, the units are cross-sectionally independent. However, this assumption may not hold for the banking sector where there is increasing evidence of interdependence due to the nature of the market where the banks operate. For instance, commercial banks in Nigeria interact through the inter-bank window, and as such, the decision of a unit will automatically impact on the behaviour of others. Besides, all the banks in the industry are exposed to common shocks and this buttresses the fact that the assumption of independence is unrealistic. Therefore, any attempt to assume away this interdependent relationship might produce misleading results. Based on this, cross-sectional dependence (CD) tests are conducted for the sampled banks using three different CD tests as proposed by Friedman (1937), Frees (1995) and Pesaran (2004). The null hypothesis of the CD tests is that the residuals are cross-sectionally uncorrelated (Hoyos & Sarafidis, 2006; Hoechle, 2007). Table 6 presents the outcome of the CD tests.

Table 6: Cross Sectional Dependence Test

	CD tests	Prob
Frees	0.637*	0.000
Friedman	43.481*	0.000
Pesaran	4.551*	0.000

*Notes: * denotes 1% level of significance*
Source: Authors' Computation

Based on the results in Table 6, there is a strong evidence to reject the null hypothesis of no cross-sectional dependence among the sampled banks. The results are consistent across the three CD tests employed.

Table 7: Cross-Sectional Dependence Unit Root Test

Variable	CIPS Test	Order
CE	-3.070***	I(0)
ASSET	-2.500**	I(0)
ROA	-3.688***	I(0)
CAR	-3.770***	I(0)
LDR	-2.376**	I(0)
OPEXTA	-3.337***	I(0)
LTA	-2.781***	I(0)

*Note: ***,** denote 1% and 5% level of significance respectively*

Critical Values: 1%= -2.520, 5% = -2.280, 10% = -2.160

Source: Authors' computation

Having confirmed that the sampled banks are cross-sectionally dependent, it is important to employ the unit root test and estimation techniques that account for cross-sectional dependence in order to obtain consistent and reliable estimates. To do this, the study employs a second-generation unit root test known as the cross-sectionally augmented Im, Pesaran and Shin (CIPS) test introduced by Pesaran (2007). The test is used in heterogeneous panels with cross-sectional dependence. One major advantage of the CIPS unit root test is its ability to account for cross-sectional dependence inherent among the units in the panel model. The outcome of the CIPS test is presented in Table 7. Looking at the outcome of the CIPS test, it can be observed that all the series are stationary at level, thus confirming the outcome of the first-generation unit root tests in Table 5.

Effcet of bank size on cost efficiency

The presence of cross-sectional dependence in the model precludes the use of the conventional Hausman test to choose between the generalised least squares (GLS) random and fixed effects models with Driscoll and Kraay (1998) robust standard errors. To account for cross-sectional dependence, the study applies the robust Hausman test for fixed effects proposed by Wooldridge (2002) and Hoechle (2007) using the xtscc command in Stata. The approach provides a consistent way to decide between the results of the fixed (within) effects and GLS random effects regressions with Driscoll and Kraay standard errors estimations. The results of the robust Hausman test is contained in Table 8. The probability value of 0.000 reported shows that the null hypothesis that the random effect (RE) model is preferred is rejected. The alternative hypothesis that the fixed effects (FE) model is more appropriate than the random effects model is thus accepted in the study. However, for comparison, the study estimates both the fixed and GLS random effects regressions proposed by Driscoll and Kraay (1998). The results from the two estimators for the whole sample size and the three groups are presented in Table 8.

Table 8: Estimation Results: Discroll and Kraay Standard Errors

Dependent Variable: Cost Efficiency

	Fixed Effects (Within) regression				GLS Random Effects regression			
	Full	Big	Medium	Small	Full	Big	Medium	Small
Lasset	-0.0143	-0.0373***	-0.00837	0.0251	-0.0236	-0.0215**	-0.0463***	0.00887
	(0.0276)	(0.00753)	(0.0126)	(0.0495)	(0.0206)	(0.00883)	(0.0127)	(0.0597)
Roa	0.0800	-0.530*	-0.580	0.439	0.00667	-1.154**	-0.453	0.468
	(0.118)	(0.273)	(0.430)	(0.249)	(0.146)	(0.416)	(0.602)	(0.264)
Car	0.0264***	-0.220**	0.104	0.0270**	0.0278***	-0.221	-0.000996	0.0212*
	(0.00390)	(0.0906)	(0.136)	(0.00912)	(0.00355)	(0.184)	(0.127)	(0.00974)
Ldr	0.0859**	0.0375***	0.308*	-0.0627	0.0847*	0.0306***	0.409**	-0.0622
	(0.0363)	(0.00506)	(0.156)	(0.197)	(0.0449)	(0.00358)	(0.161)	(0.325)
Opexta	-1.675**	-1.871***	-1.435	1.569	-1.617**	-0.914	-0.736	-0.930
	(0.745)	(0.592)	(1.564)	(1.094)	(0.671)	(0.628)	(1.173)	(1.048)
Lta	0.217***	0.999***	0.130	1.156**	0.210***	0.956***	0.0711	0.927
	(0.0418)	(0.0911)	(0.112)	(0.396)	(0.0416)	(0.101)	(0.0739)	(0.541)
Gdpgr	0.00784	0.00502*	0.0101**	-0.00384	0.00636	0.00599**	0.00581	0.00608
	(0.00507)	(0.00241)	(0.00412)	(0.00851)	(0.00490)	(0.00226)	(0.00378)	(0.0112)
Inf	0.00196	0.00210	-0.00229	0.00184	0.00225	0.00144	-0.00232	0.00484
	(0.00442)	(0.00176)	(0.00263)	(0.00253)	(0.00494)	(0.00158)	(0.00428)	(0.00303)
Constant	0.963	1.212***	0.775**	-0.165	1.160**	0.871***	1.504***	0.301
	(0.594)	(0.157)	(0.262)	(0.975)	(0.434)	(0.162)	(0.267)	(1.132)
F-Stat	86.00	546.00	34.00	632.30	4855.oo	13204.00	428.65	7677.00
Prob (F stat)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hausman test	44.220							
Prob (Hausman test)	0.000							
Observations	195	91	65	39	195	91	65	39
Number of groups	15	7	5	3	15	7	5	3

Standard errors in parentheses

**** p<0.01, ** p<0.05, * p<0.1*

Source: Authors' computation

Starting with the entire sample, after accounting for cross-sectional dependence in the model, the results of both the FE and GLS models are consistent for all the parameters. Considering the variable of interest which is the bank size (proxied with log of total assets), the results from the two estimators suggest that bank size is not statistically significant and is negatively related to cost efficiency. This can be interpreted to mean that smaller banks are more efficient than big banks, and confirms the previous studies by Ding and Sickles (2018) and Hadhek, Frifita and Hmida (2018). However, the effect of bank size on cost efficiency is not significant, which implies that the size of the bank does not influence cost efficiency in the banking sector. This again confirms the earlier findings under the analysis of cost efficiency where the cost efficiency scores across the bank sizes are approximately the same over the years. The finding conforms with that of Banya and Biekpe (2018) for Ghanaian banks, and negates those of Eriki and Osifo (2015) for Nigeria, Anwar

(2018) for Indonesia and Otero *et al*. (2020) for MENA countries, all of which imply that bank size promotes cost efficiency. A plausible reason for divergent findings may be the failure of earlier studies to consider cross-sectional dependence in their analyses. The implication of the finding is that for the effect of bank size on cost efficiency to be adequately explored and understood, there is a need to account for cross-sectional dependence among the banks. This is based on the fact that the entire sector is subject to common shocks, indicating that the behaviour of one bank significantly influences the decisions of other banks in the industry.

Considering the results from the three groups, the FE and GLS regressions also produce the same outcomes with that of the entire sample, except that the effect of bank size on cost efficiency is significant for the large banks in both models and for the medium banks in the GLS model. This suggests that the effect of bank size on cost efficiency is negative and significant for large and medium banks. Under the FE model, for the large banks, a 1% increase in total assets (size) reduces the cost efficiency by 0.03%, while a 1% increase in bank size deteriorates the cost efficiency of large and medium size banks by 0.02% and 0.05% respectively under the GLS model. This indicates that smaller banks achieve better cost efficiency. However, for small banks, the effect of bank size on cost efficiency is positive but not significant under the two estimators. This finding is similar to those of Banya and Biekpe (2018) for Ghanaian banks, Almanidis *et al.* (2019) for US commercial banks, Goswani *et al.* (2019) for Indian banks, and Sultana and Rahman (2020) for Bangladesh banks. In addition, the finding agrees with the conclusion of Okorie and Agu (2015) that bank size does determine cost efficiency among commercial banks in Nigeria.

Looking at other variables in the model, for the full sample, the magnitude of return on assets (ROA) (a measure profitability) is positive but not significant in the two models, which suggests that the effect of profitability on cost efficiency is inconsequential. Therefore, the ROA is not a driver of cost efficiency in Nigeria. This outcome is in conformity with the study by Oredegbe (2020) for Canadian banks. A similar result is obtained for small banks in the two estimators. This suggests that the effect of profitability on cost efficiency is not material. Conversely, the estimate of ROA is negative and significant for the big banks under the two models, while its impact is negative but not significant on the cost efficiency of medium banks. This suggests that the effect of profitability on cost efficiency is not material, although the results are in conflict with apriori expectation as higher profit is expected to improve cost efficiency. One possible explanation for this may be that the banks, in their attempt to generate more profit, incur huge overhead expenses which in turn erodes their cost efficiency.

The coefficient of capital adequacy ratio (CAR), a measure of capitalisation, is positive and significant for all the banks under the two estimators. This suggests that higher capitalisation enhances cost efficiency in Nigeria. This implies that overall, the recapitalisation exercise of 2005 positively influenced the cost efficiency of Nigerian commercial banks, indicating that well-capitalised banks are cost-efficient. The result is consistent for the small banks where a positive and significant relationship between capitalisation ratio and cost efficiency is obtained under the preferred fixed effects regression. Hence, capitalisation rate is a key determinant of cost efficiency over the study period. However, considering the outcomes from other categories, the result from Table 8 suggests that the effect of capitalisation ratio on the cost efficiency of the big banks is negative and significant, while its impact on the cost efficiency of medium banks is inconsequential. Meanwhile, the ability of the banks to convert deposit to loan is measured by the loan-deposit ratio (LDR), which measures the liquidity position of banks at any given time. The results from the two estimators are consistent for all the banks and across different bank sizes. It is apparent from Table 8 that the effects of LDR on cost efficiency is positive and significant for all the banks as well as the big and medium banks. Since loan creation is a major intermediation role of deposit money banks, it implies that the more commercial banks create loans, the higher the profitability, and this in turn enhances the cost efficiency. This finding is in agreement with those of Anwar (2018) for Indonesia and Oredegbe (2020) for the Canadian banking industry. However, the reverse is the case for small banks under the two models. The effect of loan-to-deposit ratio on cost efficiency is negative and not statistically significant for the small banks. This suggests that they failed to manage their loan portfolio in a way that improves their cost efficiency compared to their big and medium counterparts. This might be due to increase in the cost of funds of smaller banks which in turn leads to increase in interest rate charged on loans by the smaller banks. Eventually, higher interest rate on loan might lead to increase in their nonperforming loan which might consequently deteriorate their cost efficiency.

For other variables, the results from the two estimators suggest that operating expenses as a ratio of total asset (OPEXTA) has a negative and significant impact on cost efficiency for all the banks and the big banks category. This result is in tandem with apriori expectation as reduction in operating expenses is expected to raise profit which will, in turn, promote the banking sector's cost efficiency. In addition, the results show that the effect of loan to total asset on cost efficiency is positive and significant for all the banks under the two models. This is expected as increase in loan portfolio may suggest an indication of higher interest income to the banks which will consequently increase the bank profitability, and hence, improve their cost efficiency. Furthermore, the findings from Table 8 reveal that the effect of GDP growth on cost efficiency is positive but not significant when all the banks are examined. However, for the big and medium-sized banks under the FE model, the outcomes reveal that GDP growth has a significant and positive effect on cost efficiency. The result is consistent for the two estimators. This implies that the level of economic activity proxied with economic growth is a major determinant of cost efficiency among the big banks in Nigeria. This is not surprising as people tend to have confidence in the banking sector when the economy is experiencing growth, unlike in the case of economic recession. The finding is in tandem with those of Anwar (2018) and Djalilov and Piese (2019) for transition economies. However, for the small banks, the results under the FE model show that the effect of GDP growth on cost efficiency is negative and not significant. This implies that the improvement in economic activity negatively affects cost efficiency of the small-sized banks, and conforms to the findings of Chan and Karim (2010) for North African banks and Adjei-Frimpong *et a*l. (2014) for Ghanaian commercial banks. Additional evidence from Table 8 reveals that the effect of inflation is not significant on cost efficiency for all the models estimated.

Overall, one major inference from the analysis is that when bank size is controlled for, cost efficiency behaves and responds differently across the three classifications. This further implies that any analysis on the size-cost efficiency nexus among Nigerian commercial banks must take into consideration different classifications of banks as revealed in this study.

Robustness test

Given the fact that the Driscoll and Kraay standard errors presented and discussed above are static models and only control for cross-sectional dependence in the model, this study also employs the dynamic system GMM technique to ensure the robustness of the results to different methodologies. This is vital to validate the findings of the size-cost efficiency nexus from the Driscoll and Kraay (1998) robust standard errors. The use of GMM is crucial to address and correct the perceived endogeneity issue in the model. This is based on the fact that it is possible for one of the independent variables—for instance, profitability ratio—to be influenced by cost efficiency, as observed by Bolarinwa *et al.* (2019). This suggests that profitability ratio and other independent variables in equation 8 cannot be treated as strictly exogenous. Hence, there is a need to employ an estimation technique that is robust to reverse causality and endogeneity issues in the model. However, to satisfy the condition that the number of cross-sectional units (N) must be greater than the number of time series observation (T) in GMM estimations, only the GMM results for the entire sample are presented. The outcomes of the system GMM estimation are presented in Table 9.

Table 9: Robustness Test: GMM Results

Dep. Variable: Cost Efficiency	
CE(-1)	0.185
	(0.212)
Lasset	-0.0241
	(0.0286)
Roa	-1.161*
	(0.645)
Car	0.244***
	(0.0760)
Ldr	-0.146
	(0.196)
Opexta	-3.276
	(2.633)
Lta	1.115***
	(0.409)
Gdpgr	0.00769***
	(0.00244)
Inf	0.000406
	(0.00211)
Constant	0.907
	(0.676)
AR(1) test (p-value)	0.176
AR(2) test (p-value)	0.187
Sargan test (p-Value)	0.477
Observations	180
Number of c_id	15

Standard errors in parentheses

**** p<0.01, ** p<0.05, * p<0.1*

Source: Authors' computation

As a preliminary check, the probability value of the Sargan test for the overidentifying restriction confirms the validity and appropriateness of the chosen instruments. This is based on the acceptance of the null hypothesis that the instruments employed are not correlated with the error term since the probability value of the Sargan test (0.477) is not statistically significant. Similarly, the robustness of the GMM estimates is confirmed by the second-order autocorrelation test. The probability value of AR (2) suggests that the GMM model does not suffer from second-order autocorrelation. Hence, the estimates from the dynamic system GMM model are robust and reliable. However, evidence from Table 9 suggests that the coefficient of the lagged variable is not significant and this implies that the past value of cost efficiency has no effect on the current cost efficiency. Again, the outcomes of the dynamic GMM model validates the findings from the Driscoll and Kraay standard errors estimation presented in Table 8. The results of the GMM regression confirm the earlier finding on the focal variable, implying that bank size has no significant impact on the cost efficiency of the sampled banks over the study period. The results obtained are thus robust and reliable, even when different methodologies are employed.

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Conclusion

This study analyses the cost efficiency of Nigerian commercial banks and investigates the effect of bank size on cost efficiency in Nigeria in the post-consolidation era of 2006-2015, focusing on 15 commercial banks that accounted for more than 95% of the sector's total assets as at 2018. The parametric stochastic frontier analysis is employed to obtain the cost efficiency scores of the sampled banks, and then the effect of bank size on cost efficiency is examined. Unlike previous studies on the size-efficiency nexus, this paper accounts for cross-sectional dependence among the units by employing the Driscoll and Kraay (1998) fixed effects estimator with robust standard errors, while the dynamic system GMM technique is adopted to serve as robustness check on the parameter estimates and control for endogeneity in the panel model.

Findings from the study reveal that the bank consolidation exercise of 2005 has improved cost efficiency of the banking sector with an above average cost efficiency score during the post-consolidation period examined. Specifically, the study obtains a mean cost efficiency score of 78% for the banking industry as a whole, indicating that the industry can still achieve its current level of output with a 22% cost reduction. Comparatively, there is no noticeable difference in the efficiency score across different bank sizes. Based on the outcome of the robust Hausman test, the fixed effects model estimated with the Driscoll and Kraay (1998) robust standard errors is preferred over the GLS random effects model. Findings from Driscoll and Kraay estimations show that for all the banks, the impact of bank size on cost efficiency is immaterial, and this aligns with the SFA outcome as there is no significant difference in cost efficiency across different bank sizes. This suggests that larger banks in Nigeria have no cost advantage over their smaller counterparts. The result is consistent across different estimation techniques. On other bank-specific variables, the outcomes from the robust standard errors estimation reveal that loan-to-deposit ratio, operating expenses as a percentage of total assets, loan to total asset and capitalisation ratio are major determinants of cost efficiency in Nigeria. However, the effects of return on assets, GDP growth and inflation on cost efficiency are inconsequential within the period of study. The study therefore concludes that increase in bank capitalisation ratio improves cost efficiency of the banking sector. However, increase in bank size does not translate to improvement in cost efficiency in Nigeria.

The findings from the study provide insights on policy directions to policymakers in the banking sector. First, bank management should place less emphasis on size by closing down the inefficient branches to reduce their operating expenses and stimulate cost efficiency. Second, more attention should be paid to the creation of quality loans as this is observed to be a key promoter of cost efficiency. Since loan-to-deposit ratio and loan to total asset are identified as major determinants of cost efficiency, bank managers should create quality assets and work more on loan recovery to reduce the portfolio of their nonperforming loans. In addition, loan monitoring and evaluation should be given utmost priority by bank managements to reduce their exposure to delinquent assets and thus improve their cost efficiency level. Third, the Central Bank of Nigeria should continue to embrace policies that increase bank capitalisation ratio in the sector to achieve greater cost efficiency. Lastly, there is need for sound macroeconomic policies that will engender a healthy macroeconomic environment and sustained economic growth in order to improve cost efficiency. In terms of limitation, this study does not unravel the sources of inefficiency in the banking sector. Future studies can thus be carried out in this regard.

References

Adesei, M. (2016). Determinants of bank technical efficiency: Evidence from rural and community banks in Ghana. *Cogent Business & Management*. 3, 1199519

Aigner, D., Lovell, C. A. L., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics.* 6(1), 21-37.

Adje-Frimpong, K., Gan, C. and Hu, B, (2014). Cost Efficiency of Ghana's Banking Industry: a Panel data analysis. *The International Journal of Business and Finance Research.* 8 (2), 69 – 86.

Alhassan AL (2015). Income Diversification and Bank Efficiency in an Emerging Market. *Manag Finance* 41(12), 1318–1335.

Almanidis, P., Karakaplan, M.U. & Kutlu, L. (2019). A dynamic stochastic frontier model with threshold effects: U.S. bank size and efficiency, *Journal of Productivity Analysis*, https://doi.org/10.1007/s11123-019-00565-6

Aremu, M. A., Ekpo, I. C. & Mustapha, M. A. (2013). Determinants of Banks' Profitability in a Developing Economy: Evidence from the Nigerian Banking Industry. Interdisciplinary. *Journal of contemporary Research in Business*. 4(9), 155- 181.

Ariff, Mohamed, & Can Luc. (2008). Cost and profit efficiency of Chinese banks: A non-parametric analysis. *China Economic Review.* 19, 260–73.

Anwar, M. (2018). Cost efficiency performance of Indonesian banks over the recovery period: A stochastic frontier analysis. *The Social Science Journal*, https://doi.org/10.1016/j.soscij.2018.08.002.

Babalola, Y. A. (2013). The Effect of Firm Size on Firms Profitability in Nigeria. *Journal of Economics and Sustainable Development*, 4 (5), 90 - 94

Banya, R. & Biekpe, N. (2017). Banking efficiency and its determinants in selected frontier African markets. *Econ Change Restruct*, DOI 10.1007/s10644-016-9200-3

Battese, G. E., & Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of Productivity Analysis*, 3, 153–169.

Berger, A.N. & Mester, L.J. (1997). Inside the black box: What explains differences in the Efficiencies of financial institutions. *Journal of Banking and Finance*. 21, 895-947.

Berger, A.N. & Humphrey, D. B. (1997). Efficiency of financial institutions: International Survey and directions for future research. *European Journal of Operational Research*. 98, 175-212.

Berger A., N, Hunter W. C. & Timme S. G. (1993) Efficiency of financial institutions: a review and preview of research, past present, and the future. *J Bank Finance* 21:895–947.

Bikker, J. A. (1999). Efficiency in the European banking industry: an Exploratory Analysis to rank countries. Research Series Supervision (discontinued) 18, Netherlands Central Bank, Directorate Supervision, 1999.

Bolarinwa, S. T & Obembe, O. B. (2017). Firm Size–Profitability Nexus: An Empirical Evidence from Nigerian Listed Financial Firms. *Global Business Review*, 20(5), 1–13

Bolarinwa, S. T., Obembe, O. B. & Olaniyi, C. (2019). Re-examining the determinants of bank profitability in Nigeria. *Journal of Economic Studies*, 46 (3), 633-651.

Bolarinwa, S. T. & Adegboye, A. A. (2020). Re-examining the determinants of capital structure in Nigeria. *Journal of Economic and Administrative Sciences*. DOI 10.1108/JEAS-06-2019-0057.

Catalbas, G. K., & Atan, M., (2005). Efficiency in Banking And The Effect Of Capital Structure Efficiency in Banks. *Journal of Economics Business and Finance. 20(237)*, 49-62.

Chan, S.G., and Karim, M. (2010) Bank Efficiency and Macroeconomic Factors: The Case of Developing Countries. *Global Economic Review, 39,* 269-289.

Chen, Y. (2001). Three Essays on Bank Efficiency. Ph.D. thesis, Drexel University.

Choi, I. (2001), Unit Root Tests for Panel Data, *Journal of International Money and Finance*, 20, 249–272.

Dharmendra, S. & Bashir, A. F (2015). Technical Efficiency and its determinants: and empirical Study on banking sector of Oman. *Problems and Perspective in Management*, 13(1-1), 168-175.

Darrat, A. T & Yousif, T. (2002). Assessing cost and technical efficiency of Banks in Kuwait. Paper presented at ERF, 8th annual conference, January, Cairo, Egypt. 2002.

De Nicolò, G., Phillip, B., Jhanara, Z., & Mary, Z. (2004). Bank Consolidation, Internationalization and Conglomeration: Trends and Implications for Financial Risk. *Financial Markets, Institutions & Instruments*. 13(4), 173-217

Ding, D., & Sickles, R.C. (2018) Frontier efficiency, capital structure, and portfolio risk: An empirical analysis of U.S. banks. *BRQ Bus. Res.Q.* ,https://doi.org/10.1016/j.brq.2018.09.002

Driscoll, J.C. and Kraay, A.C. (1998), Consistent covariance matrix estimation with spatially dependent panel data, *Review of Economics and Statistics*, 80, 549-560.

Djalilov, K. & Piesse, J. (2019). Bank regulation and efficiency: Evidence from transition countries. *International Review of Economics and Finance,* 64, 308–322

Drake, L. & Hall, M. J.B. (2003). Efficiency in Japanese Banking: An empirical analysis. *Journal of Banking and Finance*. 27, 891–917.

Eriki, P. O. & Osifo, O. (2015). Determinants of Performance Efficiency in Nigerian Banking Industry: A DEA Approach. *International Journal of Economics, Commerce and Management*. III(2), 1- 13.

Erkoc, T. E. (2012). Estimation Methodology of Economic Efficiency: Stochastic Frontier Analysis vs Data Envelopment Analysis. *International Journal of Academic Research in Economics and Management Sciences*. 1 (1), 1- 23.

Enyi, P. E. (2007). Banks consolidation in Nigeria: A synergistic harvest. Retrieved from http://eprints.convenantuniversity.edu.ng/111/1/banks-consolidation-in-Nigeria.pdf.

Fagge, A. (2019) Comparative Analysis of Technical, Allocative and Cost Efficiency of Nigerian Deposit Money Banks *Economic and Financial Review Volume 57/1, 47 - 63*

Favero, C., & Papi, L. (1995). Technical efficiency and scale efficiency in the Italian Banking sector: A nonparametric approach. *Applied Economics*, 27, 385–395.

Fenando, J. M. R. & Nimal, P. D. (2014). Does Ownership and Size Influence Bank Efficiency? Evidence from Sri Lankan Banking Sector. *Ruhuna Journal of Management and Finance*.1(1), 83 – 90.

Frees, E. W. 1995. Assessing cross-sectional correlation in panel data. *Journal of Econometrics* 69, 393-414.

Friedman, M. 1937. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *Journal of the American Statistical Association* 32, 675-701.

Girardone, C., Molyneux, P., & Gardener, E. P. (2004). Analysing the Determinants of Bank Efficiency: The Case of Italian Banks. *Applied Economics*, 36, 215-227.

Goswani, Husain and Kumar (2019). Banking Efficiency Determinants in India: A Two-stage Analysis. *The Journal of Applied Economic Research* 13 (4), 361–380.

Green, W. (2005). Efficiency of Public Spending in Developing Countries: A Stochastic Frontier Approach. Stern School of Business, New York University.

Gunes, H. & Yildrim, D. (2016). Estimating Cost Efficiency of Turkish Commercial Banks under Unobserved Heterogeneity with Stochastic Frontier Models. ERC Working Papers in Economics 16/03 March /2016.

Hadhek, Z., Frifita, M. & Hmida, A. (2018). The Determinants of Cost Efficiency of Islamic Banks using SFA Approach. *International Research Journal of Finance and Economics* 168, 33 – 47.

Halkos G. E. & Salamouris, D. S. (2004). Efficiency measurement of the Greek Commercial banks with the use of financial ratios: a data envelopment analysis approach. *Management Accounting Research*, 15(2), 201-224.

Hasan, I. & Marton, K. (2003). Development and efficiency of the banking sector in a transitional economy: Hungarian experience. *Journal of Banking and Finance*, 27, 2249-2271.

Hausman, J. A. 1978. Speci_cation tests in econometrics. *Econometrica* 46, 1251-1271.

Hoechle, D. (2007), Robust standard errors for panel regressions with cross-sectional dependence, *The Stata Journal*, yy(ii),1-31.

Hoyos, R. E. & Sarafidis, V. (2006). Testing for cross-sectional dependence in panel-data models. *The Stata Journal*, 6 (4), 482–496.

Idialu, J. U. & Yomere, G. O. (2010). Stochastic Frontier Analysis of the Efficiency of Nigerian Banks, *Indian Journal of Economics and Business*, 9(1), 75 – 86.

Im, K.S., Pesaran, M.H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53-74.

Isik, I. & Hassan, M. K. (2003). Financial Deregulation and Total Factor Productivity change: An empirical study of Turkish commercial banks. *Journal of Banking and Finance*, 27, 1455-1485.

Ismail, F., Abd Majid, M. S., & Rossazana Ab, R. (2013). Efficiency of Islamic and conventional banks in Malaysia. *Journal of Financial Reporting and Accounting*, 11(1), 92-107.

Jackson, P. M. & Fethi, M. D. (2000). Evaluating the Technical Efficiency of Turkish Commercial Banks: An Application of DEA and Tobit Analysis, University of Leicester, Mimeo.

Kamberoglou, N. C., Liapis, E., Smigiannis, G. T., & Tzamourani, P. (2004). Cost efficiency in Greek Banking. Working Paper, no 9: 1 – 25.

Kaparakis, E.I., Miller, S.M., & Noulas, A. G. (1994). Short-run cost inefficiencies of commercial banks, *Journal of Money, Credit and Banking*, 26 (4), 875- 893.

Karim, M.Z.A., Chan, S & Hassan, S. (2010). Bank Efficiency and Non-Performing Loans: Evidence from Malaysia and Singapore. Prague Economic Papers, 2 DOI: 10.18267/j.pep.367

Karray, S. C. & Chichti, J.E. (2013). Bank Size and Efficiency in Developing Countries: Intermediation Approach versus Value Added Approach and Impact of Non- Traditional Activities. *Asian Economic and Financial Review*, 3(5), 593-613.

Kashian, R., Lin, E.Y. & Xue, Y. (2019). Cost Efficiency Analysis of Local Commercial Banks in Taiwan. *Asian Economic Journal*, 33(1), 87–108.

Kennedy, P. (2008), A Guide to Econometrics, Blackwell Publishing, Oxford.

Kolapo, F.T., Ajayi, L. B. & Aluko, O.A. (2016). How is Size Related to Profitability? Post-Consolidation Evidence from Selected Banks in Nigeria. *Journal of Finance & Banking Studies* 5(4), 30-38.

Le, T.H., Tran-Nam, B. (2018). Trade liberalization, financial modernization and economic development: an empirical study of selected Asia–Pacific countries. *Res. Econ*. 72 (2), 343–355.

Le, T-H., Le, H-C. & Taghizadeh-Hesary, F. (2020). Does financial inclusion impact CO2 emissions? Evidence from Asia?. *Finance Research Letters*, 34, 1-7.

Leong, W. H. & Drollery, B. (1999). The Productive Efficiency of Singapore Banks: an Application and extension of the barr et al (1999) approach, working paper study in economics.No.9.

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, *108*(1), 1–24.

Leykun, F. (2018). How to measure banks' efficiency? Application of data envelopment approach and frontier efficiency analysis: An Overview. *Singaporean Journal of Business economics, and management Studies*, 6(9), 10 – 25

Maddala, G. and S. Wu (1999), A Comparative Study of Unit Root Tests and a New Simple Test, *Oxford Bulletin of Economics and Statistics*, 61, 631-652.

Manlagnit, M., 2011. The economic effects of foreign bank presence: Evidence from the Philippines. *Journal of International Money and Finance*, 30(2), 1180-1194

Meeusen, W. and Van den Broeck, J. (1977), Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economics Review*, 189(2), 435-446.

Ncube, M. (2009). Efficiency of the Banking Sector in South Africa. University of the Witwatersrand, South Africa. 1- 44.

Nkem, I. S. & Akujinma, A. F. (2017). Financial Innovation and Efficiency on the Banking Sub-sector: The Case of Deposit Money Banks and Selected Instruments of Electronic Banking (2006 - 2014). *Asian Journal of Economics, Business and Accounting,* 2(1), 1-12.

Nitoi, M. & Spulbar, C. (2015). An Examination of Banks' Cost Efficiency in Central and Eastern Europe. *Procedia Economics and Finance* 22, 544 – 551.

Nyong, M. O. (2017). Relative Efficiency of Commercial Banks in Nigeria: A Nonparametric Mathematical Optimization Analysis. *Noble International Journal of Economics and Financial Research,* 2(2), 27-49.

Oke, D. M. & Poloamia, I. D. (2012). Further Analysis of Bank Efficiency Correlates: The Nigerian Experience. *Journal of Applied Finance & Banking*. 2(4), 1-11.

Okorie, M. C. & Agu, D. O. (2015). Does banking sector reform buy efficiency of banking sector operations? – Evidence from recent Nigeria's banking sector reforms. *Asian Economic and Financial Review*, 5(2), 264-278.

Olaoye, O & Aderajo, O (2020) Institutions and economic growth in ECOWAS: an investigation into the hierarchy of institution hypothesis (HIH). International Journal of Social Economics. DOI 10.1108/IJSE-10-2019-0630.

Oluitan, R. O., Ashamu, S. O. & Ogunkenu, O. S. (2015). The Effect of Recapitalization on Bank Performance in Nigeria**.** *International Finance and Banking***,** 2 (1), 79-90.

Omar, M. A., Abdul Rahman, A. R. Mohd Yusuf, R., Abd. Majid, M. S & Mohd. Rasid, M. E. S. (2006), Efficiency of Commercial Banks in Malaysia, *Asian Academy of Management Journal of Accounting and Finance*, 2 (2), 19-42.

Oredegbe, A. (2020), Cost Efficiency Determinants: Evidence from the Canadian Banking Industry. *International Journal of Business and Management*, 15(1), 86 - 91

Otero, L. Rasia., A., Cunill, O. M. & Mulet-Forteza C. (2019). What determines efficiency in MENA banks? *Journal of Business Research*, https://doi.org/10.1016/j.jbusres.2019.11.002.

Owoputi J.A., Kayode, O. F. & Adeyefa, F. A. (2014). Bank Specific, Industry Specific and Macroeconomic Determinants of Bank Profitability in Nigeria. *European Scientific Journal*, 10(25), 408 – 423.

Pesaran, M. H. 2004. General diagnostic tests for cross section dependence in panels. University of Cambridge, Faculty of Economics, Cambridge Working Papers in Economics No. 0435.

Pesaran, M. H. (2007). A Simple Panel Unit Root Test In The Presence Of Cross-section Dependence." *Journal of Applied Econometrics* 22: 265–312.

Sathye, M. (2001). X-efficiency in Australian banking: An empirical investigation. *Journal of Banking and Finance*, 25, 613-630.

Sealey, C., & Lindley, J. (1977). Inputs, Outputs and a Theory of Production and Cost of Depository Financial Institutions. *Journal of Finance.* 32, 1251–1266.

Spong, K., Sullivan, R. J. & De Young, R. (1995). What makes a bank efficient?. A look at financial characteristics and bank management and ownership structure. *Financial industry perspective, FRB of Kansas City Review.* 1-19.

Stanek, R. (2015). Determinants of Bank Efficiency: Evidence from Czech Banking Sector. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, Vol. 63(3): 1005 – 1011.

Staub, R. B., Souza, G. S., & Tabak, B. M. (2010). Evolution of bank efficiency in Brazil: a DEA approach. *European Journal of Operational Research*, 202(1), 204-213

Stevenson, A. (1980), Likelihood functions for generalized stochastic frontier estimation, *Journal of Econometrics*, 13(1), 57-66.

Sufian, F. (2009). Determinants of bank efficiency during unstable macroeconomic environment: Empirical evidence from Malaysia. *Research in International Business and Finance* 23, 54–77.

Sufian, F., & Noor, M. A. N. M. (2009). The determinants of Islamic banks' efficiency changes: Empirical evidence from the MENA and Asian banking sectors. *International Journal of Islamic and Middle Eastern Finance and Management*, 2(2), 120-138.

Tan Y. (2016) Theory of Bank Efficiency and Bank Risk. In: Investigating the Performance of Chinese Banks: Efficiency and Risk Features. Palgrave Macmillan Studies in Banking and Financial Institutions. Palgrave Macmillan, London. https://doi.org/10.1057/978-1-137-49376-7_3

Usman, O. A. & Fadipe, M. (2014). An Empirical Analysis of Allocative Efficiency of Nigerian Commercial Banks: A DEA Approach. *International Journal of Economics and Financial Issues,* 4(3), 465 – 475.

Wooldridge, J.M. (2002). Econometric analysis of cross section and panel data MIT press. Cambridge, MA, 108.

Worimegbe, P. M., Oladimeji, M.S., & Eze, B. U. (2019). The Effect of Bank Efficiency on Bank Performance in Deposit Money Banks in Nigeria. *European Journal of Applied Business Management,* 5(3), 68-78.

Appendix

Table A1: Classification of banks by total asset

Total Asset	Classification	Banks
Below N500 billion	Small	Citi Bank, Unity Bank and Wema Bank.
Between N500 billion and N1 trillion	Medium	Diamond Bank, Fidelity Banks, Stanbic IBTC Bank, Sterling Bank and Union Bank
Above N1 trillion	Large	Access Bank, Eco Bank, First Bank, First City Monumental Bank, Guarantee Trust Bank, United Bank for Africa Bank and Zenith Bank

Source: Compiled by the author.

Table A2: Data and measurement of Variables

Variable	Description	Definition/measurement
Efficiency	CE	It is generated from Stochastic Frontier Analysis.
Total asset	ASSET	Log of total loan and advances to customers. It is an indicator of bank' size. It is a proxy for bank size,
Capital adequacy ratio	CAR	Total equity as a percentage of total asset. CAR is a measure of capitalization ratio.
Operating expenses to total asset	OPEXTA	Total operating expenses as a percentage of total assets. It measure bank's operational efficiency
Return on Asset	ROA	Profit after tax as a percentage of total asset. It is a measure of profitability.
Total loan to total asset	LTA	Total loan as a percentage of total asset. It is a measure of liquidity risk.
Loan to Deposit Ratio	LDR	It is the ratio of total loan to total deposit. It provides information on bank's intermediation and liquidity risk
Economic growth	GDPGR	It measured by annual growth rate of real gross domestic product
Inflation	INF	It is measured by changes consumer price index

Source: compiled by the authors