

Measuring the Connectedness of the Nigerian Banking System

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Abstract

The Global Financial Crisis showed that crises can quickly spread from one banking institution to others, thereby reigniting the interest of bank regulators in the connectedness of banking systems. In this study, we used the spillover approach of Diebold and Yilmaz (2009) to examine the connectedness of the Nigerian banking system. We find that the banking system in Nigeria is deeply interconnected with a mean *total connectedness index* of 76.13%, suggesting that there is a high likelihood that crises can spread from one institution to another. We also find that while the tier-1 banks exert dominant influence on the Nigerian banking system and therefore have the potential to propagate systemic risks, a few tier-2 banks are vulnerable to systemic risks arising from the connectedness of banks in Nigeria. These findings suggest that there is a need for the CBN to focus its regulatory oversight more on these banks, thereby highlighting the fact that in managing systemic risk in a banking system, the monetary authority can use connectedness analysis to focus on certain banks more than others. Our findings further indicate that the 2016 economic recession amplified the risk of the systemic banking crisis in Nigeria, suggesting that banking systems should be rigorously monitored during crisis periods to limit systemic risk. Lastly, our findings indicate that two of the banks taken over by the CBN in August 2009 were not vulnerable at the point of take-over, suggesting that connectedness analysis can be used to improve regulatory decision-making in such situations. The study concludes that the CBN can strengthen its regulatory oversight by extending its systemic risk management framework to include connectedness analysis.

Keywords: Connectedness; Systemic Risk; Banking System; Central Banking; Spillover; Approach

JEL Codes: F02; G33; G21; E58; C53

1. Introduction

The 2007-2008 Global Financial Crisis demonstrated that shock originating from one institution or asset class can quickly spread to other institutions, markets, and even across borders. This crisis not only showed how interconnected the global financial and banking systems have become but also rekindled the interest of policymakers and bank regulators in the connectedness of banking systems¹ given that connectedness measurement and evaluation can be used in managing systemic risk in the banking system. Besides, as a key component of the financial system, and given the important roles that banks play in financial intermediation and their highly leveraged operations, the banking system is usually the starting point of systemic risk analysis in a given country. Iori et al (2006) described ‘systemic risk’² in banking systems as the tendency for crises to spread from institution to institution, and explained that at a large enough scale, it could lead to ‘systemic failure’. According to Kaufman and Scott (2003), “systemic risk in banking is evidenced by high correlation and clustering of bank failures in a single country, in several countries, or throughout the world”.

An interesting feature of the Nigerian banking system is that it has witnessed episodes of multiple bank collapses similar to the submission of Kaufman and Scott (2003) in the foregoing paragraph. This makes the study of the connectedness of the Nigerian banking system quite interesting. For instance,

¹According to Diebold and Yilmaz (2015b), banking institutions are interconnected not only through their exposures to other common obligors (i.e. their borrowing customers) but also through mutual exposures among themselves in the interbank market. Statistics from CBN (2017) show that at the Nigerian interbank market, the value of transactions has risen to N32,910.37 billion as of 2017. Indeed, one of the reasons why Nigeria makes an interesting case study is that it has an active interbank market. Banks are also connected through holding of similar portfolios and having bulk of similar depositors.

² There is no generally accepted definition of systemic risk in the literature as it means different things to different people. Kaufman and Scott (2003) and Borio and Drehmann (2009) document alternative definitions of systemic risk in banking, which generally indicate that it has to do with the likelihood of breakdowns in the entire banking system instead of one or a few banking institutions. However, three sources of systemic failure observed in the literature have been used to conceptualize systemic risk (Iori et al., 2006). The first is a ‘bank run’, which Iori et al (2006) defined as “a self-fulfilling panic in which depositors and investors attempt to withdraw funds leading to a collapse of the system”. The second is a situation in which banks invest in similar types of assets such that a large enough failure by one bank can induce a fall in the price of its assets, which in turn affects the solvency of other banks holding the same asset. The last aspect of systemic risk in banking emanates from inter-locking exposures among banks, usually in the interbank market, which not only provides mutual insurance for the banks, but also generates the potential for one bank’s failure to have knock-on effect on the financial health of other banks (Iori et al., 2006; Allen and Gale, 2000).

out of 25 indigenous banks operating in the country between 1930 and 1958, 21 failed in quick succession. Furthermore, between 1994 and 1998, 31 Nigerian banks collapsed, while the banking consolidation exercise of 2004 swept away 14 banks that could not meet the minimum capital requirement for deposit money banks. The banking sector crisis of 2009 led to the collapse of 9 Nigerian banks that were plagued by huge non-performing loans, which eroded their operating capital (Babalola, 2011; Egbo, 2012; Elegbe, 2013). These episodes of multiple bank failures suggest the existence of both direct and indirect forms of contagion in the Nigerian banking system. On one hand, the direct effect implies that the failure of a given bank has a knock-on effect on its creditors; while on the other hand, the indirect effect advocates that bank failures tend to weaken the banking system as a whole and push it to an unstable state in which it becomes vulnerable to further multiple failures. This is akin to the systemic risk model of Iori et al (2006). Thus, this study on the connectedness of the Nigerian banking system is expected to be of utmost interest to bank regulators globally as it shows how bank regulation can focus on certain banks more than others through connectedness analysis, thereby improving regulatory oversight and bank supervision. Besides, macroeconomic conditions in Nigeria have remained volatile since the Global Financial Crisis, thereby making Nigeria an interesting subject for study. For instance, the economy is highly susceptible to oil price shocks (Abdulkareem and Abdulhakeem, 2016).

Interestingly, following the network approach advanced by Diebold and Yilmaz (2009) for the measurement and evaluation of connectedness among entities in the global economy, some empirical studies on the connectedness of financial and/or banking systems have emerged (Diebold and Yilmaz, 2012, 2014; Bu *et al.*, 2013; Echevarria-Icaza and Rivero, 2016; Andrada-Félix *et al.*, 2018; Barunik and Krehlik, 2018; Buse and Schienle, 2019; Bostanci and Yilmaz, 2020; Rodríguez and Sosvilla-Rivero, 2020). However, to the best of our knowledge, none of these studies has so far examined the connectedness of the banking system in any individual African economy. This study fills this gap in the literature. Specifically, this study raises several pertinent questions on the connectedness of the Nigerian banking system. First, what is the degree of the connectedness of the Nigerian banking system? This question is relevant because apart from showing how connected the banking system is, it also provides insight into the likelihood that crises can spread from one institution to another. Second, are there banks that exert dominant influence and therefore have the potential to spread systemic risk in the Nigerian banking industry? This study used this question to demonstrate how bank regulators can use connectedness analysis to focus on certain banks as a way of

advancing systemic risk analysis and management in the banking system. This, in turn, enhances regulatory oversight and banking system supervision. Indeed, these facts also motivated the third question investigated in this study. The third question asks: which banks are most vulnerable to systemic risks arising from the connectedness of banks in Nigeria?

The fourth question addressed in this study asks: how did the 2016 economic recession in Nigeria impact the connectedness of the Nigerian banking system? This question is used to show how the connectedness of a typical banking system evolves during a crisis and how bank regulators can design a regulatory framework for responding to such a crisis. This study focused on the 2016 economic recession in Nigeria due to several reasons. The first reason is that the recession has been mainly attributed to oil price shock, which underlines the vulnerability of the economy to fluctuations in the international oil market (Ibrahim et al, 2018). Many economies around the world are also susceptible to oil price shocks. In addition, information from Nigeria's National Bureau of Statistics (NBS) indicates that due to this recession, the real GDP growth rate declined from 2.11% in 2015Q4 to -1.30% in 2016Q4, while the unemployment rate increased from 10.4% to 14.2% over the same period (NBS, 2017a,b). Thus, this recession represents a typical crisis episode characterized by declining economic activities and rising macroeconomic volatility. Since every economy experiences a crisis from time to time, bank regulators and policymakers globally should be interested in how the connectedness of the banking system evolves during such a typical crisis.

Besides, central banks usually intervene in the banking system to limit systemic risk. This is because the mutual exposures among banks in the interbank market not only generate mutual insurance for the banks but also create the potential for a given bank's failure to have knock-on effects on the financial health of other banks in the system (Iori et al., 2006). In other words, there may be a need for a central bank to intervene and target a bank that threatens the system as a whole. However, such interventions by the Central Bank of Nigeria (CBN) have been viewed by some stakeholders as acts of vendetta rather than the outcome of rigorous regulatory activities. Such stakeholders argue that the CBN manages the banking system based on "as the spirit directs" rather than the rigorous application of any econometric tool (Onu, 2010). For instance, the takeover of some banks by the CBN in August 2009 was perceived as largely political by some stakeholders. For situations like this, connectedness analysis can be used to improve regulatory decision-making. We demonstrated this in the study by addressing the question: were the banks taken over by the CBN in August 2009 vulnerable at the point of

takeover?³ As we shall see later in this study, the status of each bank in the *dependence-influence* space provides a robust mechanism for addressing this question in the connectedness framework of Diebold and Yilmaz (2009).

Given the foregoing paragraphs, the broad objective of this study is to measure and evaluate the connectedness of the Nigerian banking system. The specific objectives are to:

- i. Estimate the degree of the connectedness of the Nigerian banking system.
- ii. Determine the banks that exert dominant influence and therefore have the potential to spread systemic risks in the Nigerian banking industry.
- iii. Establish the banks that are most vulnerable to systemic risks arising from the connectedness of banks in Nigeria.
- iv. Examine the impact of the 2016 economic recession on the connectedness of the banking system in Nigeria.
- v. Ascertain if the banks taken over by CBN in August 2009 were vulnerable or otherwise.

2. Literature Review

Most recent studies on financial connectedness are based on the network approach of Diebold and Yilmaz (2009). Some of the studies focused exclusively on financial connectedness at the country-specific level, while others were multi-country studies. However, the multi-country studies are either regional or global. In what follows, the extant literature is x-rayed from these various perspectives. First, studies that examined international financial connectedness are considered. In their seminal paper, Diebold and Yilmaz (2009) analyzed 19 global equity markets over the period 1992M1-2007M11. The results show significant evidence of divergent behavior in the dynamics of return spillovers and return volatility spillovers. While the former displayed a gently increasing trend but no bursts, the latter displayed no trend but clear bursts.

Diebold and Yilmaz (2015a) also focused on the international transmission of financial contagion among 18 European and 17 American major financial institutions from 2004M1 to 2014M6. The results indicate that the direction of connectedness was mainly from the U.S. to Europe during the period 2007-

³This question is not meant to query the decision of the CBN. It is specifically aimed at highlighting how regulatory decision making in such situations can be enhanced through connectedness analysis, which should be of general interest to central banks around the world.

2008. This highlights the U.S. as the source of the global financial crisis during this period. However, the results also show increased connectedness between European and U.S. financial institutions towards mid-2011, which is consistent with the massive deterioration in the health of European financial institutions. The study obtained a total connectedness index of 81.7% across all the financial institutions. Overall, the study demonstrated that connectedness is dynamic and that crisis episodes increase the connectedness measures beyond their pre-crisis levels. These results are consistent with the findings of Yilmaz (2014), who studied the dynamic measures of volatility connectedness of major bank stocks in the US and the EU member countries.

Guimarães-Filho and Hong (2016) studied the connectedness of Asian equity markets based on the Diebold and Yilmaz (2009) framework. The results indicate that financial shocks emanating from Asia can no longer be called insignificant. The results further indicate that the global financial crisis increased the aggregate equity return and volatility connectedness indices substantially, which is consistent with the already established trend of financial connectedness in the literature. However, the pattern of connectedness differed between advanced economies and emerging markets after the crisis. While the advanced economies became net receivers of financial shocks, the emerging market economies, especially China, ASEAN-5 (Indonesia, Malaysia, the Philippines, Singapore, and Thailand), and Korea became key financial shock transmitters.

Several other studies have also applied the Diebold and Yilmaz (2009) methodology in the study of financial connectedness at the international level. Demirer *et al.* (2018) used this empirical approach to find that both the 2007-08 global financial crisis and the EU debt crisis increased global equity connectedness considerably. Echevarria-Icaza and Rivero (2016) studied the connectedness of European Economic and Monetary Union (EMU) sovereign and bank CDS and found that the systemic impact of banks varies speedily during crisis periods. Cipollini *et al.* (2014) studied the connectedness of five European stock markets (France, Germany, the UK, Switzerland and the Netherlands). The results showed that the total connectedness index had been relatively stable. Buse and Schienle (2019) examined the connectedness of European sovereigns and found that unstable countries were relatively more affected by financial crises. Bostanci and Yilmaz (2020) showed that emerging market countries are the main transmitters of sovereign credit risk shocks across the globe, while shocks to other financial assets are quickly transmitted to the sovereign credit risk spreads.

Ogbuabor *et al.* (2016) estimated the real and financial connectedness of selected African economies with the global economy based on the Diebold and

Yilmaz (2009) approach. The study found that the connectedness of African economies with the rest of the world was quite substantial and that the global financial crisis increased the connectedness measures above their pre-crisis levels. The results also showed that the U.S., EU, and Canada dominate Africa's equity markets, while China, India, and Japan dominate Africa's real activities. The study concluded that African economies are mainly small open economies, which are profoundly interconnected with the global economy but vulnerable to headwinds emanating from the rest of the world. Andrada-Félix *et al.* (2018), Rodríguez and Sosvilla-Rivero (2020), and Barunik and Krehlik (2018) also applied the Diebold and Yilmaz (2009) framework in their study of international financial connectedness.

The foregoing paragraphs indicate that the Diebold and Yilmaz (2009) framework has been widely applied in the study of international financial connectedness. Interestingly, the framework has also been applied to country-specific studies of financial system connectedness. In this regard, Diebold and Yilmaz (2014) investigated the stock return volatilities connectedness of major U.S. financial institutions and found the highest pairwise directional connectedness between Citigroup and J. P. Morgan. The results further showed that Citigroup, which was the worst hit among the top five U.S. commercial banks, transmitted its difficulties to the stocks of the other top commercial banks. Fannie Mae, Freddie Mac, and AIG had the least pairwise directional connectedness, suggesting that they had lots of troubles during the 2007-08 global financial crises and that they could have gone under without the intervention of the U.S. government.

Diebold and Yilmaz (2012) is another country-specific study, which investigated the connectedness of four main classes of U.S. assets markets (stocks, bonds, foreign exchange, and commodities markets). The study found that the direction of volatility shock transmission was mainly from the stock market to other markets. This shows that the U.S. stock market is an important transmitter of financial shocks. The study also found that the 2007-08 global financial crisis increased the total connectedness measure beyond its pre-crisis level. Bu *et al.* (2013) studied the connectedness of the Korean financial system and found that securities companies and foreign banks are systemically dominant, while regional banks are generally vulnerable to shocks. The study also found that credit card companies play important roles mainly in the long-run, while insurance companies are mainly vulnerable in the long-run. Kookmin Bank and Shinhan Bank were shown to have systemically dominated the Korean financial system.

Apart from the Diebold and Yilmaz (2009) approach, other methodologies have also been used in the study of financial connectedness, and by extension,

systemic risk. Billio *et al.* (2012) and Merton (2014) used the Granger Causality method to describe networks to show how the connectedness or linkages among entities can be characterized and understood. The major drawback of this method is that it captures only pairwise relations. Thus, this method is not suitable for answering the research questions in this study, such as: “What is the degree of the connectedness of the Nigerian banking system?” Kose *et al.* (2003) and Brunetti *et al.* (2019) applied correlation-based measures to characterize connectedness. The shortcomings of this method can be found in the fact that correlation is also a pairwise measure and it is non-directional. This study goes beyond pairwise connections by exploring the connectedness of the banking system in Nigeria as a whole based on the *total connectedness index* of Diebold and Yilmaz (2015b, 2016). Unlike the Granger causality and correlation-based measures of connectedness, the connectedness measures used in this study, based on the Diebold and Yilmaz (2009) framework, are non-pairwise, yet directional.

Other methods that have also been applied in financial connectedness studies include: the marginal expected shortfall (Acharya *et al.*, 2017); the CoVar approach (Adrian & Brunnermeier, 2016); the Dynamic Tail-Event Driven Networks (TENETs) model (Wang *et al.*, 2018); the Out-Of-Sample Variance Decomposition of Model Forecast Errors (Buse & Schienle, 2019); Factor-Augmented VAR (FAVAR) (Barattieri *et al.*, 2013); and Ordinary Least Square (OLS) Method (Magknonis & Tsopanakis, 2019; Rauch *et al.*, 2015). The major shortcoming of these methods is their inability to estimate the degree of connectedness of a given banking or financial system. According to Diebold and Yilmaz (2015b), these alternative approaches deal entirely with testing rather than measurement of connectedness, which is the main issue in this study. Specifically, the measurement of total systemic risk (“How connected are all the banks?”), which is important for macro-prudential policymaking, can be readily captured by the *total connectedness index* of Diebold and Yilmaz (2015b, 2016)⁴.

Overall, our review of the empirical literature shows that the connectedness of the banking system is yet to be investigated in any African economy based on the Diebold and Yilmaz (2009) framework. However, such an investigation is important not only to assist the monetary authorities in systemic risk analysis and management but also to safeguard the financial system, particularly

⁴ Diebold and Yilmaz (2015b) noted that policy toward systemic risk such as taxing financial institutions according to their connectedness, as in Acharya *et al.* (2017), first requires a connectedness measurement. This indicates that the Diebold and Yilmaz (2009) framework adopted in this study is similar in spirit to the marginal expected shortfall approach of Acharya *et al.* (2017) and that both approaches can indeed work to complement each other.

during crisis periods. To address this gap, this study examined the connectedness of the Nigerian banking system based on the Diebold and Yilmaz (2009) framework.

3. Methodology and Data

Model Specification

This study follows the spillover approach of Diebold and Yilmaz (2009, 2015b). The choice of this approach is based on its ability to use the size and direction of shocks to build both directional and non-directional connectedness measures. In line with this approach, the normalized generalized forecast error variance decompositions (NGFEVDs) obtained from an underlying p -th order vector autoregression (VAR) model for the $N \times 1$ vector of endogenous variables, Z_t , are used to construct the connectedness measures for this study. Thus, the VAR (p) model for this study is specified as follows:

$$Z_t = \alpha_y + \sum_{j=1}^p \Phi_j Z_{t-j} + \varepsilon_t, \quad t = 1, 2, \dots, \quad (1)$$

where α is $N \times 1$ vector of intercepts; Φ_j is $N \times N$ matrix of coefficients; the lag order is p ; and the residuals $\varepsilon_{it} \sim iid(0, \sum_{\varepsilon, ii})$ so that $\varepsilon_t \sim (0, \sum_{\varepsilon})$, where \sum_{ε} is positive definite covariance matrix. The vector of endogenous variables (Z_t) includes the log of equity returns for all the banks included in the study. These equity returns data are presumed to embody investors' expectations⁵. N is the number of deposit money banks captured in the study. The VAR lag order is selected based on Schwarz Information Criterion to ensure serially uncorrelated residuals.

After estimating the underlying VAR model in equation (1), the generalized forecast error variance decompositions (GFEVDs) are then generated and used to build the connectedness measures. The GFEVDs are invariant to the

⁵ Since the interbank market provides an important channel through which the banks are connected in Nigeria, it would have been great to use interbank data in this study just as in Brunetti *et al.* (2019). Unfortunately, this data is unavailable. So, this study used equity returns data following Diebold and Yilmaz (2009, 2014, 2015a,b). Indeed, studies of this nature generally use equity returns data to measure connectedness and its evolution. This is because, according to Diebold and Yilmaz (2015b), stock market returns “reflect forward-looking assessments of many thousands of smart, strategic and often privately informed agents as regards precisely the relevant sorts of connections”. Thousands of such agents (i.e. professional traders) participate actively in the Nigerian Stock Exchange and no one else can be better than them.

reordering of the variables in the system. Following Diebold and Yilmaz (2016), Pesaran and Shin (1998), and Koop *et al.* (1996), the GFEVDs are defined as:

$$GFEVD(Z_{it}; \varepsilon_{jt}, H) = d_{ij}^{gH} = \frac{\sigma_{\varepsilon, jj}^{-1} \sum_{h=0}^{H-1} (e_i' \Theta_h \Sigma_{\varepsilon} e_j)^2}{\sum_{h=0}^{H-1} (e_i' \Theta_h \Sigma_{\varepsilon} \Theta_h' e_i)} \quad (2)$$

where $i, j = 1, \dots, N$; $H = 1, 2, \dots$ is the forecast horizon; $e_i(e_j)$ is $N \times 1$ selection vector whose i -th element (j -th element) is unity with zeros elsewhere; Θ_h is the matrix of coefficients multiplying the h -lagged shock vector in the infinite moving-average representation of the non-orthogonalized VAR; Σ_{ε} is the covariance matrix of the shock vector in the non-orthogonalized VAR; and $\sigma_{\varepsilon, jj}$ is the j -th diagonal element of Σ_{ε} . The GFEVD environment assumes that all the banks are hit by shocks at the same time. This assumption looks plausible in this study because a graphical plot of the stock prices of the banks in this study over the full sample shows that these prices generally track themselves, especially during crisis periods. This is consistent with the assumption that shocks generally hit the banks at the same time.

In the GFEVD environment, shocks are hardly ever orthogonal (Diebold & Yilmaz, 2016). This means that sums of forecast error variance contributions are not necessarily unity. In other words, row sums of the GFEVD matrix, D^{gH} are not essentially unity. This renders the interpretation of the GFEVDs difficult. To restore a percentage interpretation of the GFEVDs in this study, we adopted the normalized GFEVDs (NGFEVDs) as defined by Diebold and Yilmaz (2014). The NGFEVDs are given by:

$$\tilde{D}^g = [\tilde{d}_{ij}^g], \text{ where } \tilde{d}_{ij}^g = \frac{d_{ij}^g}{\sum_{j=1}^N d_{ij}^g}, \quad d_{ij}^g = GFEVD(Z_{it}; \varepsilon_{jt}, H) \quad (3)$$

It can easily be seen that by construction, $\sum_{j=1}^N \tilde{d}_{ij}^g = 1$ and $\sum_{i,j=1}^N \tilde{d}_{ij}^g = N$, so that the overall sum of the generalized forecast error variance share of each bank in the VAR system is normalized to 100%. Recall that H is the forecast horizon. For ease of notation but without loss of generality, the remainder of this study drops the superscripts g and H whenever they are not needed for clarity such that \tilde{d}_{ij}^{gH} is simply written \tilde{d}_{ij} respectively.

The Generalized Connectedness Measures (GCMs)

In this section, the generalized connectedness measures (GCMs) used in this study are defined. The intuition behind the spillover approach of Diebold and Yilmaz (2009) is fairly simple. Variance decomposition allows the breaking up of the forecast error variances of each entity in the system into fractions

attributable to the various system shocks. By so doing, one can then address such issues as: What component of the h-step-ahead error variance in forecasting Z_1 , for example, is attributable to shocks to Z_1 ? Shocks to Z_2 ? In general, what component of the h-step-ahead error variance in forecasting Z_j is attributable to shocks to Z_i , for all $i, j = 1, 2, \dots, N$? Hence, this spillover approach marries network topology theory and VAR variance decomposition theory by underlining the fact that VAR variance decompositions form networks. Characterizing connectedness in those variance decomposition networks portrays the connectedness of the entities in the VAR system. Herein lies the intuition behind this spillover approach. To conserve space, we do not dwell further on the relations between VAR variance decomposition and network theory, which has been documented by Diebold and Yilmaz (2015b).

Table 1: Connectedness Table Schematic

Variables	Z_1	Z_2	...	Z_N	From Others
Z_1	\tilde{d}_{11}	\tilde{d}_{12}	...	\tilde{d}_{1N}	$\sum_{j=1}^N \tilde{d}_{1j}, \quad j \neq 1$
Z_2	\tilde{d}_{21}	\tilde{d}_{22}	...	\tilde{d}_{2N}	$\sum_{j=1}^N \tilde{d}_{2j}, \quad j \neq 2$
\vdots	\vdots	\vdots	\ddots	\vdots	\vdots
Z_N	\tilde{d}_{N1}	\tilde{d}_{N2}	...	\tilde{d}_{NN}	$\sum_{j=1}^N \tilde{d}_{Nj}, \quad j \neq N$
To Others	$\sum_{i=1}^N \tilde{d}_{i1}, \quad i \neq 1$	$\sum_{i=1}^N \tilde{d}_{i2}, \quad i \neq 2$...	$\sum_{i=1}^N \tilde{d}_{iN}, \quad i \neq N$	$\frac{1}{N} \sum_{i,j=1}^N \tilde{d}_{ij}, \quad i \neq j$

Source: Adapted from Diebold and Yilmaz (2014)

To construct the generalized connectedness measures (GCMs) relevant for the ensuing analysis, let the H-step ahead NGFEVDs of equation (3) be denoted by \tilde{d}_{ij} . The connectedness table schematic shown in Table 1 is developed by cross-tabulating \tilde{d}_{ij} . This table is akin to the connectedness matrix of Greenwood-Nimmo *et al.* (2015). Each row in this table is normalized to sum

up to 100% so that the GCMs can be interpreted as percentages. This table is now used to define the various GCMs and their relationships. The diagonal entries in Table 1 capture the own variance contributions (or *own-effect*). The off-diagonal entries capture the variance contributions arising from shocks to other entities in the system. They are, therefore, acknowledged as pairwise directional connectedness. Thus, the *own-effect* (also known as the *heatwave*) is constructed in this study as:

$$H_j = \tilde{d}_{jj} \quad (4)$$

Another important GCM in this study is known as the *from-effect*. This measure captures the total spillovers from all other banks in the system to a given bank, say Z_{jt} . Put differently, the *from-effect* is a directional connectedness measure which captures the spillovers from all other variables to Z_{jt} as fractions of the H-step-ahead error variance in the forecasts of Z_{jt} resulting from Z_{it} , where $i = 1, 2, \dots, N$ and $i \neq j$. The *from-effect* is therefore constructed in this study as:

$$F_j = \sum_{i=1, i \neq j}^N \tilde{d}_{ji} \quad (5)$$

Since each row of Table 1 is normalized to 100%, it is easily seen that $H_j + F_j = 1$ by construction $\forall j = 1, 2, \dots, N$. Just like the *from-effect* connectedness, this study also defines the *to-effect* connectedness in order to account for the total directional connectedness from a given bank, say Z_{jt} , to all other banks in the system. Thus, the *to-effect*, which effectively captures the total contributions or spillovers from a particular bank, Z_{jt} , to all other banks in the VAR system is constructed as:

$$T_j = \sum_{i=1, i \neq j}^N \tilde{d}_{ij} \quad (6)$$

By construction, the *to-effect* shows the impact or influence of a given bank on other banks in the system. The difference between the *to-effect* and the *from-effect* gives the net directional connectedness of a given bank, Z_{jt} . Hence, the *net-effect* connectedness measure is constructed in this study as:

$$N_j = T_j - F_j \quad (7)$$

Since there are N banks in the system, it also follows that there are $2N$ total directional connectedness measures made up of N *to-effect* measures capturing spillovers to others and N *from-effect* measures capturing spillovers from others. These are akin to total lending to and total borrowing from other banks for each of the N banks in the system. Furthermore, there are N *net-effects* accounting for the total spillovers to all others less the total spillovers from all others, akin to the total interbank balance for each of the N banks in the system. It is easily seen that since the *to-effects* and the *from-effects* are

two sides of the same coin, then the overall sum of the *net-effect* is $\sum_{j=1}^N N_j = 0$ by construction.

To measure the total connectedness between a given bank and other banks in the system, this study constructs a *sum-effect* connectedness measure, S_j^e . In other words, the bank with the highest *sum-effect* is deemed to have the highest connectedness or interlinkage with other banks; while the bank with the lowest *sum-effect* is considered to have the least connectedness with other banks in the system. The *sum-effect* connectedness measure is constructed in this study as:

$$S_j^e = T_j + F_j \quad (8)$$

To measure the aggregate connectedness of the banking system in Nigeria, this study constructs the *total connectedness index* (also known as the *total-effects*). This is the most aggregative non-directional connectedness measure in this study. It is constructed as:

$$C = \frac{1}{N} \sum_{j=1}^N F_j = \frac{1}{N} \sum_{j=1}^N T_j \quad (9)$$

The *total-effects* captures the grand total of the off-diagonal elements in Table 1, which is equivalent to the sum of the *from-effects* column or *to-effects* row. There is just one *total-effects* connectedness measure, analogous to the total interbank borrowings or lendings, since the two are identical. Notice also that since there are N banks in the system, it must be the case that by construction:

$$N = \frac{(\sum_{j=1}^N F_j + \sum_{j=1}^N H_j)}{100} \quad (10)$$

To assess the dependence of a given bank on external shocks and the influence of a given bank on the system as a whole, this study defines two essential indices. These are the *dependence index* and the *influence index*. Technically, the *dependence index* is constructed in this study as:

$$O_j^H = \frac{F_j}{H_j + F_j}, \quad \forall j = 1, 2, \dots, N \quad (11)$$

where $0 \leq O_j^H \leq 1$ expresses the relative importance of external shocks for the j -th bank in the system. If the *dependence index* is close to one (i.e. $O_j^H \rightarrow 1$), it means that conditions in the j -th bank is quite sensitive to external shocks. Put differently, it means that the j -th bank is open to external shocks. However, if the *dependence index* is close to zero (i.e. $O_j^H \rightarrow 0$), it means that the j -th bank is less sensitive to external conditions.

The *influence index* is constructed for this study as:

$$I_j^H = \frac{N_j}{S_j^e}, \quad \forall j = 1, 2, \dots, N \quad (12)$$

The influence index lies between -1 and +1 (i.e. $-1 \leq I_j^H \leq 1$). A given bank (e.g. the j -th bank) is a net shock receiver if its *influence index* is negative (i.e. $-1 \leq I_j^H < 0$). Such a bank is said to be vulnerable to shocks emanating from the system as a whole. A given bank is a net shock transmitter if its *influence index* is positive (i.e. $0 < I_j^H \leq 1$). Such a bank is said to be influential or systemically dominant in the system. A given bank is neither a net receiver nor a net transmitter of shocks if its *influence index* is zero (i.e. $I_j^H = 0$). Hence, the *influence index* captures the extent to which a given bank influences or is influenced by external shocks.

The coordinate pair (O_j^H, I_j^H) in the *dependence-influence* space gives a clear understanding of a given bank's role or status in the Nigerian banking system. The economic expectation is that a small bank would be typically positioned around the point (1,-1), indicating that it is open to external conditions and vulnerable. On the other hand, a dominant bank would be situated close to the point (0,1), indicating that it is influential and less sensitive to external conditions.

3.3. The Data

The data for this study consists of monthly real equity returns, from January 2006 to November 2016. This period ensures that the banking system that emerged following the 2004/2005 consolidation exercise is substantially accounted for. We examine thirteen deposit money banks that were operational during the period and whose stock prices are consistently available from the Nigerian Stock Exchange (NSE). As of November 2016, these thirteen banks accounted for 83% of the total assets and 81% of the total deposits of deposit money banks in Nigeria⁶.

The monthly local-currency stock prices of the banks were used to compute the nominal equity returns as the change in log price. Thereafter, the monthly nominal returns were converted to real terms using monthly consumer price indices taken from the National Bureau of Statistics. Following Diebold and Yilmaz (2009), we computed the monthly real equity returns as $\frac{(1+i_t)}{(1+\pi_t)} - 1$,

⁶ The thirteen banks include: Access Bank Plc (Access), Diamond Bank Plc (Diamond), First Bank of Nigeria Plc (FBN), First City Monument Bank Plc (FCMB), Fidelity Bank Plc (Fidelity), Guaranty Trust Bank Plc (GTB), Skye Bank Plc (SKYE), Sterling Bank Plc (STERLING), United Bank for Africa Plc (UBA), Union Bank of Nigeria Plc (UBN), Unity Bank Plc (UNITY), Wema Bank Plc (WEMA), and Zenith Bank Plc (Zenith). When grouped by size of capital, Access, FBN, GTB, UBA and Zenith are tier-1 banks, while the other banks are tier-2 banks. Each of the tier-1 banks has a capital of at least N238 billion, while the five tier-1 banks jointly account for 54% of total assets, 54% of total deposits, and 51% of total capital in the Nigerian banking system. Thus, these five tier-1 banks can be said to be systemically important given the size of their capital, assets and/or deposits.

where i_t is the monthly nominal return and π_t is the monthly inflation rate. Appendix 1 provides a variety of descriptive statistics of the real equity returns data, while Appendix 2 provides the unit root test results showing that all the series are stationary at level.

4. Empirical Results and Discussions

The results are based on monthly vector autoregression of order one (selected using the Akaike criterion), 24-month forecast horizons, and connectedness measures distilled from NGFEVDs, which are invariant to the reordering of the variables in the system. In what follows, we report and discuss the results for each of the specific objectives in this study.

The Degree of the Connectedness of the Nigerian Banking System

The first specific objective of this study is to estimate the degree of the connectedness of the Nigerian banking system. To achieve this objective, we computed the *total connectedness index* following equation (9). The results are shown in Table 2. Here, the first forecast horizon (i.e. horizon 1) is used to describe the short-run results, while the highest forecast horizon (i.e. horizon 24) is used to depict the long-run results. Thus, the results in Table 2 show the movement of the *total connectedness index* from the short-run (i.e. from horizon 1) to the long-run (i.e. to horizon 24). The results indicate that the *total connectedness index* increased smoothly from 71.64% in the short-run to 76.35% in the long-run. However, on average, the degree of connectedness of the banking system in Nigeria is found to be 76.13%, which is quite substantial. These results indicate that both in the short-run and the long-run, the Nigerian banking system is deeply interconnected. This finding is consistent with Diebold and Yilmaz (2014), which reported a *total connectedness index* of 78% for financial institutions in the United States. It is also consistent with the pattern of bank failure in Nigeria, which shows that each episode of bank failure usually involves many banks. In other words, the finding indicates that there is a high risk of knock-on effects in the Nigerian banking system arising from the connectedness of the system. This, in turn, makes the management of systemic risk an important policy issue in the Nigerian banking system.

Table 2: Series of Total Connectedness Index (%)

Horizon	Total Connectedness Index
1	71.6441
2	75.8095
3	76.2943
4	76.3398
5	76.3519
6	76.3538
7	76.3541
8	76.3542
9	76.3542
10	76.3542
11	76.3542
12	76.3542
13	76.3542
14	76.3542
15	76.3542
16	76.3542
17	76.3542
18	76.3542
19	76.3542
20	76.3542
21	76.3542
22	76.3542
23	76.3542
24	76.3542
Average	76.1321

Source: Authors' computation

The Banks that exert Dominant Influence in the Nigerian Banking Industry

The second specific objective of this study is to determine the banks that exert dominant influence in the Nigerian banking system and therefore have the potential to spread systemic risks in the industry. To achieve this objective, we computed the *dependence* and *influence* indices of each bank in the system following equations (11) and (12), respectively. The results are reported in Table 3. Recall that while the *dependence index* shows how sensitive each bank is to external conditions or shocks, the *influence index* shows how influential (or vulnerable) each bank is relative to other banks in the system. Thus, the position of each bank in the *dependence-influence* space gives a clear understanding of the bank's status in terms of its influence or vulnerability.

We find that the *dependence index* ranges between 0.52 and 0.83. Specifically, we find that apart from two banks with *dependence index* values of 0.52 and 0.67, other banks in the system recorded a *dependence index* of at least 0.75. This indicates that the banks are sensitive to external conditions since the *dependence index* is predominantly close to 1. This result further validates our earlier finding that there is a high risk of knock-on effects in the Nigerian banking system arising from the connectedness of the system.

The results become more interesting when the *influence index* is considered. We find that the five biggest banks in the system (i.e. the five tier-1 banks) recorded a positive *influence index*. While the *influence index* of four of these banks ranged between 0.0600 and 0.2003, the remaining one recorded an *influence index* of 0.0472. These results indicate that the tier-1 banks, which are the five biggest banks in the system by size, are exerting some influence on the system.

We also find that three out of the eight smaller banks in the system (i.e. the tier-2 banks) also recorded a positive *influence index*, suggesting that they are also exerting some influence on the system. However, a closer examination of the results indicates that the tier-1 banks predominantly recorded a higher positive *influence index* than the tier-2 banks, indicating that the tier-1 banks are exerting dominant influence on the system. We find that the remaining five tier-2 banks recorded a negative *influence index*, indicating that they are the vulnerable banks in the system.

Table 3: Dependence and Influence Indices Results

Bank	Classification	Dependence Index	Influence Index
Bank 1	Tier-1	0.8168	0.0600
Bank 2	Tier-1	0.8022	0.1013
Bank 3	Tier-2	0.7922	-0.0316
Bank 4	Tier-2	0.7687	-0.0235
Bank 5	Tier-2	0.8272	0.0570
Bank 6	Tier-1	0.7646	0.0472
Bank 7	Tier-2	0.8031	0.0169
Bank 8	Tier-2	0.7628	0.0142
Bank 9	Tier-1	0.8139	0.1008
Bank 10	Tier-2	0.5214	-0.3779
Bank 11	Tier-2	0.7464	-0.3181
Bank 12	Tier-2	0.6686	-0.3822
Bank 13	Tier-1	0.8093	0.2003

Source: Authors' computation. **Notes:** Since these results could be market sensitive, we coded the names of the banks as Bank 1, Bank 2, ..., Bank 13, in no particular order. Names of the banks corresponding to these codes are available on request.

Banks that are Vulnerable to Systemic Risks in the Nigerian Banking Industry

The third specific objective of this study is to determine the banks that are most vulnerable to systemic risks arising from the connectedness of banks in Nigeria. To achieve this objective, this study computed the *net-effect* connectedness of each bank in the system following equation (7). The results are reported in Table 4. Recall that the *net-effect* measures the total spillovers to all others less the total spillovers from all others. In other words, it quantifies the net spillovers or shocks from a given bank to all other banks in the system. Thus, a bank with a positive *net-effect* is a net transmitter of shocks, while a bank with a negative *net-effect* is a net receiver of shocks. Here, net receivers

of shocks are said to be vulnerable, while net transmitters of shocks are said to be influential⁷.

We find that the same five tier-2 banks that earlier recorded negative *influence index* in the preceding section also recorded negative *net-effect* connectedness. In other words, these five tier-2 banks are vulnerable to systemic risks emanating from the connectedness of the banking system in Nigeria⁸. We also find that all the five tier-1 banks recorded positive *net-effect*. Indeed, apart from the tier-1 bank that recorded a positive *net-effect* of 7.6681, the other four tier-1 banks recorded higher positive *net-effect* than all the tier-2 banks in the system. This reaffirms our earlier finding that the tier-1 banks are exerting dominant influence on the system, and therefore, have the potential to propagate systemic risks.

At this point, the findings of this study can be summarized as follows. First, we find that the Nigerian banking system is deeply interconnected with an average *total connectedness index* of 76.13%. Second, we find that the tier-1 banks exert a dominant influence on the system, and therefore, have the likelihood to spread systemic risks. Third, we find that five tier-2 banks are vulnerable to systemic risks emanating from the connectedness of the banking system in Nigeria.

Table 4: Net-effect Connectedness (%) Results

Bank	Classification	To-effect	From-effect	Net-effect
Bank 1	Tier-1	92.1052	81.6843	10.4209
Bank 2	Tier-1	98.3382	80.2203	18.1178
Bank 3	Tier-2	74.3658	79.2196	-4.8538
Bank 4	Tier-2	73.3598	76.8709	-3.5111
Bank 5	Tier-2	92.7176	82.7182	9.9994
Bank 6	Tier-1	84.1254	76.4572	7.6681
Bank 7	Tier-2	83.0651	80.312	2.7531
Bank 8	Tier-2	78.4962	76.2793	2.2169

⁷ The results of the *net-effect* connectedness presented in this Section 4.3 provide robustness check on the *influence index* results discussed in Section 4.2.

⁸ These net takers of shocks are characterized by lower capital base compared to the tier-1 banks in the system.

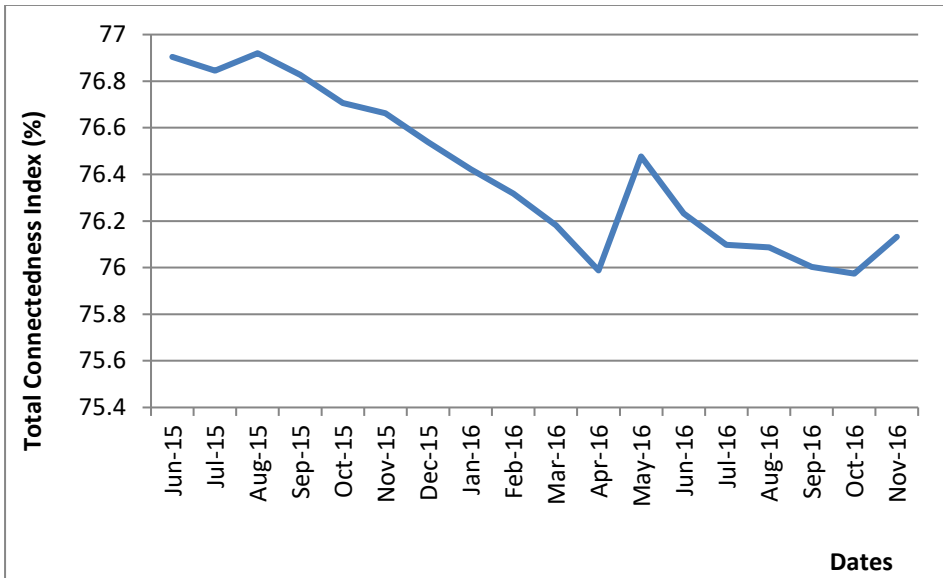
Bank 9	Tier-1	99.6488	81.3888	18.26
Bank 10	Tier-2	23.542	52.1359	-28.5939
Bank 11	Tier-2	38.5924	74.6439	-36.0516
Bank 12	Tier-2	29.8336	66.8607	-37.027
Bank 13	Tier-1	121.5269	80.9256	40.6013

Source: Authors' computation. **Notes:** The notes in Table 3 apply.

The Impact of the 2016 Economic Recession on the Connectedness of the Banking System in Nigeria

The fourth specific objective of this study seeks to examine the impact of the 2016 economic recession on the connectedness of the banking system in Nigeria. This is expected to expose the patterns in the connectedness of the Nigerian banking system during a typical crisis period. This, in turn, should guide the policy response of bank regulators during similar crises in the future. For instance, an increase in the aggregate connectedness index during the crisis period would be an indication that the crisis had induced increased shock propagation among the banks, thereby heightening the probability of knock-on effects in the system. Such patterns would require policies that can proactively secure the safety and soundness of the banking system. To achieve this objective, we adopted the technique of time-varying estimation. Consequently, we estimated the underlying model recursively so that each estimation begins from the first observation and ends in 2015M6, 2015M7, 2015M8, ..., 2016M11. Thereafter, we computed the *total connectedness index* across all the forecast horizons, $H = 1, 2, 3, \dots, 24$. A plot of the mean *total connectedness index* from the various estimations is shown in Figure 1. In what follows, we use Figure 1 to examine the evolution of the *total connectedness index* during the recession.

Figure 1: Time-varying Total Connectedness Index



Source: Author's computations. **Notes:** This index is computed recursively following equation (9) in order to trace the movement of the index before, during and after the 2016 economic recession.

We find that in June 2016 when the economy was declared recessed⁹, the *total connectedness index* witnessed a sharp upward movement. This shows that the recession stimulated increased shock transmission among the banks. In other words, the recession heightened the risk of the systemic banking crisis in Nigeria. This finding is consistent with the dynamics of the Nigerian banking sector. To see this, let us consider how some economic agents (such as banks and bank customers) in Nigeria typically behave during periods of economic recession. Periods of economic recession are usually characterized by increased uncertainty. Bank customers in Nigeria characteristically respond to such rising uncertainty by moving their deposits to the tier-1 banks, which are relatively considered safer than the tier-2 banks. Kaufman and Scott (2003) aptly described this behavior when they explained that many participants in the banking system are risk-averse and would rather be safe than sorry. Hence, during periods of heightened uncertainty, such participants quickly transfer funds to well-recognized safer banks. Obligors of the tier-2 banks also behave in this way because they are not certain that their credit lines will be renewed. Hence, they 'take a flight to safety' by moving their deposits and transactions

⁹ Appendix 3 provides a graph of real GDP growth rate from 2015Q1 to 2016Q4. The graph aptly shows when the economy became recessed in 2016Q2.

to the tier-1 banks, which are deemed to be bigger and safer. The loss of deposits by the tier-2 banks during such crisis periods usually puts them under liquidity strain¹⁰, since they may not be able to meet their maturing obligations without resorting to the interbank market or the CBN discount window. Unfortunately, the tier-1 banks are usually unwilling to lend unsecured in the interbank market during such crisis periods. Indeed, this observed attitude of the banks during periods of high uncertainty and stress is consistent with the submission of Kaufman and Scott (2003). Kaufman and Scott explained that during such periods, market participants tend not to be willing to lend at almost any rate as they are likely to take immediate flight away from all units that appear potentially at risk. These responses may induce liquidity problems, which further heighten systemic risk in the banking system.

Another characteristic behavior of Nigerian banks during periods of economic crisis is the issue of demarketing other banks. This unethical and unprofessional practice occurs when some unscrupulous bankers decide to exploit the crisis in the economy by circulating fake distress lists and/or spreading false stories about other banks, mainly tier-2 banks (Okafor, 2016). The goal is to divert patronage away from the supposedly failing banks. This behavior almost caused a run on some tier-2 banks during the 2016 economic recession (Adigun, 2016; Nelson, 2016)¹¹. The actions of various economic agents in Nigeria during periods of economic crisis are consistent with our finding that the 2016 recession heightened the risk of the systemic banking crisis in Nigeria. The key policy message for bank regulators here is that during similar economic crises in the future, bank regulators should evolve proactive policies that will guarantee the soundness and smooth functioning of their banking system. Such policies may include: (i) conducting a special examination of the banks to ensure that their corporate governance structures and risk management frameworks are functioning as expected; (ii) providing liquidity support for the banks as lenders of last resort; (iii) ensuring the smooth functioning of the interbank market by guaranteeing the transactions in the market during crisis periods; and (v) instituting sanctions against any act of demarketing; among others.

Interestingly, Figure 1 also shows that during non-crisis periods, the *total connectedness index* maintained an overall downward trend. This indicates

¹⁰ In Nigeria, it is generally believed that the tier-1 banks are safer than the tier-2 banks because they have higher capital base and are, therefore, considered more liquid. Our results reflect this general perception. Indeed, our results indicate that all the banks that reported negative *net-effect* and/or negative *influence index* are tier-2 banks that are characterized by lower capital base relative to the tier-1 banks.

¹¹ Iori et al. (2006) identified 'bank run' as one of the three sources of systemic failure that have been used to conceptualize systemic risk.

that the propagation of shocks among the banks during such periods is reduced. Overall, our results have established that the 2016 economic crisis increased the connectedness of the banking system in Nigeria, thereby heightening the risk of systemic banking crisis in the economy.

Were the Banks Taken Over by the CBN in August 2009 Vulnerable?

In July 2004, the CBN began the Bank Consolidation exercise aimed at recapitalizing Nigerian banks to reduce the risk of systemic banking crisis. The CBN further explained that this reform became necessary not only to proactively position the Nigerian banking system to become sound and reliable catalysts of development, but also to prevent the frequent failure of banks in Nigeria (Soludo, 2004). This recapitalization exercise ended in December 2005 and shrank the number of Nigerian banks from 89 to 25. The 25 banks that emerged after this recapitalization exercise were considered sound, solid, and ready to undertake “big ticket” transactions. However, in August 2009, which was just four years post-consolidation, a joint special investigation conducted by officials of the CBN and the Nigerian Deposit Insurance Corporation (NDIC) revealed that five banks were technically insolvent due to excessively high levels of non-performing loans that eroded their operating capital. The CBN blamed this situation on poor credit risk management and a lack of corporate governance. The CBN further lamented that the five banks were not only perennial net-takers of funds in the interbank market but also enjoyed liquidity support from the CBN for long periods. Consequently, to avert another round of failure in the banking system, the CBN took over Afribank Plc, Finland Bank Plc, Intercontinental Bank Plc, Oceanic Bank Plc, and Union Bank Plc, and injected N400 billion into these five banks to be repaid from proceeds of future recapitalization (Sanusi, 2009).

However, the takeover of these five banks by the CBN in August 2009 generated reactions from the public against the monetary authority. Some stakeholders perceived this takeover as largely vindictive and political rather than the outcome of a transparent regulatory activity. They argued that few other banks that were spared in the takeover process were in similar or worse situations than those taken over. Indeed, some shareholders of these banks engaged the CBN in a legal battle to stop it from the sale and/or take-over of the banks. Hence, an important question that is yet to be addressed in the literature is: Were the banks taken over by the CBN in August 2009 vulnerable at the point of takeover? To answer this question, the last specific objective in this study seeks to determine if these banks were vulnerable at the point of takeover or otherwise. However, as stated in Footnote 3, we must emphasize that this question is not aimed at querying the decision of the CBN, rather it is

meant to highlight how regulatory decision-making in such circumstances can be improved through connectedness analysis. Such enhanced decision-making procedures should be of general interest to central banks globally.

To achieve the foregoing objective, we estimated the underlying model using the weekly real equity returns¹² of twenty banks from January 2006 (i.e. the period immediately following the consolidation exercise) to June 2009 (i.e. end of the quarter before the CBN took over the five banks)¹³. The NGFEVDs from this weekly vector autoregression of order one (selected using the Akaike criterion) were used to compute the *net-effect* of equation (7) as well as the *dependence* and *influence indices* of equations (11) and (12), respectively. The results are shown in Table 5¹⁴. In this Table, the banks taken over by the CBN in August 2009 are coded as Bank 10, Bank 14, Bank 16, Bank 17, and Bank 18. The results indicate that three of the banks taken over by the CBN in August 2009 recorded negative *influence index* and negative *net-effect*. This finding indicates that these three banks were indeed vulnerable at the point they were taken over by the monetary authority. In other words, the decision of the CBN to take over these three banks deserves commendation. However, the results also indicate that two of the banks taken over by the CBN in August 2009 recorded a positive *influence index* and positive *net-effect*. This finding suggests that these two banks were not vulnerable at the point they were taken over by the CBN, rather they were exerting some influence on the system. Thus, the CBN's decision to take over these two banks may not have been well-informed. This finding is tenable because according to Sanusi (2009), three of the banks taken over were systemically important and accounted for more than 5% of assets and deposits in the system. Furthermore, the five banks taken over together accounted for 31.47% of total

¹² To compute the weekly real equity returns, we assumed that the weekly inflation rate remained constant within the month. Following Diebold and Yilmaz (2009), we computed the weekly inflation rate (π_t) as the 1/4th power of the monthly inflation rate. We also computed the weekly nominal returns (i_t) as the change in weekly average log stock price. The weekly real equity returns were then computed as $\frac{1+i_t}{1+\pi_t} - 1$, and the entire data are I(0).

¹³ The banks included in this estimation are: Access Bank Plc (Access), Afribank Plc (Afribank), Diamond Bank Plc (Diamond), Ecobank Plc (Ecobank), First Bank of Nigeria Plc (FBN), First City Monument Bank Plc (FCMB), Fidelity Bank Plc (Fidelity), Finland Bank Plc (Finland), Guaranty Trust Bank Plc (GTB), Intercontinental Bank Plc (Interc), Oceanic Bank Plc (Oceanic), Platinum Bank Plc (Platinum), Skye Bank Plc (Skye), Spring Bank Plc (Spring), Sterling Bank Plc (Sterling), United Bank for Africa Plc (UBA), Union Bank of Nigeria Plc (UBN), Unity Bank Plc (Unity), Wema Bank Plc (Wema), and Zenith Bank Plc (Zenith). These banks were selected because the stock price data are available from the Nigerian Stock Exchange.

¹⁴ This estimation produced a mean *Total Connectedness Index* of 66.79% over a 24-week horizon, which is consistent with our earlier finding that the banking system in Nigeria is considerably interconnected.

assets, 29.99% of total deposits, and 39.93% of total loans in the Nigerian banking system as of May 2009. Interestingly, the results in Table 5 also indicate that one of the tier-1 banks exerting dominant influence on the system (as explained in the last paragraph of Section 4.3) was not influential as of June 2009. However, following its acquisition of one of the banks taken over by the CBN in August 2009, it emerged as a tier-1 bank.

The results in Table 5 indicate that apart from the three banks that were vulnerable at the point of takeover, eight other banks also recorded negative *influence index* and negative *net-effect* but were not taken over by the monetary authority. However, the results in Tables 3 and 4 indicate that three out of these eight banks presently have a positive *influence index* and positive *net-effect*, thereby reflecting the efforts of these banks aimed at turning around their positions. Overall, this study has established that the decision by the monetary authority to take over some banks in August 2009 may not have been well informed in the case of two systemically important banks. This suggests that subsequent takeover decisions by the monetary authority can be improved through connectedness analysis.

Table 5: Influence Index and Net-effect, January 2006 – June 2009

Bank	Dependence Index	Influence Index	To-effect	From-effect	Net-effect
Bank 1	0.7327	0.0687	84.1112	73.27	10.8411
Bank 2	0.6839	-0.0712	59.3637	68.3947	-9.0311
Bank 3	0.7771	0.0077	78.9068	77.7068	1.1999
Bank 4	0.7102	-0.0203	68.2225	71.0234	-2.8009
Bank 5	0.7264	-0.0884	60.8278	72.6434	-11.8155
Bank 6	0.7593	0.0272	80.1824	75.9338	4.2486
Bank 7	0.7705	0.1398	102.1007	77.0496	25.0511
Bank 8	0.6549	-0.1653	46.9084	65.4933	-18.5849
Bank 9	0.7929	0.1895	116.3728	79.2903	37.0825
Bank 10	0.7504	-0.0207	72.0016	75.0403	-3.0387
Bank 11	0.6977	-0.0508	63.0256	69.766	-6.7404

Bank 12	0.4382	-0.3976	18.8757	43.8247	-24.949
Bank 13	0.7921	0.2129	122.0675	79.2073	42.8602
Bank 14	0.6686	-0.1099	53.6103	66.8556	-13.2454
Bank 15	0.4772	-0.2916	26.1684	47.7222	-21.5538
Bank 16	0.516	-0.3158	26.8288	51.6042	-24.7754
Bank 17	0.7728	0.0188	80.2556	77.2836	2.9721
Bank 18	0.7889	0.0699	90.7459	78.8882	11.8577
Bank 19	0.6595	0.0748	76.6949	65.9548	10.7401
Bank 20	0.1881	-0.3783	8.4957	18.814	-10.3183

Source: Authors' computation. **Notes:** In this table, the banks taken over by the CBN in August 2009 are coded as Bank 10, Bank 14, Bank 16, Bank 17, and Bank 18. Other notes in Table 3 apply.

5. Concluding Remarks

Every episode of bank failure in Nigeria usually involves many banks. This suggests that the management of systemic risk is an important issue in the Nigerian banking system. This study provides evidence on how connectedness analysis can be used to improve systemic risk management, public policy, and overall regulatory oversight in the Nigerian banking system. Specifically, the study: (i) estimated the degree of the connectedness of the Nigerian banking system; (ii) established the banks that exert dominant influence and therefore have the potential to spread systemic risks in the Nigerian banking industry; (iii) ascertained the banks that are most vulnerable to systemic risks arising from connectedness of banks in Nigeria; (iv) examined the impact of the 2016 economic recession on the connectedness of the banking system in Nigeria; and (v) investigated if the banks taken over by the CBN in August 2009 were vulnerable or otherwise at the point of takeover. The study used the normalized generalized forecast error variance decompositions (NGFEVDs) distilled from an underlying VAR model to build generalized connectedness measures (GCMs).

The main findings and their policy implications are summarized as follows. First, the study found that the Nigerian banking system is deeply interconnected with the *total connectedness index* averaging 76.13%. This finding implies that there is a high likelihood that crises can spread from one institution to another. To forestall this systemic risk, the CBN should monitor the system in a coordinated and continuous manner. Second, the study found that five tier-1 banks exert a dominant influence on the system and therefore have the potential to propagate systemic risks. A major policy implication of this finding is that managing systemic risk in the Nigerian banking system in a manner that will enhance regulatory oversight and overall banking system supervision requires the monetary authority to focus more on the tier-1 banks. This is because the stability of the banking system depends to some extent on the actions and/or inactions of these tier-1 banks. Thus, the bank regulator (i.e. the CBN) should pay close attention to the monitoring of these banks. It should be the policy of the CBN not to allow any form of lax supervision to be associated with these banks since the result of such laidback supervision would be dire.

Third, the study found that five tier-2 banks are vulnerable to systemic risks emanating from the connectedness of the banking system in Nigeria. This implies that there is a need for the CBN to focus more on these banks and review their operations to strengthen them. Their corporate governance and risk management structures should be properly scrutinized and fortified. In

addition, lax supervision should be avoided since the failure of any of these banks will further weaken the system. As a matter of policy, the CBN should encourage these banks to embrace mergers, where such mergers will lead to the emergence of stronger banks, thereby limiting systemic risk. Nonetheless, as a lender of last resort, the monetary authority should not withhold its emergency liquidity support from these banks whenever the need arises since the consequences of doing so could be dire. Fourth, the study found that the 2016 economic recession in Nigeria increased the connectedness of the Nigerian banking system. This shows that the recession increased the transmission of shocks among the banks, thereby amplifying the chances of a systemic banking crisis. The main policy implication of this finding is that the CBN should rigorously monitor the system during crisis episodes to limit systemic risk.

Lastly, the study found that two of the banks taken over by the CBN in August 2009 were not vulnerable at the point of take-over. This implies that the takeover decision may not have been well-informed. The main policy implication of this finding is that connectedness analysis can be used to improve regulatory decision-making in such situations. Thus, we recommend that the monetary authority should extend its systemic risk management framework to include connectedness analysis as a means of improving regulatory oversight.

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Appendix 1: Descriptive Statistics, Real Equity Returns, January 2006 – November 2016

	ACCES S	DIAMON D	FBN	FCMB	FIDELIT Y	GTB	SKYE
Mean	-0.0896	-0.1011	0.1103	0.1042	-0.1021	0.0895	0.1051
Median	-0.0986	-0.1059	0.1155	0.1044	-0.1010	0.0832	0.1103
Maximum	0.5602	0.2972	0.1083	0.2725	0.3361	0.1747	0.3461
Minimum	-0.3975	-0.6155	0.3664	0.5039	-0.4264	0.3192	0.4709
Std. Dev.	0.1278	0.1326	0.0944	0.1359	0.1226	0.0944	0.1271
Skewness	1.1987	0.0057	0.0821	0.0749	0.7489	0.1473	0.8156
Kurtosis	7.5637	4.4561	2.9601	3.8840	4.7565	3.4262	5.1050

	STERLING	UBA	UBN	UNITY	WEMA	ZENITH
Mean	-0.1022	-0.1078	-0.1058	-0.1016	-0.1061	-0.0944
Median	-0.0958	-0.1074	-0.1116	-0.1062	-0.1106	-0.0992
Maximum	0.7148	0.4524	0.7976	1.3334	0.6136	0.2521
Minimum	-0.4583	-0.4585	-0.6171	-0.4527	-0.7613	-0.3798
Std. Dev.	0.1441	0.1337	0.1619	0.1975	0.1623	0.0978
Skewness	1.5401	0.5882	0.9617	3.4534	-0.2466	0.1874
Kurtosis	10.6284	4.8843	10.8725	24.7306	9.3281	4.2893

Note: The number of observations for each bank is 131.

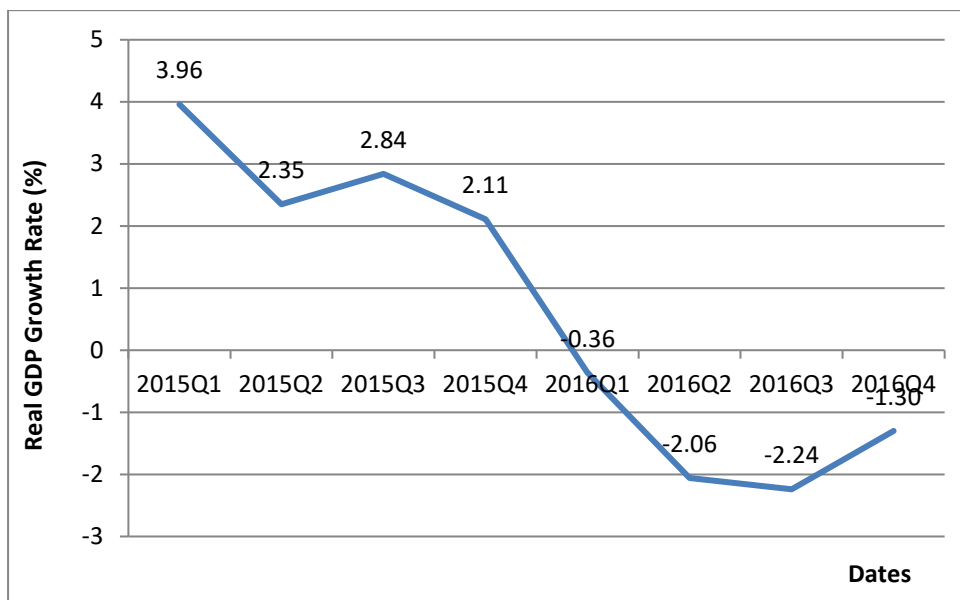
Appendix 2: Augmented Dickey-Fuller (ADF) Unit Root Test Results

Variable	ADF Statistic at Level	5% Values	Critical Order of Integration
ACCESS	-7.470781	-2.883753	I(0)
DIAMOND	-7.614841	-2.883753	I(0)

FBN	-7.835452	-2.883753	I(0)
FCMB	-6.620173	-2.883753	I(0)
FIDELITY	-6.688700	-2.883753	I(0)
GTB	-7.626084	-2.883753	I(0)
SKYE	-7.433003	-2.883753	I(0)
STERLING	-8.678236	-2.883753	I(0)
UBA	-7.427867	-2.883753	I(0)
UBN	-8.134451	-2.883753	I(0)
UNITY	-9.499558	-2.883753	I(0)
WEMA	-8.263550	-2.883753	I(0)
ZENITH	-7.134854	-2.883753	I(0)

Note: In each case, we controlled for intercept and allowed for automatic lag selection using Schwarz Criterion.

Appendix 3: Real GDP Growth Rate (%), 2015Q1 – 2016Q4



Source: Authors, with data from National Bureau of Statistics (NBS, 2017a)



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