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Measuring the Connectedness of the Nigerian Banking System

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Abstract
One of the greatest challenges presently facing the Nigerian banking system is how to manage systemic risk. This is because every episode of bank failure in Nigeria usually involves many banks collapsing simultaneously, suggesting that the Nigerian banking system may be deeply interconnected so that financial contagion becomes an important issue in managing the system. Thus, this study investigates the connectedness of the Nigerian banking system based on the spillover approach of Diebold and Yilmaz (2009). The study extended the empirical approach by constructing generalized connectedness measures at various degrees of aggregation. The results show that: (i) the banking system in Nigeria is deeply interconnected with a mean *total connectedness index* of 84% over the full sample; (ii) First Bank of Nigeria Plc, Access Bank Plc, Guaranty Trust Bank Plc, United Bank for Africa Plc and Zenith Bank Plc exert dominant influence on the system and therefore have the potential to propagate systemic risks; (iii) Wema Bank Plc, Unity Bank Plc, Diamond Bank Plc, Union Bank of Nigeria Plc, Skye Bank Plc, Sterling Bank Plc, First City Monument Bank Plc and Fidelity Bank Plc had negative *net-effects* connectedness over the full sample and are therefore vulnerable to systemic risks arising from the connectedness of banks in Nigeria; (iv) three of the banks taken over by the CBN in August 2009 (namely: Intercontinental Bank Plc, Oceanic Bank Plc and Union Bank of Nigeria Plc) had positive *net-effects* connectedness, indicating that they were not vulnerable at the point of take-over; and (v) the 2016 economic recession significantly increased the connectedness of the Nigerian banking system. These findings indicate that the CBN should interminably but rigorously and transparently monitor the banking system, especially during crisis episodes in order to limit contagion.

Keywords: Connectedness; Systemic Risk; Banking System; Central Banking; Network Approach
JEL Codes: F02; G33; G21; E58; C53

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1. Introduction

The risk of contagion amongst banks in terms of a problem in one bank spreading to another has been widely recognised as an important form of systemic risk. Systemic risk refers to the likelihood that a triggering event like bank failure or market disruption could cause widespread disruption of the stability of the banking system or the overall financial system. It includes the risk to the proper functioning of the system as well as the risk created by the system (Zigrand, 2014). Thus, an important policy challenge facing the monetary authority in Nigeria is how to manage systemic risk in the Nigerian banking system given that the system may be deeply interconnected. Indeed, Nigeria has witnessed so many bank failures since 1930 and a key feature of these bank failures is that there has hardly been any period during which a single bank failed in isolation. Every episode of bank failure in Nigeria usually involves many banks, suggesting that the banking system in Nigeria may indeed be deeply interlinked (NDIC, 2018). For example, out of 25 indigenous banks operating in the country between 1930 and 1958, 21 failed in quick successions. Between 1994 and 1998, 31 banks collapsed. In addition, the banking reforms of 2004 swept away 14 banks and decreased the number of Nigerian banks from 89 to 25; while the mergers and acquisitions of late 2009 led to the extinction of 9 banks that found themselves in a similar ugly situation of huge non-performing loans culminating in the erosion of their operating capital (Babalola, 2011; Egbo, 2012; Elegbe, 2013). The foregoing experiences informed the two simultaneous decisions took by the Central Bank of Nigeria (CBN) in December 2018, namely: the CBN sanctioned Access Bank's takeover of Diamond Bank; and the CBN took over Skye Bank and renamed it Polaris Bank preparatory to its sale to a prospective investor.

Another important fact about the banking system in Nigeria is that the banks are generally exposed not only to other common obligors (i.e. their borrowing customers) but also to themselves. For example, there is a direct connection of banks via their mutual exposures inherited in the interbank market. Also the banks are somewhat interconnected via holding of similar portfolios and having bulk of similar depositors. Nigerian banks do not operate as islands; they operate in a system where they interact among themselves and with the international banking system. They perform different kinds of transactions among themselves, and through these transactions, they are exposed not only to themselves but also to other common obligors. For instance, CBN (2015) statistics show that in the first quarter of year 2015, interbank market transactions amounted to N2, 809.58 billion, while the unsecured call and tenored transactions stood at N956.63 billion. This explains why it is difficult for any of the banks to collapse in isolation.

The trend of episodes of the failures also makes it difficult to rule out the fact that previous banking crises in Nigeria have been largely systemic. The experiences of bank failure or distress in Nigeria as detailed above underlines one important fact, which is that the banks may be deeply interconnected so that financial contagion becomes a very key issue in the management of the banking system in Nigeria. Indeed, banking institutions in Nigeria can be connected through counterparty linkages associated with their positions in various assets, through contractual obligations associated with services provided to their clients and other financial institutions, and through deals recorded in their balance sheets (Diebold & Yilmaz, 2015b). Diebold and Yilmaz (2012) explain that interactions between intermediaries in the financial sector provide possible transmission channels for financial risks. For example, banks interact with one another in the interbank market. For instance, suppose bank A collapses, the interbank market could transmit the shock (interbank contagion) to other banks, which in turn could lead to the failure of other banks in the system. Allen and Gale (2000) argued that one possible source of financial contagion is the inter-banking system. Credit risk associated with interbank lending may lead to a situation in which the failure of a given bank results in the failure of other banks even if the other banks are not directly affected by the initial condition or shock or does not hold open positions with the originally failing bank. Cohen-Cole (2011) called this situation the domino effect. Hence, interlinkages among banks facilitate the propagation of distress in the event of a large shock (Shakya, 2016).

The banking system in Nigeria operates in such a manner that it is difficult for any bank to prosper or collapse in isolation, at least because of the inter-banking dealings that exist among them. This underscores the fact that the Nigerian banking system may be deeply interconnected, such that failures are strongly propagated from one institution to another. It also underlines the fact that managing systemic risk in the Nigerian banking system requires deeper understanding of the links and connections in the system in terms of measurement and evaluation. Hence, connectedness measurement is central to micro- and macro-prudential policymaking by the CBN (Diebold & Yilmaz, 2015b). A better knowledge of how the banks are connected may therefore provide a valuable insight on how to design regulatory policy that prevent systemic crises in the financial system and avoid total bank failure. A good starting point should then include evidence-based measurement and evaluation of the connectedness of the banking system in Nigeria. Unfortunately, despite the growing empirical literature on connectedness of entities in the financial system globally, especially as it relates to the propagation of financial contagion and the troubling issue of bank failure, the connectedness of the banking system in Nigeria is yet to be empirically investigated. In fact, no empirical study known to the researchers has so far examined the connectedness of the financial system in any individual African economy. The only available study known to us is Ogbuabor *et al.* (2016), which focused on the real and financial connectedness of selected African economies with the global economy. This leaves an obvious gap in the literature, which this study intends to fill.

In the light of the foregoing, this study is poised to achieve the following specific objectives that are aimed at exposing different aspects of the connectedness of the banking system in Nigeria: (i) to estimate the degree of the connectedness of the Nigerian banking system; (ii) to determine the banks that exert dominant influence and therefore have the potential to spread systemic risks in the Nigerian banking industry; (iii) to determine the banks that are most vulnerable to systemic risks arising from connectedness of banks in Nigeria; (iv) to determine if the banks taken over by the CBN in August 2009 were vulnerable or otherwise; and (v) to examine the impact of the 2016 economic recession on the connectedness of the banking system in Nigeria.

Measuring and evaluating the connectedness of the banking system in Nigeria have some key policy implications. It will assist the CBN in systemic risk analysis and management as well as formulating policies in advance to manage future crises in the banking system especially as it has been observed that most policies pursued to address banking crises in Nigeria usually come when the crises had already crystallized. An evidence-based knowledge of the impact of the 2016 economic recession on the connectedness of the Nigerian Banking system will help the CBN to design appropriate regulatory framework that will serve as a basis for responding to such crisis situation in the future. Till date, the model of banking regulation in Nigeria always seeks to enhance the safety and soundness of individual banks within the system by supervising and limiting the risk of distress. However, a key challenge in regulating the banking sector is the absence of a transparent regulatory framework to capture the status of each bank in the *dependence-influence* space. Hence, the CBN often intervenes in the financial system to prevent crisis by citing the contagion that might otherwise have occurred as justification for its intervention. This argument has traditionally been based on historical experience rather than rigorous application of any econometric tool or regulatory framework. It is as a result of the lack of such transparent framework or tool that the CBN was accused of managing the banking system on the basis of "as the spirit directs" (Onu, 2010). This means that the absence of a transparent mechanism for monitoring the banking system, especially during crisis period, is a challenge to the monetary authority. For example, the action of CBN on the takeover of Intercontinental Bank Plc by Access Bank Plc in 2011 generated reactions from the public against the CBN. While this takeover was perceived as largely political by some stakeholders, others saw it as an act of vendetta rather than the outcome of a transparent regulatory activity. It also explains why some shareholders of Union Bank Plc, Finbank Plc, Intercontinental Bank Plc, and Afribank Plc engaged the CBN in legal battle to stop it from sale and/or take-over of the banks. Hence, it is the overall goal of this study to provide a pioneer investigation into the degree and dynamics of the complex connectedness structure of the banking system in Nigeria using a simple, coherent and transparent framework.

2. An Overview of the Nigerian Banking System

This section presents an overview of the policy environment, detailing the regulation of the banking sector, the banking sector recapitalization, the troubling issue of bank distress in Nigeria and some key advances in the banking sector. The patterns of transactions connecting the banks to one another and how these transactions provide the potential links for the propagation of financial contagion through the banking system are also discussed.

2.1. Bank Regulation

The Banking Ordinance which imposed minimum paid-up capital requirement and also established reserve fund was introduced in 1952. The ordinance was later reinforced with the enactment of Banking Decree of 1969. The apex bank in Nigeria, which is the CBN, and the Nigerian Deposit Insurance Corporation (NDIC) are the two main regulatory bodies with mandates to manage the banking sector in Nigeria through regulation and supervision. The CBN has powers to control the deposit money banks and function as a lender of last resort; while the NDIC has the mandate to deliver on two main roles, which are to guaranty deposits and to protect depositors through supervision. The payment of depositors is guaranteed by the NDIC should an insured bank fail. In addition, the NDIC supervises the covered banks to ensure that they are safe, sound and adhere to banking practices. Thus, the NDIC protects bank customers against the loss of their deposits.

Two important instruments which CBN and NDIC employ in conducting their regulatory and supervisory functions are off-site and on-site examinations. The former is conducted through the assessment of banks returns by analyzing bank data on financial ratios generated periodically from the bank financial reports submitted to regulators, while the latter requires that the regulators should be on ground physically in the banks to assess the banks internal controls, compliance to the rules and regulations set out for the operations of the banks so as to determine their level of exposure to risks. Other instruments of banking supervision used by the regulators include maiden examination, routine examination, target/special examination and spot checks[1].

2.2. Bank Distress

The challenge of bank failure has been a reoccurring one in Nigeria over the years. The first round of bank failure in Nigeria took place between 1930 and 1958. Out of the 25 indigenous banks operating in the country, 21 failed in quick successions during this period. Since then, Nigeria has witnessed several other episodes of bank failure. Between 1994 and 1998, 31 banks collapsed. The banking sector reforms of 2004 which was aimed at stabilizing the sector resulted in the shrinking of the number of Nigerian banks from 89 to 25. The 25 surviving banks experienced significant structural transformations particularly in the areas of ownership structure, magnitude of a shareholders fund, expanded deposit base and branch network. The CBN explained that factors such as disregard for corporate governance, fragile capital base, poor quality of assets, constant illiquidity, insider abuse, overreliance on government funds and non-profitable operation necessitated the 2004 banking sector reform in Nigeria (Soludo 2004). These factors are consistent with the submissions of the 1948 Paton's Commission of Enquiry that investigated the causes of bank failure in Nigeria in the 1940s. However, in spite of the 2004 reforms aimed at ensuring a sound and stable banking sector in Nigeria, the mergers and acquisitions of late 2009 led to the extinction of 9 Nigerian banks that found themselves in ugly situations of huge non-performing loans culminating in the erosion of their operating capital (Egbo, 2012; Elegbe, 2013).

Some economists have argued that the actions of the monetary authority sometimes trigger bank distress in Nigeria. For instance, Ebhodaghe (1997) argued that most loans offered to priority areas in order to meet CBN developmental expectations of providing subsidized credit in the 1980s were mostly not repaid, and this worsened the liquidity positions of the banks. Also, the withdrawal of government funds from the commercial banks led to the loss of deposits amounting to N8.27 billion, and this consequently worsened the liquidity problems of the banks (NDIC, 1989). Besides, the sequences of CBN monetary policy measures between 1988 and 1996 resulted in liquidity crises in the banking sector. Ademola *et al.* (2013) explained that the monetary policy measures pursued in those periods were counterproductive and subsequently resulted in the failure of some of the banks between 1994 and 1996.

2.3. Bank Recapitalization

In attempt to strengthen the banking sector and prevent it from unexpected collapse, and to increase depositors' confidence, the CBN had always invoked its policy on recapitalization. Bank

[1] Paseda (2012) and the references therein provide a detailed review of bank regulation in Nigeria.

recapitalization in Nigeria began in 1979, when the capitalization for commercial banks was increased from N600 thousand to N2 million. The minimum-paid up capital was increased to N5 million in February 1988 and N10 million in October 1988. In 1989, the minimum-paid up capital was increased to N20 million, and by 1990, it was further increased to N50 million. Between 1991 and 2005, the minimum-paid up capital for banks was increased as follows: N500 million in 1997; N1 billion in 2001; N2 billion in 2002; and N25 billion in 2005 (Adegbaju & Olokoyo, 2008; Onaolapo, 2008).

The recapitalization exercise of 2005 anticipated that the banks would pump in new cash where appropriate; however, the banks were also encouraged to consider either merger or acquisition arrangement. This is consequently expected to reduce the operational costs of the banks and enhance their competitiveness. The 89 banks in operation prior to the 2005 recapitalization entered into either merger or acquisition in order to meet the minimum capital base of N25 billion. In the aftermath of that recapitalization exercise, 25 deposit money banks emerged. Nonetheless, the Stanbic IBTC merger took place in 2006 thereby bringing the overall number of deposit money banks in operation to 24. These banks were considered sound and solid, and ready to undertake "big ticket" transactions. Furthermore, it was expected that these banks can easily come together as consortiums to fund developmental projects that require huge capital outlay, which they could not undertake prior to the recapitalization exercise. The resulting contractual obligations and balance sheet deals means that the banking system would then become more interconnected post-recapitalization.

A key objective of the 2004/05 bank consolidation exercise was to reduce the frequent distress and failure in the banking industry. However, in spite of the initial gains of this consolidation exercise, a joint CBN/NDIC special investigation into the books of Nigerian banks in 2009 revealed that the some systemically important banks were technically insolvent on account of capital inadequacy, poor credit risk management, liquidity and lack of corporate governance. Accordingly, the CBN took over the management of Afribank Plc, Finland Plc, Intercontinental Bank Plc, Oceanic Bank Plc, and Union Bank Plc in August 2009, and immediately injected N620 billion into the banking system to avert imminent danger of complete distress and failure.

2.4 Inter-Bank Transactions

Nigerian banks play financial intermediation role in the economy, and this requires that they possess sufficient liquidity to manage any likely customers' mass withdrawal arising from bank runs. Any bank that is unable to meet up with the liquidity requirement usually borrow cash in the interbank market to make up for the shortfall, while banks that have surplus cash over the liquidity requirements play the lender role in the interbank market and in return receive interest. Thus, Nigerian banks give loans to each other with a definite term for repayment in the interbank market. Some of those loans mature in less than or after a week, but most of them mature overnight. In addition, interbank deposit with specified interest and maturity date is also one of the channels of interaction among banks. The interbank deposits may be short-term or long term in nature depending on maturity period which ranges from one day to one month. Clearly, interbank transactions, such as interbank borrowings and deposits, provide a channel through which Nigerian banks are interconnected.

Table 1 shows the volume of interbank transaction of some selected banks in Nigeria. It can be seen from this table that activities in the Nigerian interbank market are quite voluminous. It can also be seen that the banks are generally exposed not only to other common obligors (i.e. their borrowing customers) but also to themselves. Again, the CBN (2015) statistics show that in the first quarter of 2015, interbank market transaction was N2,809.58 billion, while the unsecured call and tenored transactions stood at N956.63 billion. Hence, the banking system in Nigeria operates in such a manner that it is difficult for any bank to prosper or collapse in isolation. Given the speed with which financial shocks or contagions propagate, there is, therefore, an urgent need to understand the degree and dynamics of the complex web of interconnectedness of the banking system in Nigeria.

Table 1: Interbank Transactions of Some Nigerian Banks (N' million)

		Loans to Other Banks		**Deposits from Other Banks**	
S/N	**Bank**	**December 2017**	**December 2018**	**December 2017**	**December 2018**
1	Access Bank Plc	68,114,076	142,489,543	450,196,970	994,572,845
2	First Bank of Nigeria Plc	742,929,000	563,435,000	665,366,000	749,315,000
3	First City Monument Bank Plc	-	-	6,355,389	39,140,044
4	Guaranty Trust Bank Plc	750,361	2,994,642	85,430,514	82,803,047
5	Stanbic IBTC Bank	9,623,000	8,548,000	61,721,000	160,272,000
6	Sterling Bank Plc	51,066,000	43,542,000	11,048,000	10,640,000
7	United Bank for Africa	20,640,000	15,797,000	134,289,000	174,836,000
8	Unity Bank Plc	15,152,227	33,139,298	42,957,842	100,347,202
9	Wema Bank Plc	26,495,664	-	26,575,260	369,199,768
10	Zenith Bank Plc	495,803,000	674,274,000	-	-

Source: Annual reports of the banks for the various years.

2.5. Market Power

Market power explains how firms in a given market influence prices, and reveals the level of competition in the market (Ajide & Aderemi, 2015). Studies have shown that healthy competition in the banking system improves the efficiency in the delivery of financial services, enhances the quality of financial products, increases the degree of innovation in the system, and has implications for monetary policy effectiveness (Claessens & Laeven, 2003; Ajide, 2014; Ajisafe & Akinlo, 2014; Bikker, 2003). CBN statistics as shown in Table 2 indicate that five banks (including First Bank of Nigeria Plc, Zenith Bank Plc, Guaranty Trust Bank Plc, Access Bank Plc and United Bank for Africa) dominate the Nigerian banking system in terms of total deposits and total assets. These five banks jointly accounted for 54% of both deposits and assets in the banking system as of October 2016.

Table 2: Market Power of Deposit Money Banks in Nigeria (October 2016)

S/N	Bank	Total Assets (Naira)	Share in Total Assets (%)	S/N	Bank	Total Deposits (Naira)	Share in Total Deposits (%)
1	Zenith Bank Plc	4,123,858,835,076.00	14.17	1	First Bank Of Nigeria Plc	2,528,862,254,933.00	13.89
2	First Bank Of Nigeria Plc	3,615,220,853,586.00	12.42	2	Zenith Bank Plc	2,322,916,067,969.00	12.76
3	Access Bank Plc	2,928,017,328,078.31	10.06	3	Guaranty Trust Bank Plc	1,703,412,072,175.24	9.36
4	Guaranty Trust Bank Plc	2,673,916,925,781.79	9.19	4	United Bank For Africa Plc	1,696,662,333,576.57	9.32
5	United Bank For Africa Plc	2,498,136,395,140.36	8.58	5	Access Bank Plc	1,544,597,053,185.53	8.48
6	Ecobank Nigeria Plc	1,931,854,276,608.92	6.64	6	Ecobank Nigeria Plc	1,279,190,836,636.73	7.03
7	Diamond Bank Plc	1,615,339,609,665.93	5.55	7	Diamond Bank Plc	1,107,055,955,664.36	6.08
8	Fidelity Bank Plc	1,353,832,023,949.31	4.65	8	Fidelity Bank Plc	759,450,415,102.21	4.17
9	Skye Bank Plc	1,179,547,486,679.79	4.05	9	Standard Chartered	724,121,047,833.71	3.98
10	First City Monument Bank Plc	1,171,260,964,359.01	4.02	10	First City Monument Bank Plc	695,471,374,580.32	3.82
11	Union Bank Of Nigeria	1,109,210,589,369.00	3.81	11	Union Bank Of Nigeria	634,476,729,375.00	3.48
12	Stanbic IBTC Bank Plc	1,039,534,872,847.90	3.57	12	Skye Bank Plc	622,298,367,209.85	3.42
13	Standard Chartered	1,027,916,575,077.80	3.53	13	Stanbic IBTC Bank Plc	609,671,332,723.50	3.35
14	Citibank Nigeria LTD	691,294,262,193.07	2.37	14	Citibank Nigeria LTD	523,888,198,863.26	2.88
15	Heritage Bank LTD	565,264,549,447.73	1.94	15	Heritage Bank LTD	363,888,819,256.00	2.00
16	Unity Bank Plc	475,704,736,778.56	1.63	16	Unity Bank Plc	297,331,488,226.14	1.63

S/N	Bank	Total Assets (Naira)	Share in Total Assets (%)	S/N	Bank	Total Deposits (Naira)	Share in Total Deposits (%)
17	Wema Bank Plc	405,945,672,591.64	1.39	17	Wema Bank Plc	291,368,648,376.68	1.60
18	Keystone Bank Limited	267,878,859,824.00	0.92	18	Keystone Bank LTD	236,854,184,831.00	1.30
19	FSDH Merchant Bank	130,829,075,985.01	0.45	19	FBN Merchant Bank LTD	86,719,658,276.00	0.48
20	FBN Merchant Bank LTD	121,426,182,186.00	0.42	20	FSDH Merchant Bank	76,923,558,573.32	0.42
21	Coronation Merchant Bank	103,441,745,221.00	0.36	21	Coronation Merchant Bank	71,414,932,129.00	0.39
22	Rand Merchant Bank	63,101,882,591.66	0.22	22	Rand Merchant Bank	27,493,691,999.26	0.15
23	Suntrust Bank Nigeria LTD	15,175,090,625.68	0.05	23	Suntrust Bank Nigeria LTD	3,165,200,482.14	0.02
	Total	**29,107,708,793,664.50**	**100.00**			**18,207,234,221,977.80**	**100.00**

Source: CBN Database

2.6. Some Recent Developments in the Nigerian Banking Sector

Over time, the Nigerian banking sector has witnessed increased volume of operations, innovation and adoption of electronic and telecommunication networks for service improvement, and development of various value added products and services. The banking sector has benefitted from information and communication technology (ICT), which is the product of technological advancement. Electronic fund transfer (EFT), mobile telephone banking, personal computer banking, automated teller machine and internet banking have become common features of the Nigerian banking system. These products make it easy for funds to move from one bank to another, thereby enhancing the connectedness of the banking sector in Nigeria.

The Nigerian banking system has also witnessed periods of unhealthy and stiff competition that resulted in distress of some banks and aggressive marketing practices that occasioned poor treatment of customers by some banks. This was particularly the case as the banks struggled to meet the N25 billion capital base stipulated by the CBN in 2004, thereby resulting in unethical practices in the system (Ahmad, 2004). Some banks employed unqualified managers to man sensitive positions, thereby weakening ethical standards and professionalism in the sector. The CBN responded to these ugly developments by rolling out the Banking Sector Code of Conduct to avert and punish misconducts and unethical behaviors in the system. The major aim of the Code of Conduct is to ensure stringent compliance to best practices in the industry and genuine commitment to ethical and professional standards. This greatly helped to shape the behavior of the players in the system. Again, in trying to address the unwholesome practice of de-marketing (a situation where banks tried to pull down one another through deceitful information and unsubstantiated rumor) in 2006, the CBN read the riot act through a circular to all commercial banks concerning de-marketing. It described the trend as unethical and unprofessional. According to the CBN, de-marketing has the potential of creating panic amongst bank customers and could ultimately lead to a run on the affected bank. Unfortunately, a run on a de-marketed bank has the potential of affecting the entire banking system since the banks are interconnected through their exposures to common obligors as well as to themselves.

Overall, this review shows that the banking system in Nigeria has evolved over the years from manual to electronic system, which offers products that facilitate easy movement of funds from one bank to another, thereby enhancing the connectedness of the banking system. It also shows that the system has witnessed periods of unhealthy competition and aggressive marketing practices, which in turn have the potential of spreading contagion across the entire system. In addition, this review shows that the domestic interbank market provides a veritable channel through which deposit money banks in Nigeria are interconnected. Furthermore, the review shows that the recapitalization exercise of 2005 produced bigger and stronger banks that could undertake increased contractual obligations and balance sheet deals, which will in turn result in a more interconnected banking system in the post-recapitalization period. Lastly, this review shows that Nigeria has witnessed several episodes of bank distress/failure, and that each episode is usually characterized by the collapse of several banks. This clearly shows that the banking system in Nigeria is interconnected, such that it is difficult for any bank to collapse in isolation, which is consistent with Greenwood-Nimmo *et al.* (2015).

3. Literature Review

3.1. Some Theoretical Perspectives: The theory of financial contagion and the concept of systemic banking crises are relevant in explaining the co-occurrence of bank failures in Nigeria as well as the complex web on connectedness in the Nigerian banking system. Financial contagion is seen as the transmission of shocks from one financial market or bank in the case of this study to other banks. Contagion happens both at global and domestic levels. At the international level, it is the transmission of shock or crises from a country undergoing crises to other countries. This is possible because of the fact that the world is a global village where countries interact with one another as they trade. However, at the domestic level, financial contagion occurs when a bank or financial institution in crises spreads the shocks or crises to other banks. This is possible because of the interactions and interdependencies that exist among the banks. According to Dornbusch *et al.* (2000), financial contagion is the transmission of market shocks or imbalances. The central issue in theories of contagion is identifying the channels of transmission. Eichengreen *et al.* (2001) explains that mutual influence is one cause of contagion and the contagion transmission process relates to interdependence, whether real or financial and they referred to the latter as mechanical contagion. Literature identified two main channels of transmission of contagion: the first is based on fundamental links and the second is based on investors behavior associated with social learning (Kaminsky *et al.*, 2003). Trevino (2014) demonstrates how fundamentals and social learning affect individual behavior, and how this behavior leads to contagion under different economic environments. Trevino showed that contagion happens when a country witnesses a crisis and the crisis spreads to other countries as a result of connections that affect their key fundamentals such as through financial or trade links.

Bank runs model was used by Allen and Gale (2000) to extend the theory of financial contagion beyond the idea of financial fragility by demonstrating that shock affecting a smaller bank within the banking system can be a threat to a larger bank. Banks within a given financial system are endangered to similar shocks as a result of unexpected liquidity demands or unplanned changes that arises from the asset value of the banks like securities and loans. In order to provide a buffer against danger of unexpected shock, the banks hold claim against one another within the system. Under normal circumstance, the claim enables the banks within the system to maintain smooth and stable liquidity demands and assets returns. Suppose Bank A is having excess liquidity and Bank B is facing liquidity shortage, Bank B can call up some of its claims on Bank A. But if there is a general problem of illiquidity within the system, the response of Bank A to Bank B's claim would be less kindly. Because the level of liquidity within the financial system in a given time is fixed, the available means of increasing the liquidity level is to liquidate some of the less liquid assets, that is, selling some longer term assets possibly at attractive prices or by terminating some investments prematurely. The bank that sells its assets is faced with loss of asset value that comes with it, and if the loss is much larger, this may trigger a bank run which in turn could force more asset liquidation and bigger loss of value. Allen and Gale (2000) argue that the connectedness of the banking system is the cause of the spread of contagion process to other banks. If Bank A collapses and Bank B holds claims against Bank A, spillover effect will set in. Thus, the loss of value of Bank A's asset will reduce Bank B's claims against Bank A. Suppose the spillover effect is much bigger, it might cause Bank B to go bankrupt. Due to the fact that Banks A and B have been affected by crises, there will be panic within the system since depositors having knowledge of the information could forestall imminent financial crises within the banking system and engage in massive withdrawal from other banks. This could trigger another round of bank runs particularly if another bank (Bank C) is holding claims against Bank B, hence the losses of Banks A and B will compound Bank C's woes. This could again precipitate or snowball into a financial crisis within the system and the overall economy.

According to Laeven and Valencia (2008), banking crisis is a situation whereby a country's financial sector witnesses bank runs, sharp increases in default rates accompanied by large losses of capital that result in public intervention, bankruptcy, or merger is imposed compulsorily on the core financial institutions. They further defined systemic banking crisis as a situation where a financial sector of a country witnesses a large number of defaults and the financial institutions are confronted with difficulties in repaying contracts on time. Consequently, non-performing loans increase sharply and all or most of the capital of the entire banking system is exhausted. Under this circumstance, depressed asset prices like prices of equity and real estate on the heels of run-ups before the crisis, sharp increases in real interest rates, and a slowdown or reversal in capital flows ensues. The theory of financial contagion and the concept of systemic bank crisis aptly reflect the Nigerian situation where the banking system has severally witnessed cases of bank failures. Between 1930 and 1958, 21 banks out 25 indigenous banks failed in quick successions. In 1994, 5 banks ceased to exist; between 1995 and 1998, 26 banks collapsed; while the banking reforms of 2004 swept away 14 banks and in 2009 mergers and acquisitions led to the extinction of 9 banks. In December 2018, Access Bank took over Diamond Bank while the CBN took over Skye bank and renamed it Polaris Bank preparatory to its sale to a prospective investor (Babalola, 2011; Egbo, 2012; Elegbe, 2013).

3.2. Empirical Literature: 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 country-specific level while others were multi-country studies. Besides, the multi-country financial connectedness studies have also been found to be either regional or global in nature. In what follows, the empirical 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 using the network methodology they advanced, which can study both crisis and non-crisis episodes at the same time, including trends and bursts in equity markets spillovers. 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.

Another major study that focused on international transmission of financial contagion is the study by Diebold and Yilmaz (2015a), which examined daily stock return volatilities of 35 major financial institutions, 18 European and 17 U.S., from January 2004 to June 2014. The European sample includes only commercial banks. The study also used the econometric framework advanced by Diebold and Yilmaz (2009). The results indicate that the direction of connectedness was mainly from the U.S. to Europe during the period 2007-2008, which highlights the U.S. as the source of the global financial crisis within this period. However, the connectedness became largely bi-directional around late 2008. In fact, the results show increased connectedness from European to U.S. financial institutions towards mid-2011, which is consistent with the massive deterioration in the health of European financial institutions. Overall, the study established a total connectedness of 81.7% across all the financial institutions, with the highest pairwise connectedness occurring between the U.S. and the UK, which highlights the strong ties between their financial sectors. One major fact established by this study is that crises episodes increase the connectedness measures beyond their pre-crisis levels, which is consistent with the bulk of the empirical literature.

Yilmaz (2014) studied the dynamic measures of volatility connectedness of major bank stocks in the US and the EU member countries using the Diebold and Yilmaz (2009) connectedness framework. The study transparently characterized the contributions of each individual bank to the overall volatility connectedness and find that the direction of the volatility connectedness was mainly from the U.S. banks to the EU banks during the initial stages of the 2007-2008 global financial crisis. However, the volatility connectedness became bi-directional when the crisis assumed a global dimension in the last quarter of 2008. The study explained that the increased volatility connectedness moving from the EU banks to the US banks around mid-2011 clearly highlighted the huge and unprecedented deterioration of the EU banks. Furthermore, the study established the European debt and banking crisis increased the connectedness of the EU banks after 2007, which is consistent with the finding of Diebold and Yilmaz (2016) that crises episodes increase the connectedness measures beyond their pre-crisis levels.

Guimarães-Filho and Hong (2016) studied the connectedness of Asian equity markets from 1996M1 to 2015M10 using the Diebold and Yilmaz (2009) methodology. The results indicate that financial shocks emanating from Asia can no longer be called insignificant, and 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 both return and volatilities 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. This is consistent with the trend of growing intra-regional financial integration between Asia and the rest of the world.

Other studies that have applied the Diebold and Yilmaz (2009) methodology in the study of financial connectedness at the international level include: Demirer *et al.* (2018) which extended the Diebold and Yilmaz (2009) approach by confronting the dimensionality problem using LASSO methods and find that both the 2007-08 global financial crisis and the EU debt crisis increased the global equity connectedness considerably; Echevarria-Icaza and Rivero (2016) which studied the connectedness of European Economic and Monetary Union (EMU) sovereign and bank CDS from 2008M4 to 2014M12 and find that the systemic impact of banks varies speedily during crises period such that it becomes difficult to determine which banks are systemically important or otherwise; Cipollini *et al.* (2014) which studied the connectedness of five European stock markets (namely France, Germany, UK, Switzerland and the Netherlands) and find that over the period 2000M1–2013M8, the total volatility connectedness index has been relatively stable with France exhibiting an increasing role while Germany showed a positive but declining importance;

Gatjen and Schienle (2015) which studied the connectedness of European sovereigns and find that unstable countries are relatively more affected by financial crisis than stable ones that mainly react during the peak of such financial crisis; Bostanci and Yılmaz (2020) which studied the connectedness of global sovereign credit risk and find that on the average, emerging market countries are the main transmitters of sovereign credit risk shocks across the globe and that shocks to other financial assets are quickly transmitted to the sovereign credit risk spreads; Rodríguez and Sosvilla-Rivero (2016) which studied the connectedness of stock and foreign exchange markets of seven major world economies from 1988M7 to 2015M1 and find that the total connectedness index was 48.75% and that volatility connectedness is time-varying, with a surge during periods of increasing economic and financial instability. Andrada-Félix *et al.* (2018) and Barunik and Krehlik

(2016) also applied the Diebold and Yilmaz (2009) framework in their study of international financial connectedness.

The above studies indicate that the Diebold and Yilmaz (2009) network methodology has been widely applied to the study of international transmission of financial contagion. But beyond the study of financial connectedness at the international level, the framework has also been applied to country-specific studies of financial system connectedness. Indeed, one of the pioneer country-specific studies focusing on financial connectedness is the study by Diebold and Yilmaz (2014), which investigated the stock return volatilities connectedness of major U.S. financial institutions from 1999 to 2010. The results indicate that the highest pairwise directional connectedness occurred between Citigroup and J. P. Morgan, and 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. The results further indicate that Fannie Mae, Freddie Mac and AIG had the least pairwise directional connectedness, which highlights the fact that these three institutions had lots of troubles during the 2007-08 global financial crises and could have gone under without the intervention of the U.S. government.

Other country-specific studies of financial connectedness include: Diebold and Yilmaz (2012) which studied four main classes of U.S. assets markets (stocks, bonds, foreign exchange and commodities markets) from January 1999 to January 2010 and find that the 2007-08 global financial crisis increased the volatility connectedness beyond its pre-crisis level and that the direction of volatility shock transmission was mainly from the stock market to other markets thereby showcasing the role of the U.S. stock market in the propagation financial shocks; Bu, Kim and Shin (2013) which studied the connectedness of the Korean financial system from 1999 to 2012 and find that securities companies and foreign banks are systemically dominant, credit card companies play important roles mainly in the long-run, regional banks are generally vulnerable, insurance companies and credit specialized companies are mainly vulnerable in the long-run, while Kookmin Bank and Shinhan Bank are found to be systemically dominate the Korean financial system.

In a pioneer study of the connectedness of Africa and the rest of the world, Ogbuabor *et al.* (2016) estimated the real and financial connectedness of selected African economies with the global economy from 1981Q1 to 2012Q3 based on the Diebold and Yilmaz (2009) approach. The study used the normalized generalized forecast error variance decompositions (NGFEVDs) distilled from an approximating vector autoregressive (VAR) model to construct connectedness measures at various levels of aggregation. The results indicate that the connectedness of African economies with the rest of the world is quite substantial and that the global financial crisis increased the connectedness measures above their pre-crisis levels. The results also show that the U.S., EU and Canada dominate Africa's equity markets, while China, India and Japan dominate Africa's real activities. Overall, the results indicate that African economies are mainly small open economies, which are profoundly interconnected with the global economy but are systemically unimportant and vulnerable to headwinds emanating from the rest of the world.

Beyond the Diebold and Yilmaz (2009) network approach, several other methodologies have also been used to empirically examine the financial linkages among entities in the global economy. Billio *et al.* (2012) and Merton (2014) used the Granger Causality method to describe networks in order to show how interlinkages among entities can be characterized and understood. A major drawback of the Granger Causality Approach is its ability to capture only pairwise relations and it is bivariate focusing on only two variables without consideration for simultaneous effect of other variables. Thus, it may not be suitable to answer essential question like "What is the degree of connectedness of deposit money banks in Nigeria?" since the banks are more than two in number. Kose *et al.* (2003) and Brunetti *et al.* (2019) applied the Correlations-Based Measures. The three major shortcomings of this method are: correlation is simply a pairwise measure of association, it measures only linear relationship and it is non-directional. This means that the method is unable to answer the questions of "how connected is Zenith Bank Plc to all other deposit money banks in Nigeria?" Unlike the correlation-based measures of connectedness, the connectedness measures of Diebold and Yilmaz (2009) are non-pairwise, yet directional. Other methods that have also been applied in financial connectedness studies include the Dynamic Tail-Event Driven Networks (TENETs) model (Wang *et al.*, 2018); the Out-Of-Sample Variance Decomposition of Model Forecast Errors (Gätjen & Schienle, 2015); 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 studies is that they were only able to establish the existence of spillovers and its direction, while the methodology was unable to show the estimate of their degree of connectedness within a given financial system. The above review of the empirical literature further shows that the Diebold and Yilmaz (2009) network methodology provides an explicit and transparent means of empirically studying both financial and real connectedness of entities at country, regional and global levels.

4. Methodology and Data

This study follows the network approach of Diebold and Yilmaz (2009, 2015b). The choice of this approach is based on its ability to transparently use the size and direction of shocks to build both directional and non-directional connectedness measures over a given forecast horizon. The broad goal of this study is to investigate the connectedness of the banking system in Nigeria. In line with Diebold and Yilmaz (2009), the normalized generalized forecast error variance decompositions (NGFEVDs) obtained from an underlying $\boldsymbol{p}$-th order vector autoregression (VAR) model for the $\boldsymbol{N\ x\ 1}$ vector of endogenous variables $\boldsymbol{Z_t}$ are used to construct the measures of connectedness for this study. The VAR($\boldsymbol{p}$) model for this study is specified as follows:

$$\boldsymbol{Z_t = \alpha_y + \sum_{j=1}^{p} \Phi_j Z_{t-j} \ + \ \varepsilon_t, \qquad t = 1, 2, \dots, T} \tag{1}$$

where $\boldsymbol{\alpha}$ is $\boldsymbol{Nx1}$ vector of intercepts; $\boldsymbol{\Phi_j}$ is $\boldsymbol{N\ x\ N}$ matrix of coefficients; the lag order is $\boldsymbol{p}$; and the residuals $\boldsymbol{\varepsilon_{it} \sim iid(0, \sum_{\varepsilon,ii})}$ so that $\boldsymbol{\varepsilon_t} \sim (\boldsymbol{0}, \sum_{\boldsymbol{\varepsilon}})$, where $\sum_{\boldsymbol{\varepsilon}}$ is positive definite covariance matrix. For the baseline analysis, the vector of endogenous variables ($\boldsymbol{Z_t}$) includes the log of real equity returns, which embody investors behavior that in turn reflect the fundamentals or balance sheets of the banks. Data on interbank exposures are not available and are therefore not used in the analysis. However, for the robustness or sensitivity analysis, the vector of endogenous variables includes logs of total deposits and total assets of the banks, which reflect the market power of the banks. These balance sheet data are consistent with the fact that banking institutions in Nigeria can be connected through counterparty linkages associated with their positions in various assets, through contractual obligations associated with services provided to their clients and other financial institutions, and through deals recorded in their balance sheets. Allen and Babus (2009) explains that banks are interconnected through their mutual exposures inherited in the interbank market, through holding of similar portfolios, and through having bulk of similar depositors, such that assets and liabilities in the balance sheets of banks cause a high degree of interdependence and connections among them. $\boldsymbol{N}$ is the number of deposit money banks selected for this study. The approach adopted in this study is to estimate equation (1) separately for real equity returns, total deposits and total assets connectedness. The appropriate VAR lag orders were selected based on Schwarz Information Criterion (SIC) so that sufficient lags are included to ensure serially uncorrelated residuals.

By adopting the basic VAR in equation (1), this study takes the view that the data should talk about themselves. This is because VAR models are generally termed ‘atheoretical’, since they are generally not based on any economic theory. Hence, even though the methodology for this study is built around the theoretical framework underpinned by the theory of financial contagion, all the banks in the VAR system would be allowed to interact among themselves. This study uses the Wold’s Representation Theorem, which stipulates that all stationary processes, apart from their deterministic components (if any), can be explained solely in terms of current and past innovations. This study also uses the technique of back-substitution in equation (1) so that as $\boldsymbol{T} \rightarrow \infty$, $\boldsymbol{Z_t}$ can be expressed as an infinite vector moving average representation given by:

$$\boldsymbol{Z_t = \varepsilon_t + \Theta_1 \varepsilon_{t-1} + \Theta_2 \varepsilon_{t-2} + \ldots = \sum_{j=0}^{\infty} \Theta_j \varepsilon_{t-j}} \tag{2}$$

where $\boldsymbol{\Theta_0 = I_N}$, $\boldsymbol{\Theta_j = \Phi^j}$, $\boldsymbol{j = 1, 2}, \ldots$, and $\boldsymbol{I_N}$ stands for an $\boldsymbol{N \times N}$ identity matrix in which all the principal diagonal elements are ones and all other elements are zeros.

The Diebold and Yilmaz network approach requires that after estimating the underlying VAR model, the forecast error variance decompositions are then generated and used to build connectedness measures. The primary area of attention in this study therefore lies in the shocks to the disturbances, $\boldsymbol{\varepsilon_{it}}$ in the bank-specific equations. Accordingly, this study follows the established literature such as Diebold and Yilmaz (2016), Pesaran and Shin (1998), and Koop *et al.* (1996) by adopting the generalized forecast error variance decompositions (GFEVDs), which are invariant to the reordering of the variables in the system. The GFEVDs are defined as:

$$\boldsymbol{GFEVD(Z_{it};\ \varepsilon_{jt}, H) = d_{ij}^{gH} = \frac{\sigma_{\varepsilon,jj}^{-1} \sum_{h=0}^{H-1} (e_i' \Theta_h \Sigma_\varepsilon e_j)^2}{\sum_{h=0}^{H-1} (e_i' \Theta_h \Sigma_\varepsilon \Theta_h' e_i)}} \tag{3}$$

where $i, j = 1, \ldots, N$; $H = 1, 2, \ldots$ is the forecast horizon; $e_i(e_j)$ is $N\ x\ 1$ 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; $\sum_{\boldsymbol{\varepsilon}}$ is the covariance matrix of the shock vector in the non-orthogonalized VAR; and $\boldsymbol{\sigma_{\varepsilon,jj}}$ is the *j*-th diagonal element of $\sum_{\boldsymbol{\varepsilon}}$ (i.e. the standard deviation of ε_j). It must be stressed that the choice of GFEVDs for this study rather than the orthogonalized forecast error variance decompositions (OFEVDs) of Diebold and Yilmaz (2009) is based on several justifications. One, OFEVDs depend on the reordering of the variables in the VAR model, which means that once the order of variables in the VAR is reshuffled, a different outcome results. Two, the choice of Cholesky decomposition is not unique since there are a number of alternative sets of orthogonalized variance decompositions which can be obtained from any estimated VAR model. Three, a given choice of orthogonalization might be suggested by economic theory, but Sims (1980) approach to choosing an orthogonalization was to impose a causal ordering on the VAR. However, this requires recourse to economic theory, thereby defeating the object of this approach; and in general, no such restrictions are available or acceptable. Four, in the absence of such restrictions, the orthogonalized variance decompositions are hard to understand economically, so that the estimated model gives few important insights into the economic system that it represents, and is mainly used as a pure forecasting tool. Overall, the generalized variance decomposition framework adopted in this study does not require orthogonalized shocks; rather, it allows and accounts for correlated shocks using the historically observed error distribution, under a normality assumption. Equation (3) shows the entries in the GFEVD matrix.

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, and therefore render the interpretation of the GFEVDs difficult. To restore a percentage interpretation of the GFEVDs in this study, we adopt the normalized GFEVDs (NGFEVDs) as defined by Diebold and Yilmaz (2014). The NGFEVDs are given by:

$$\widetilde{D}^g = [\tilde{d}_{ij}^g], \ \ \textbf{where } \tilde{d}_{ij}^g = \frac{d_{ij}^g}{\sum_{j=1}^N d_{ij}^g}, \ \ d_{ij}^g = \boldsymbol{GFEVD(Z_{it};\ \varepsilon_{jt}, H)} \qquad (4)$$

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 entity 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 superscript H whenever it is not needed for clarity such that $\mathrm{D^{gH}}$ and $\mathrm{d_{ij}^{gH}}$ are simply written as $\mathrm{D^g}$ and $\mathrm{d_{ij}^g}$ respectively.

4.1. The Generalized Connectedness Measures (GCMS)

In this section, a range of connectedness measures used in this study is defined. Even though these measures were initially proposed by Diebold and Yilmaz (2009), they were later extended by Greenwood-Nimmo *et al.* (2015) to include more complex but intuitively appealing *dependence* and *influence* indices. The intuition behind the Diebold and Yilmaz (2009) methodology is somewhat 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 $\boldsymbol{Z_1}$, for example, is attributable to shocks to $\boldsymbol{Z_1}$? Shocks to $\boldsymbol{Z_2}$? In general, what component of the h-step-ahead error variance in forecasting $\boldsymbol{Z_j}$ is attributable to shocks to $\boldsymbol{Z_i}$, for all $\boldsymbol{i, j = 1, 2, \dots, N}$? Hence, the Diebold and Yilmaz (2009) network approach marries network topology theory and VAR variance decomposition theory by underlining the fact that VAR variance decompositions form networks and also characterizing connectedness in those variance decomposition networks, which in turn portrays the connectedness of the entities in the VAR system. Herein lies the intuition behind this methodology, which has been exploited in subsequent studies with great success. To conserve space, we do not dwell further on the relations between VAR variance decomposition and network theory, which has been authoritatively documented by Diebold and Yilmaz (2015b).

Table 3: Connectedness Table Schematic

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

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 (4.4) for the vector of endogenous variables $\boldsymbol{Z_t}$ be denoted by $\boldsymbol{d_{ij}}$. The connectedness table schematic shown in Table 3 is developed by cross-tabulating $\boldsymbol{d_{ij}}$. 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. It must be stressed here that the GCMs can be constructed at various levels of aggregation. This study will, however, define only the measures that are needed for the ensuing analysis, while other background information on how the GCMs are constructed is left for the references such as Diebold and Yilmaz (2015b) and Greenwood-Nimmo *et al.* (2015).

The diagonal entries in Table 3 capture the own variance contributions (or *own-effect*), while the off-diagonal entries capture the variance contributions arising from shocks to other entities in the system and are thus acknowledged as pairwise directional connectedness. Accordingly, the *own-effect*, also known as the *heatwave*, is constructed in this study as:

$$\boldsymbol{H_j = d_{jj}} \tag{5}$$

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

$$\boldsymbol{F_j = \sum_{i=1, i \neq j}^{N} d_{ji}} \tag{6}$$

Since each row of Table 3.1 is normalized to 100%, it is easily seen that $\boldsymbol{H_j + F_j = 1}$ by construction $\forall\, \boldsymbol{j = 1, 2, \dots, N}$. 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 $\boldsymbol{Z_{jt}}$, to all other banks in the system. Thus, the *to-effect*, which effectively captures the total contributions or spillovers from a particular bank, $\boldsymbol{Z_{jt}}$, to all other banks in the VAR system is constructed as:

$$\boldsymbol{T_j = \sum_{i=1, i \neq j}^{N} d_{ij}} \tag{7}$$

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, $\boldsymbol{Z_{jt}}$. Hence, the *net-effect* connectedness measure is constructed in this study as:

$$\boldsymbol{N_j = T_j - F_j} \tag{8}$$

Since there are $\boldsymbol{N}$ banks in the system, it also follows that there are $\boldsymbol{2N}$ total directional connectedness measures made up of $\boldsymbol{N}$ *to-effect* measures capturing spillovers to others and $\boldsymbol{N}$ *from-effect* measures capturing spillovers from others. These are akin to total lending to and total borrowing from other banks for each of the $\boldsymbol{N}$ banks in the system. Furthermore, there are $\boldsymbol{N}$ *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 $\boldsymbol{N}$ 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 $\boldsymbol{\sum_{j=1}^{N} N_j = 0}$ by construction.

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

$$\boldsymbol{S_j^e = T_j + F_j} \tag{9}$$

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:

$$\boldsymbol{C = \frac{1}{N}\sum_{j=1}^{N} F_j = \frac{1}{N}\sum_{j=1}^{N} T_j} \tag{10}$$

The *total-effects* captures the grand total of the off-diagonal elements in Table 3, which is equivalent to the sum of the *from-effects* column or *to-effects* row, and 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 $\boldsymbol{N}$ banks in the system, it must be the case that by construction:

$$\boldsymbol{N = \frac{(\sum_{j=1}^{N} F_j + \sum_{j=1}^{N} H_j)}{100}} \tag{11}$$

To assess the vulnerability or dependence of a given bank (the j-th bank, say) on external shocks on the one hand, and the dominance or influence of a given bank (the j-th bank, say) on the system as a whole, this study defines two essential indices, namely: the dependence index and the influence index. These indices are specifically needed in this study given the desire to examine the influence or vulnerability of deposit money banks in Nigeria. Technically, the dependence index is constructed in this study as:

$$\boldsymbol{O_j^H = \frac{F_j}{H_j + F_j}}, \qquad \forall\, \boldsymbol{j = 1, 2, \ldots, N} \tag{12}$$

where $\boldsymbol{0 \le O_j^H \le 1}$ expresses the relative importance of external shocks for the j-th bank in the VAR system. If $\boldsymbol{O_j^H} \rightarrow \boldsymbol{1}$, then conditions in the j-th bank is quite sensitive to external shocks; but if $\boldsymbol{O_j^H} \rightarrow \boldsymbol{0}$, then the j-th bank is less sensitive to external conditions. Likewise, the influence index is constructed for this study as:

$$\boldsymbol{I_j^H = \frac{N_j}{S_j^e}}, \qquad \forall\, \boldsymbol{j = 1, 2, \ldots, N} \tag{13}$$

where $\boldsymbol{-1 \le I_j^H \le 1}$. For a given horizon H, the j-th bank is a net shock receiver if the index is positive, i.e. $\boldsymbol{-1 \le I_j^H} < 0$; a net shock transmitter if the index is negative, i.e. $\boldsymbol{0 < I_j^H \le 1}$; and neither a net receiver or transmitter of shocks if the index is zero, i.e. $\boldsymbol{I_j^H = 0}$. Hence, the influence index captures the extent to which the j-th bank influences or is influenced by external conditions. In sum, the coordinate pair $(\boldsymbol{O_j^H}, \boldsymbol{I_j^H})$ in the dependence-influence space gives a clear understanding of bank j's role or status in the Nigerian banking system. A priori expectation is that a small bank like Wema Bank Plc would be typically positioned around the point (1,-1), while an overwhelmingly dominant bank like First Bank of Nigeria Plc would be situated close to the point (0,1).

4.2 Justification for the Choice of Underlying Model

The main reason for adopting the VAR framework for this study is that it can be used to identify an underlying set of identically and independently distributed (*iid*) shocks in line with the Diebold and Yilmaz (2009) Generalized Forecast Error Variance Decompositions (GFEVD). Besides, the generalized variance contributions of the VAR model can be used to define and build connectedness network in the manner akin to Diebold and Yilmaz (2015b, 2016). Indeed, the approach here is based on modern network approach. This means that the VAR methodology adopted for this study performs far better than correlation-based measures of connectedness, which are generally non-directional and the Granger Causality Approach which captures only pairwise relations. The VAR variance decompositions form networks and characterize connectedness in the variance decomposition networks, which in turn characterize connectedness of the variables in the VAR. Furthermore, the VAR approach will enable this study to effectively and efficiently model time-varying connectedness in a flexible manner in order to better understand the impact of the 2016 economic recession on the interlinkages among deposit money banks in Nigeria. This is because the VAR framework is dynamic and its parameters are time-varying. In addition, since the emphasis in this study is on both measurement and estimation, the use of VAR methodology will aptly capture these goals. Summarily put, the VAR variance decomposition adopted for this study facilitates the building of connectedness networks that are directed, weighted and dynamic.

4.3 Data and Preliminary Descriptive Statistics

The full sample data for this study covers the monthly period June 2005 to November 2016. The choice of this period is to enable us account for Skye Bank (which became Polaris Bank in September 2018) and Diamond Bank (which announced its merger with Access Bank in December 2018). This is to ensure that the banking system that emerged following the 2004/2005 consolidation exercise is substantially accounted for. The full sample includes thirteen deposit money banks that were operational during the period and whose stock prices are consistently available from the Nigerian Stock Exchange (NSE). These 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). The monthly stock prices of these banks were used to compute the stock returns as the logged stock prices.

The sub-sample data for this study consists of weekly observations on the stock prices of twenty deposit money banks operating in the Nigerian banking system from January 2006 (i.e. the period immediately following the consolidation exercise) to August 2009 (i.e. when the CBN took over five banks that were adjudged unsound). The banks in the sub-sample include: 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). The stock prices of these banks are consistently available from the NSE over this period. The choice of this period is to facilitate an indepth evaluation of the CBN intervention in the banking system in August, 2009. This sub-sample will further serve as a robustness check on the full sample estimations. For this sub-sample, the stock prices were also used to compute the stock returns as logged stock prices. Unlike the full sample which comprises monthly observations on the stock prices, the choice of weekly frequency for the sub-sample period is due to the relatively short span of this period. However, each weekly observation is obtained as the average stock price for that week. In what follows, the descriptive statistics of the variables based on the raw stock prices before they were logged for estimation are presented in Table 4, in which Panel 1 reports for the full sample while Panel 2 reports for the sub-sample.

Focusing on Panel 1, we find that Unity and Wema recorded the least stock price of 50 kobo, which occurred between May to September, 2012. However, Unity also witnessed this price from January 2014 to March 2015. This is one of the typical cases in which the stock price remained inactive for a prolonged period of time. We also find that Zenith, FBN and UBA recorded the maximum stock prices of N63.50, N59.62 and N59.37 which occurred in July 2007, July 2006 and May 2008, respectively. This shows that as of May 2008, the banking system in Nigeria was yet to feel the impact of the 2008-09 Global Financial Crisis (GFC). The descriptive statistics in Panel 1 also indicate that Zenith, GTB and FBN recorded the highest mean stock prices of N21.71, N20.65 and N20.26, respectively. The maximum values indicate that Zenith, FBN, and UBA had the recorded the highest values of N63.50, N59.62, and N59.37, respectively. The descriptive statistics also show that all the variables witnessed variability to some extent as seen in the standard deviations, with UBA, FBN, UBN and Zenith showing the highest variability in stock prices.

Table 4: Descriptive Statistics of the Variables

Panel 1: Full sample (June 2005 – November 2016)

	ACCESS	DIAMOND	FBN	FCMB	FIDELITY	GTB	SKYE
Mean	8.4831	7.2007	20.2568	6.1783	3.4181	20.6517	5.5803
Median	7.5736	6.5588	15.4013	4.8151	2.5433	19.2554	4.1878
Maximum	24.1833	22.2871	59.6186	19.9938	11.9900	37.4061	17.8159
Minimum	2.3741	0.9935	3.0258	0.7924	0.8400	9.4786	0.5500
Std. Dev.	4.8987	4.6622	13.4336	4.4954	2.9104	6.9236	4.1423
Skewness	1.4446	1.4735	0.8752	1.5935	2.0134	0.4410	1.3948
Kurtosis	4.7963	4.9668	2.6821	4.8423	5.8328	2.2508	4.3149
Jarque-Bera	66.5551	72.1782	18.1973	77.9160	139.3802	7.7006	54.6861
Probability	0.0000	0.0000	0.0001	0.0000	0.0000	0.0213	0.0000
Sum	1170.6690	993.6941	2795.4380	852.6027	471.7035	2849.9300	770.0835
Sum Sq. Dev.	3287.5750	2977.8060	24723.2100	2768.5430	1160.4220	6567.2170	2350.7350

Observations	138	138	138	138	138	138	138

	STERLING	UBA	UBN	UNITY	WEMA	ZENITH
Mean	2.8475	14.0206	15.0102	2.0093	3.4831	21.7104
Median	2.3110	8.7886	9.6355	1.1080	1.1496	17.6558
Maximum	8.8595	59.3665	44.1195	9.1376	15.0000	63.5041
Minimum	0.7718	2.0560	2.0900	0.5000	0.5000	11.4914
Std. Dev.	1.8898	14.1438	12.6036	2.0921	4.5271	11.3283
Skewness	1.6280	1.8022	1.0388	1.7855	1.7616	1.8282
Kurtosis	4.5514	5.1612	2.7211	5.3012	4.6224	5.5385
Jarque-Bera	74.8010	101.5576	25.2683	103.7714	86.5105	113.9231
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	392.9566	1934.8480	2071.4090	277.2886	480.6745	2996.0390
Sum Sq. Dev.	489.2836	27406.2900	21762.4200	599.6125	2807.7690	17581.3800
Observations	138	138	138	138	138	138

Panel 2: Sub-sample (January 2006 – August 2009)

	ACCESS	AFRIBANK	DIAMOND	ECOBANK	FBN	FCMB	FIDELITY
Mean	11.2068	15.4993	11.3841	12.9951	35.7419	9.9785	6.2297
Median	8.9320	11.5100	9.5400	8.2000	38.3960	7.4100	4.4460
Maximum	25.0000	35.6100	23.1280	27.9600	64.6600	20.7650	12.4240
Minimum	2.2660	5.1400	4.0880	3.4633	14.1620	3.4800	2.0780
Std. Dev.	7.3345	8.7596	5.6657	9.3901	11.3081	5.7698	3.7831
Skewness	0.3369	0.6496	0.5379	0.7967	-0.2071	0.4296	0.4399
Kurtosis	1.6376	1.8263	1.8133	1.8781	2.6683	1.5255	1.4960
Jarque-Bera	18.1919	24.1395	20.2048	29.9033	2.2179	22.9354	23.9092
Probability	0.0001	0.0000	0.0000	0.0000	0.3299	0.0000	0.0000
Sum	2118.0830	2929.3630	2151.5870	2456.0810	6755.2250	1885.9430	1177.4120
Sum Sq. Dev.	10113.5700	14425.2800	6034.8150	16576.7900	24040.0100	6258.6550	2690.5630
Observations	189	189	189	189	189	189	189

	FINLAND	GTB	INTERC	OCEANIC	PLATINUM	SKYE	SPRING
Mean	6.0386	22.1362	20.9104	17.0271	13.4451	8.7436	4.7790
Median	4.4850	18.4800	16.1300	14.9325	7.6120	6.8120	5.5900
Maximum	14.0340	38.8700	45.6620	37.0800	34.0900	18.9080	7.5720
Minimum	1.6725	8.5320	5.7480	5.2650	2.0640	3.0600	1.9100
Std. Dev.	3.8445	9.1417	11.7868	8.9514	10.9554	5.2921	1.6273
Skewness	0.6340	0.2632	0.6901	0.2411	0.4596	0.4222	-1.0587
Kurtosis	2.0577	1.5423	2.3935	1.6504	1.5021	1.6066	2.5278

Jarque-Bera	19.6561	18.9168	17.8993	16.1742	24.3225	20.9047	37.0593
Probability	0.0001	0.0001	0.0001	0.0003	0.0000	0.0000	0.0000
Sum	1141.3040	4183.7430	3952.0590	3218.1210	2541.1230	1652.5330	903.2400
Sum Sq. Dev.	2778.6480	15711.3800	26118.7700	15063.9400	22563.8600	5265.2260	497.8246
Observations	189	189	189	189	189	189	189

	STERLING	UBA	UBN	UNITY	WEMA	ZENITH
Mean	4.7652	29.2727	29.9180	4.3326	8.5205	32.4916
Median	4.5760	26.3600	29.3220	3.6660	7.1760	26.8040
Maximum	9.6360	62.6400	48.0060	9.7520	15.0000	65.9640
Minimum	1.1260	7.1660	10.0700	1.1000	2.1175	11.3700
Std. Dev.	2.3002	16.3783	10.5254	2.3319	5.1487	14.5680
Skewness	0.0997	0.3480	-0.2311	0.5376	0.1904	0.3922
Kurtosis	1.5159	1.6423	1.8689	2.0111	1.2781	1.9761
Jarque-Bera	17.6584	18.3297	11.7584	16.8041	24.4922	13.1000
Probability	0.0001	0.0001	0.0028	0.0002	0.0000	0.0014
Sum	900.6305	5532.5420	5654.5100	818.8675	1610.3700	6140.9030
Sum Sq. Dev.	994.6558	50430.6300	20827.3600	1022.2920	4983.7360	39898.3700
Observations	189	189	189	189	189	189

Source: Author's computation.

Focusing on Panel 2, it is observed from the descriptive statistics that Unity and Sterling recorded the least stock price of 1 naira, which occurred between 24th and 31st March 2009. Similar to the pattern in the panel 1, we also find that Zenith, FBN and UBA recorded the maximum stock prices of N65.96, N64.66 and N62.64 which occurred in the 2nd week of July 2007, 2nd week of January 2006 and last week of May 2008, respectively. This again shows that as of May 2008, the banking system in Nigeria was yet to feel the impact of the 2008-09 Global Financial Crisis (GFC). The descriptive statistics also indicate that FBN, Zenith UBN, and UBA recorded the highest mean stock prices of N35.74, N32.49, N29.92 and N29.27, respectively. The statistics also show that all the variables witnessed some variability as seen in the standard deviations, with UBA, Zenith, Intercontinental, and FBN showing the highest levels of variability in stock prices. On the whole, we find that these statistics readily point towards the important roles that FBN, Zenith and UBA are playing in the Nigerian banking system. To conserve space, we do not report the descriptive statistics for total deposits and total assets of the banks since they follow the patterns established here in Table 4 as well as the pattern seen in Table 2, which indicate that FBN, Zenith, UBA, GTB and Access play significant roles in the system.

5. Empirical Results and Discussion

This empirical analysis began by investigating the time series properties of the data. The entire data for this study was subjected to unit root test using the Augmented Dickey-Fuller (ADF) unit root test procedure. In doing this, this study did not control for trend in the test equations since the patterns in the data did not show any particular trend. The results of the ADF unit root tests for the baseline analysis using the equity returns data are presented in Table 5. Panel 1 reports for the full sample while Panel 2 reports for the sub-sample. The results indicate that all the variables became stationary after first differencing, that is, they are all integrated of order one, I(1). This suggests that cointegration test is required to determine if these variables have an equilibrium relationship. The Johansen cointegration test was conducted for both the full sample and the sub-sample. The results are shown in Table 6. As before, Panel 1 reports for the full sample while Panel 2 reports for the sub-sample. In both cases, the trace test returned full rank, indicating the absence of cointegration or equilibrium relationship. According, this study estimated a VAR in first differences rather than a vector error correction model (VECM). These cointegration test results are consistent with Diebold and Yilmaz (2009) and Ogbuabor *et al.* (2016). The total deposits and total assets data also follow similar patterns, that is, the series are I(1) but not cointegrated. To conserve space, we do not report separately for these two variables.

Table 5: ADF Unit Root Test Results

Panel 1: Full sample (June 2005 – November 2016)

Variables	ADF Stat at level	5% Critical Values	ADF Stat at 1st Diff	5% Critical Values	Order of Integration
ACCESS	-2.214421	-2.882748	-8.328348	-2.882748	I(1)
DIAMOND	-0.608684	-2.882748	-8.236336	-2.882748	I(1)
FBN	-0.035714	-2.882748	-8.626463	-2.882748	I(1)
FCMB	-1.236216	-2.882748	-7.283071	-2.882748	I(1)
FIDELITY	-1.246763	-2.882748	-7.585493	-2.882748	I(1)
GTB	-2.715963	-2.882748	-8.754651	-2.882748	I(1)
SKYE	-0.106489	-2.882748	-8.520164	-2.882748	I(1)
STERLING	-0.883445	-2.882748	-9.584279	-2.882748	I(1)
UBA	-1.172427	-2.882748	-8.440036	-2.882748	I(1)
UBN	-1.536393	-2.882748	-8.852147	-2.882748	I(1)
UNITY	-1.262205	-2.882748	-10.06294	-2.882748	I(1)
WEMA	-1.012274	-2.882748	-9.163439	-2.882748	I(1)
ZENITH	-1.951612	-2.882748	-8.214493	-2.882748	I(1)

Panel 2: Sub-sample (January 2006 – August 2009)

Variables	ADF Stat at level	5% Critical Values	ADF Stat at 1st Diff	5% Critical Values	Order of Integration
ACCESS	-1.459192	-2.876843	-9.220883	-2.876843	I(1)
AFRIBANK	-0.980860	-2.876843	-8.910591	-2.876843	I(1)
DIAMOND	-1.311604	-2.876843	-10.55945	-2.876843	I(1)
ECOBANK	-0.905112	-2.876843	-9.668344	-2.876843	I(1)
FBN	-0.554013	-2.876843	-12.20860	-2.876843	I(1)

FCMB	-1.116895	-2.876843	-10.08869	-2.876843	I(1)
FIDELITY	-0.825304	-2.876843	-9.765681	-2.876843	I(1)
FINLAND	-1.148220	-2.876843	-12.17783	-2.876843	I(1)
GTB	-1.204578	-2.876843	-1.095718	-2.876843	I(1)
INTERCONT	-1.095718	-2.876843	-9.023070	-2.876843	I(1)
OCEANIC	-0.876246	-2.876843	-2.876843	-2.876843	I(1)
PLATINUM	-1.335904	-2.876843	-8.992563	-2.876843	I(1)
SKYE	-1.488213	-2.876843	-10.29315	-2.876843	I(1)
SPRING	-2.140627	-2.876843	-10.62841	-2.876843	I(1)
STERLING	-0.809590	-2.876843	-9.968834	-2.876843	I(1)
UBA	-1.077049	-2.876843	-10.88301	-2.876843	I(1)
UBN	-0.266347	-2.876843	-12.10109	-2.876843	I(1)
UNITY	-0.788714	-2.876843	-10.12517	-2.876843	I(1)
WEMA	-1.338617	-2.876843	-5.886003	-2.876843	I(1)
ZENITH	-0.773468	-2.876843	-11.05288	-2.876843	I(1)

Source: Author's computation

Table 6: Johansen Cointegration Test Results

Panel 1: Full sample (June 2005 – November 2016)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.6822	794.0110	431.9200	0.0000
At most 1 *	0.6515	641.5371	348.9784	0.0000
At most 2 *	0.5525	501.3455	298.1594	0.0000
At most 3 *	0.4977	394.4046	251.2650	0.0000
At most 4 *	0.4206	302.8347	208.4374	0.0000
At most 5 *	0.3554	230.2468	169.5991	0.0000
At most 6 *	0.3033	171.8445	134.6780	0.0001
At most 7 *	0.1957	123.7758	103.8473	0.0013
At most 8 *	0.1759	94.8169	76.9728	0.0012
At most 9 *	0.1528	69.0906	54.0790	0.0013
At most 10 *	0.1379	47.0422	35.1928	0.0017
At most 11 *	0.1263	27.3015	20.2618	0.0045
At most 12 *	0.0678	9.3367	9.1645	0.0464

Panel 2: Sub-sample (January 2006 – August 2009)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.7102	1803.1200	1186.9438	0.0000
At most 1*	0.6990	1575.2320	1036.9314	0.0000

At most 2*	0.6515	1354.3300	891.5178	0.0000
At most 3*	0.6088	1160.3510	763.8268	0.0000
At most 4*	0.5208	987.6830	650.1643	0.0000
At most 5*	0.4954	852.3271	561.0632	0.0000
At most 6*	0.4358	726.4597	478.2082	0.0000
At most 7*	0.3902	621.1428	408.8810	0.0000
At most 8 *	0.3366	530.1430	348.9784	0.0000
At most 9 *	0.3283	454.6305	298.1594	0.0000
At most 10 *	0.3049	381.4113	251.2650	0.0000
At most 11 *	0.2897	314.5014	208.4374	0.0000
At most 12 *	0.2362	251.5643	169.5991	0.0000
At most 13 *	0.2240	201.9799	134.6780	0.0000
At most 14 *	0.2045	155.3284	103.8473	0.0000
At most 15 *	0.1825	113.2235	76.9728	0.0000
At most 16 *	0.1299	76.1460	54.0790	0.0002
At most 17 *	0.1139	50.5529	35.1928	0.0006
At most 18 *	0.0908	28.3019	20.2618	0.0031
At most 19 *	0.0570	10.7901	9.1645	0.0244

Source: Author's computation

5.1. Total Connectedness Index Results

The underlying model for this study was estimated separately for the full sample and the sub-sample using lag length of 2 throughout as recommended by the Schwarz Information Criterion (SIC). This is not only consistent with the established literature, such as Diebold and Yilmaz (2009), Bu *et al*. (2013) and Ogbuabor *et al.* (2016), but will also ensure that the results of this study are directly comparable to these established studies. The estimations were also conducted for the full sample and the sub-sample using 22 rolling samples throughout. This is also consistent with the literature, such as Diebold and Yilmaz (2015b), Greenwood-Nimmo *et al.* (2015), Ogbuabor *et al.* (2016), and the references therein. Specifically, Diebold and Yilmaz (2015b) shows that the GCMs follow similar patterns regardless of the choice of window widths (and hence, rolling samples) and forecast horizons. In this study, the maximum forecast horizon is set at 24 in order to capture the long-run results better. This means that for the full sample, the long run is defined as 24 months while for the sub-sample, the long run is defined as 24 weeks. This study computed the GCMs across each forecast horizon, and thereafter aggregated the results by computing the averages across these horizons.

Recall that the first objective of this study is to estimate the degree of connectedness of the Nigerian banking system. To achieve this objective, the total connectedness index series are reported in Table 7 following equation (10). While Panel 1 reports for the full sample, Panel 2 reports for the sub-sample. The results indicate that in the short-run (that is, horizon 1), the degree of connectedness of the banking system is estimated at 72.94% and 62.33% for the full sample and sub-sample, respectively. In addition, in the long run, the degree of connectedness of the banking system in Nigeria is estimated at 86.52% and 86.74% for the full sample and sub-sample, respectively. On the average, however, the connectedness of the banking system in Nigeria is 84% and 80% in the full sample and sub-sample, respectively. These results indicate that 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. Overall, this study has shown that the Nigerian banking system is highly interconnected.

Table 7: Series of Total Connectedness Index %

Horizon	Panel 1: Full Sample (June 2005 – November 2016)	Panel 2: Sub-sample (January 2006 – August 2009)
1	72.9400	62.3295
2	77.1950	65.0983
3	79.7054	68.1825
4	81.3287	71.0020
5	82.4393	73.2955
6	83.2313	75.2050
7	83.8026	76.8373
8	84.2256	78.2326
9	84.5514	79.4253
10	84.8124	80.4541
11	85.0284	81.3486
12	85.2121	82.1268
13	85.3719	82.8020
14	85.5136	83.3873
15	85.6413	83.8970
16	85.7582	84.3450
17	85.8670	84.7432
18	85.9698	85.1014
19	86.0682	85.4270
20	86.1633	85.7259
21	86.2558	86.0029
22	86.3456	86.2623
23	86.4326	86.5075
24	86.5163	86.7413
Average	**84.0157**	**79.7700**

Source: Author’s computation

This study subjected the total connectedness index results to robustness checks using the balance sheet data of the banks which includes the total deposits and total assets of the banks. In the case of total deposits, the results showed a mean *total connectedness index* of 63% over the full sample and 82% over the reference sample. Furthermore, in the case of total assets, the results showed a mean *total connectedness index* of 68% over the full sample and 93% over the sub-sample period. These findings are consistent with our earlier conclusion that the Nigerian banking system is deeply interconnected.

5.2: *From-effect, To-effect* and *Net-effect* Connectedness Results

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; while the third specific objective is to determine the banks that are most vulnerable to systemic risks arising from the connectedness of banks in Nigeria. To achieve these objectives, this study estimated the *from-effect*, the *to-effect* and the *net-effect* connectedness of each individual bank in the Nigerian banking system following equations (6), (7) and (8) respectively. The results are reported in Table 8. Panel 1 of this table reports the results for the full sample estimation while Panel 2 reports for the reference sample estimation.

First, consider Panel 1. The results in this Panel indicate that the banks in the system can be classified into two categories, namely: those that have positive *net-effect* connectedness (Category 1) and those that have negative *net-effect* connectedness (Category 2). Recall that the *from-effect* connectedness measures the total spillovers or shocks from other banks in the system to a given bank; while the *to-effect* connectedness measures the total spillovers or shocks from a given bank to all other banks in the system. This means that the *net-effect* connectedness measures the net spillovers or shocks from a given bank to all other banks in the system such that a bank with positive *net-effect* is said to exert dominant influence on other banks in the system and thus belong to Category 1 while a bank with negative *net-effect* is said to be vulnerable and thus belong to Category 2. The results in Panel 1 indicate that the Category 1 banks include: FBN, Access, GTB, UBA and Zenith; while the Category 2 banks are: Diamond, FCMB, Fidelity, Skye, Sterling, UBN, Unity and Wema. This shows that while the Category 1 banks exert dominant influence on the system and therefore have the potential to propagate systemic risks, the Category 2 banks are vulnerable to systemic risks emanating from the connectedness of the banking system in Nigeria. This finding is particularly consistent with Table 2, which shows that these five banks in Category 1 dominate the system in terms of market power. From the net-effect results in Panel 1, we find that Wema is the most vulnerable with net-effect of -76.13%, followed by Unity (-41.94%), Diamond (-28.93%), UBN (-26.86%), Skye (-26.19%), Sterling (-14.59%), FCMB (-6.13%) and Fidelity (-4.55%) in that order. At this point, the results have clearly identified each bank in the system as either exerting influence on the system (i.e. belonging to Category 1) or being vulnerable (i.e. belonging to Category 2). What is yet to be seen at this point is whether the results in Panel 2 will be consistent with this finding or otherwise.

Panel 2 reports the *from-effect*, *to-effect* and *net-effect* connectedness of each bank operating in the Nigerian banking system between the period January 2006 and August 2009. Recall that the choice of this period is mainly informed by the need to evaluation the CBN intervention in the banking system in August 2009. This is in line with the fourth specific objective of this study which seeks to determine if the banks taken over by the CBN in August 2009 were vulnerable or otherwise. The results in Panel 2 also follow the same pattern as the ones in Panel 1. We find that while some banks exhibit positive *net-effects* and thus belong to Category 1, others have negative *net-effects* and therefore belong to Category 2. The Category 1 banks under Panel 2 include: FBN, Access, Diamond, FCMB, Fidelity, GTB, Intercontinental, Oceanic, UBN, and Zenith. Two important points must be stressed on these Category 1 banks. The first point is that Intercontinental, Oceanic and UBN were among the five banks taken over by the CBN in August 2009, contrary to the findings of this study. The findings here indicate that these banks have positive *net-effect*, which means that they were not vulnerable at the point of take-over, rather they were exerting considerable influence on the system. Thus, the CBN decision to take over these three banks may have been misinformed. Indeed, the results in Panel 2 indicate that the top five banks exerting dominant influence on the system based on the *net-effect* connectedness are GTB (58.99%), Zenith (58.17%), Oceanic (46.91%), FBN (41.33%), and Intercontinental (31.80%). The second important point on these Category 1 banks under Panel 2 is that the recent data used in Panel 1 indicate that some of them have become vulnerable to shocks arising from the connectedness of the system. The banks are Diamond, FCMB, Fidelity and UBN. This means that at the point of CBN intervention in August 2009, these banks were still influential, but during the full sample period ending November 2016, they have become vulnerable. 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 Intercontinental, Oceanic and UBN.

Under Panel 2, the Category 2 banks include: Afribank, Ecobank, Finland, Platinum, Skye, Spring, Sterling, UBA, Unity, and Wema. These banks exhibited negative *net-effects* in the sub-sample period. The results particularly indicate the following four points on these banks. One, the top five vulnerable banks in this Category are Spring with negative net-effect of -65.82%, Finland (-48.82%), Sterling (-45.34%), Ecobank (-43.53%), and Wema (-40.42%). Two, even though UBA is seen to be marginally vulnerable in this sub-sample period, the results earlier presented in Panel 1 show that it is now among the influential banks dominating the system. This is consistent with the restructuring exercise embarked upon by the bank in July 2011 with a view to strengthening its operations and continental presence. Three, half of these Category 2 banks are no longer operational as of December 2018. The banks in this group are Afribank, Finland, Platinum, Skye and Spring. The implication of this finding is that those banks in Category 2 in the sub-sample which are still among the vulnerable banks in the full sample should be diligently monitored and supervised by the monetary authority to forestall likely contagion. The results indicate that Sterling, Unity and Wema belong here. Lastly, the results indicate that the decision of the CBN to take over Afribank and Finland in August 2009 was well informed. This is because these two banks, especially Finland, recorded high negative net-effect in the sub-sample period.

Table 8: To-effect and From-effect Connectedness %

Panel 1: Full sample (June 2005 – November 2016)

Bank	From-effect	To-effect	Net-effect
FBN	79.7868	129.9540	50.1672
ACCESS	81.9128	142.4522	60.5394
DIAMOND	87.7052	58.7789	-28.9264
FCMB	84.5952	78.4685	-6.1267
FIDELITY	87.2517	82.7003	-4.5515
GTB	78.6738	113.9231	35.2493
SKYE	87.9705	61.7838	-26.1866
STERLING	87.9117	73.3259	-14.5858
UBA	80.4689	121.1426	40.6737
UBN	78.6247	51.7665	-26.8582
UNITY	83.7624	41.8267	-41.9357
WEMA	89.3236	13.1889	-76.1348
ZENITH	84.2164	122.8923	38.6759

Panel 2: Sub-sample (January 2006 – August 2009)

Bank	From-effect	To-effect	Net-effect
FBN	76.8187	118.1517	41.3329
ACCESS	77.4145	94.7020	17.2875
AFRIBANK	73.0179	59.1270	-13.8909
DIAMOND	84.3134	109.9144	25.6010
ECOBANK	62.7119	19.1785	-43.5334
FCMB	81.5793	110.0153	28.4360
FIDELITY	81.0258	91.3109	10.2851
FINLAND	80.4354	31.6138	-48.8216
GTB	79.2784	138.2705	58.9922
INTERC	78.6352	110.4304	31.7951
OCEANIC	83.8376	130.7429	46.9052
PLATINUM	79.4420	62.9850	-16.4570
SKYE	88.2090	58.6605	-29.5485
SPRING	78.4796	12.6616	-65.8180
STERLING	80.3301	34.9944	-45.3357
UBA	84.8440	82.2954	-2.5485
UBN	82.6576	89.3245	6.6670
UNITY	85.1461	66.0455	-19.1006
WEMA	71.1330	30.7165	-40.4164
ZENITH	86.0908	144.2594	58.1685

Source: Author’s computations

The robustness checks on the above findings based on the balance sheet data of the banks indicate that the foregoing results are not just a happenstance. Using the total deposits of the banks over the full sample, we find that FBN, GTB, UBA, Zenith, Fidelity and FCMB reported positive net-effect connectedness. This is consistent with the earlier results, the only difference being that Access did not have a positive *net-effect* while Fidelity and FCMB showed positive *net-effect*. In the reference sample, we find that FBN, GTB, UBA, Zenith, Diamond, Intercontinental, UBN, and Wema had positive *net-effects*. This is also consistent with the earlier findings, except that Access and Oceanic did not show positive net-effect. However, the results further reinforce the earlier finding that the CBN decision to take over five banks in August 2009 may have been misinformed in the cases of Intercontinental and UBN that have consistently shown positive *net-effects* in our results. Using the total assets of the banks over the full sample, we find that FBN, GTB, UBA, Access, Zenith, and FCMB clearly reported positive *net-effect*. This is consistent with the earlier finding that FBN, Access, GTB, UBA and Zenith are Category 1 banks that exert dominant influence on other banks in the system. Over the reference sample, the total assets data showed that FBN, GTB, UBA, Zenith, Stanbic, and Oceanic reported positive *net-effect*. This result supports the earlier findings that FBN, GTB, UBA, and Zenith are Category 1 banks, and that Oceanic was not vulnerable at the point of take-over in August 2009.

In sum, we conclude that FBN, GTB, UBA, Zenith, and Access are Category 1 banks that exert dominant influence on the system; while the decision of the CBN to take over five banks in August 2009 may not have been well informed in the cases of Intercontinental, UBN, and Oceanic.

5.3: Dependence and Influence Indices Connectedness Results

To further enrich the analysis and subject the foregoing findings to additional robustness check, this study computed the *dependence* and *influence* indices following equations (12) and (13), respectively. The results are presented in Table 9. As before, the full sample results are reported in Panel 1 while the sub-sample results are reported in Panel 2. Recall that while the *dependence index* shows how sensitive each bank is to external conditions, 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.

To begin, let us focus on Panel 1 which reports for the full sample. We find that the *dependence index* ranges between 0.79 and 0.89, which is very close to 1 in all cases. This indicates that all the banks are sensitive to external conditions. This result further validates the earlier result that the banks are deeply interconnected. The results become more interesting when the *influence index* is considered. We find that FBN, Access, GTB, UBA and Zenith have positive influence index, indicating that they are the banks exerting dominant influence on the system. This is consistent with the earlier findings in the *from-effect, to-effect* and *net-effect* connectedness. Furthermore, the results indicate that Diamond, FCMB, Fidelity, Skye, Sterling, UBN, Unity, and Wema have negative *influence index*, indicating that they are the vulnerable banks in the system. Interestingly, Access recently took over Diamond while the CBN took over Skye and renamed it Polaris Bank preparatory to its sale to a prospective investor. These findings remain robust even when the balance sheet data (i.e. total deposits and total assets) of the banks were used in the analysis.

Let us now consider the results in Panel 2 which reports for the sub-sample period ending August 2009. We find that the *dependence index* ranges between 0.63 – 0.88, which is consistent with the earlier findings and further validates the conclusion that all the banks are sensitive to external conditions. In the case of the *influence index*, the results indicate that while some of the banks have positive *influence index*, others have negative *influence index*. The banks that have positive *influence index* are FBN, Access, Diamond, FCMB, Fidelity, GTB, Intercontinental, Oceanic, UBN and Zenith. Notice that these are the same banks that belong to Category 1 in the discussions under the *from-effect*, *to-effect* and *net-effect* connectedness. Thus, all the discussions earlier made for this category of banks are applicable here. The banks that have negative *influence index* are Afribank, Ecobank, Finland, Platinum, Skye, Spring, Sterling, UBA, Unity, and Wema. Again, it is interesting to notice that these are the same banks that belong to Category 2 in the earlier analysis of *from-effect*, *to-effect* and *net-effect* connectedness. Indeed, all the earlier discussions in the preceding section on *from-effect*, *to-effect* and *net-effect* connectedness still hold, even when the balance sheet data of the banks (i.e. the total deposits and the total assets data) were used in the analysis. Hence, the results of the *dependence* and *influence* indices are consistent with the earlier conclusions already established in this study.

At this point, the overall results of this study can be summarized as follows: (i) the results show that the banking system is highly interconnected; (ii) the results indicate that FBN, Access, GTB, UBA and Zenith dominate the Nigerian banking system and therefore have the potential to propagate systemic risks; (iii) the results indicate that Diamond, Skye, UBN, Unity and Wema are most vulnerable to systemic risks arising from the connectedness of Nigerian banks; (iv) the results indicate that the monetary authority's decision to take over Intercontinental, Oceanic and UBN was somewhat misinformed, whereas the decision to take over Afribank and Finland was well informed. In what follows, we consider how the connectedness of the banking system in Nigeria evolved before, during and after the 2016 economic crisis. This is essentially aimed at providing some insights that can assist policymakers to respond to such crisis situation in the future.

Table 9: Dependence and Influence Indices Results

Panel 1: Full sample (June 2005 – November 2016)

Bank	D-Index	I-Index
FBN	0.7979	0.2325
ACCESS	0.8191	0.2647
DIAMOND	0.8771	-0.2033
FCMB	0.8460	-0.0401
FIDELITY	0.8725	-0.0271
GTB	0.7867	0.1764
SKYE	0.8797	-0.1778

STERLING	0.8791	-0.0903
UBA	0.8047	0.1938
UBN	0.7862	-0.2127
UNITY	0.8376	-0.3350
WEMA	0.8932	-0.7374
ZENITH	0.8422	0.1860

Panel 2: Sub-sample (January 2006 – August 2009)

Bank	D-Index	I-Index
FBN	0.7682	0.2053
ACCESS	0.7741	0.0888
AFRIBANK	0.7302	-0.1046
DIAMOND	0.8431	0.1298
ECOBANK	0.6271	-0.5206
FCMB	0.8158	0.1414
FIDELITY	0.8103	0.0510
FINLAND	0.8044	-0.4299
GTB	0.7928	0.1999
INTERC	0.7864	0.1615
OCEANIC	0.8384	0.2081
PLATINUM	0.7944	-0.1129
SKYE	0.8821	-0.2125
SPRING	0.7848	-0.7071
STERLING	0.8033	-0.3868
UBA	0.8484	-0.0154
UBN	0.8266	0.0379
UNITY	0.8515	-0.1298
WEMA	0.7113	-0.4257
ZENITH	0.8609	0.2519

Source: Author's computation

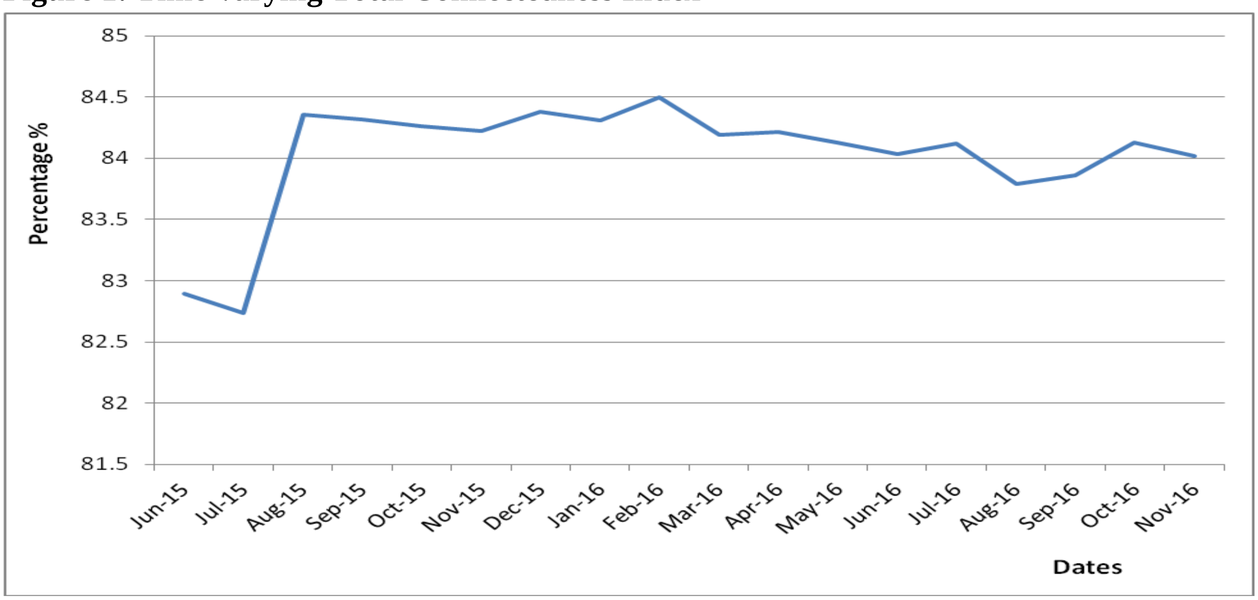
5.4: Time-varying Total Connectedness Index Results

The fifth 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 objective became necessary because the extant literature has shown that a comprehensive understanding of how the aggregate connectedness measure behaves during crisis periods is paramount towards formulating policies during future crisis episodes (see for example Diebold and Yilmaz, 2015a; Greenwood-Nimmo *et al.*, 2015; Ogbuabor *et al.*, 2018). Therefore, to achieve this objective, this study adopted the technique of dynamic or time-varying estimation, by estimating the underlying model recursively so that each estimation begins from the first observation and ends in 2015M6, 2015M7, 2015M8,

…, 2016M11. Thereafter, the total connectedness index were computed across all forecasting horizons, $H = 1, 2, 3, \ldots, 24$.

Some studies in the literature such as Diebold and Yilmaz (2015a) and Ogbuabor *et al.* (2016) have shown that the GCMs follow similar patterns regardless of the choice of forecast horizons, window lengths and rolling windows. This study however set the maximum forecast horizon at 24 in order to capture the long-run results better. Furthermore, the intuition behind the time-varying estimation procedure adopted in this study is quite simple. According to Diebold and Yilmaz (2015a), the inclusion of new observations in the sample causes significant movements in the GCMs, which indicates that the GCMs are dynamic or time-varying. However, Ogbuabor *et al.* (2016) observed that this procedure introduces a potential problem of economic homogeneousness since the results are interpreted as if they speak only to the last period in the sample, whereas the sample consists mainly of earlier observations. Nonetheless, the main advantages of this approach can be found in its tremendous simplicity and its coherence with a wide variety of possible data-generating processes involving time-varying parameters. Indeed, this procedure has been successfully utilized by the aforementioned studies which also used the VAR framework to estimate the underlying relationships. This study therefore adopts this procedure so that by examining the evolution of the total connectedness index before, during and after the recession, important insights may be gained on how the crisis affected the banking industry in Nigeria. The results of the time-varying estimations are presented in Figure 1.

Figure 1: Time-varying Total Connectedness Index

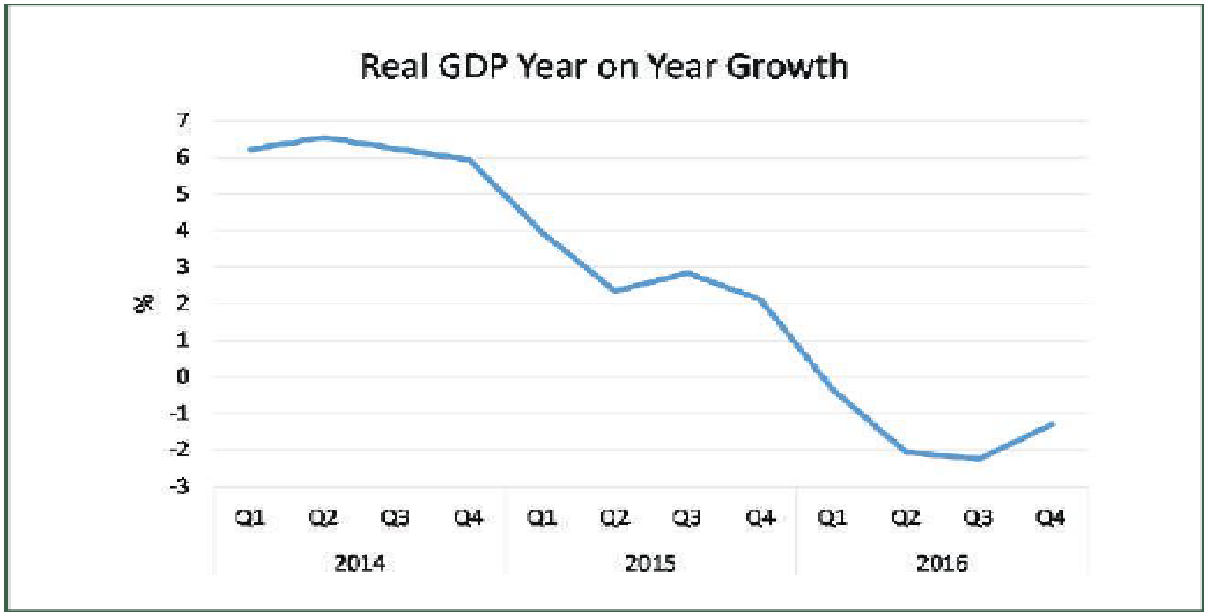


Source: Author's computations. **Notes**: This index is computed recursively following equation (10) in order to trace the movement of the index before, during and after the 2016 economic recession. Reported values are averages over all horizons.

The patterns in Figure 1 indicate that the index declined in July 2015, but in August 2015, it witnessed a significant upward jump to 84.35%. From August 2015 to the end of the data in November 2016, the index consistently remained higher than its initial levels in June and July 2015. Figure 1 also shows that the index witnessed its highest value of 84.5% in February 2016, which was only four months before the economy technically went into recession. These results indicate that the index witnessed significant upward jump following the 2016 economic recession. The upward jump which occurred in August 2015 was rapid and considerable, indicating that the banking system reacted to the crisis much earlier than June 2016, when the economy was technically declared recessed. This rapid reaction of the *total connectedness index* to the crisis is consistent with the pattern established in the extant literature, such as Diebold and Yilmaz (2014, 2015a) and Ogbuabor *et al.* (2016). The latter demonstrated that the financial system reacts more rapidly to crisis situations than the real sectors of the economy. Overall, our results indicate that the index witnessed a significant increase following the crisis. In other words, the huge upward jump in the index shows that the crisis is associated with a remarkable increase in the connectedness of the banking system in Nigeria.

The foregoing results are consistent with the dynamics of the Nigerian economy. To see this, let us consider the quarterly real GDP year on year growth published by the National Bureau of Statistics in February 2017 as presented in Figure 2 (NBS, 2017). Figure 2 indicates that even though the real GDP growth (year on year) witnessed a slight recovery in 2015Q3, it declined afterwards until the economy was declared recessed in June 2016. The long period of decline in the real GDP growth corresponds to the crisis period during which the *total connectedness index* in this study not only witnessed a significant upward jump but also remained high. This means that the high values of the *total connectedness index* during this period can be attributed mainly to the connectedness engendered by the crisis. Notice also that in the periods immediately following June 2016, when the economy became technically recessed, the *total connectedness index* did not return to its pre-crisis levels, rather it remained significantly higher than the pre-crisis values. Overall, this study has established that the 2016 crisis episode significantly increased the connectedness of the banking system in Nigeria. This finding remained consistent even when the balance data of the banks were used in the analysis. In what follows, we provide more robustness checks on the findings of this study by investigating the connectedness of each individual bank in the system under the baseline analysis.

Figure 2: Real GDP Year on Year Growth



Source: National Bureau of Statistics (2017)

5.5: More Robustness Checks Based on the Connectedness of Each Individual Bank

One of the main findings of this study as seen in the foregoing section is that FBN, Access, GTB, UBA and Zenith dominate the Nigerian banking system and therefore have the potential to propagate systemic risks. This finding is seen to be consistent with the distribution of market power in the Nigerian banking system as shown in Table 2. This study now brings these five banks together under the name "Big5" so that their joint influence on the other banks operating in the system can be evaluated. In the case of the full sample period of June 2005 to November 2016, this study constructs a generalized connectedness measure (GCM) called the *own-Big5-ROB effect*. Essentially, this GCM measures how sensitive each individual bank in the system is to its own internal conditions (i.e. own or idiosyncratic conditions) as well as conditions in the Big5 (i.e. Big5 conditions) and conditions in the rest of the banking system (i.e. *ROB* conditions).

To construct this GCM, let $\boldsymbol{O_j^{own}}$, $\boldsymbol{O_j^{Big5}}$ and $\boldsymbol{O_j^{ROB}}$ denote the *own effect*, *Big5 effect* and *ROB effect* for the $\boldsymbol{j^{th}}$ bank in the system. Then:

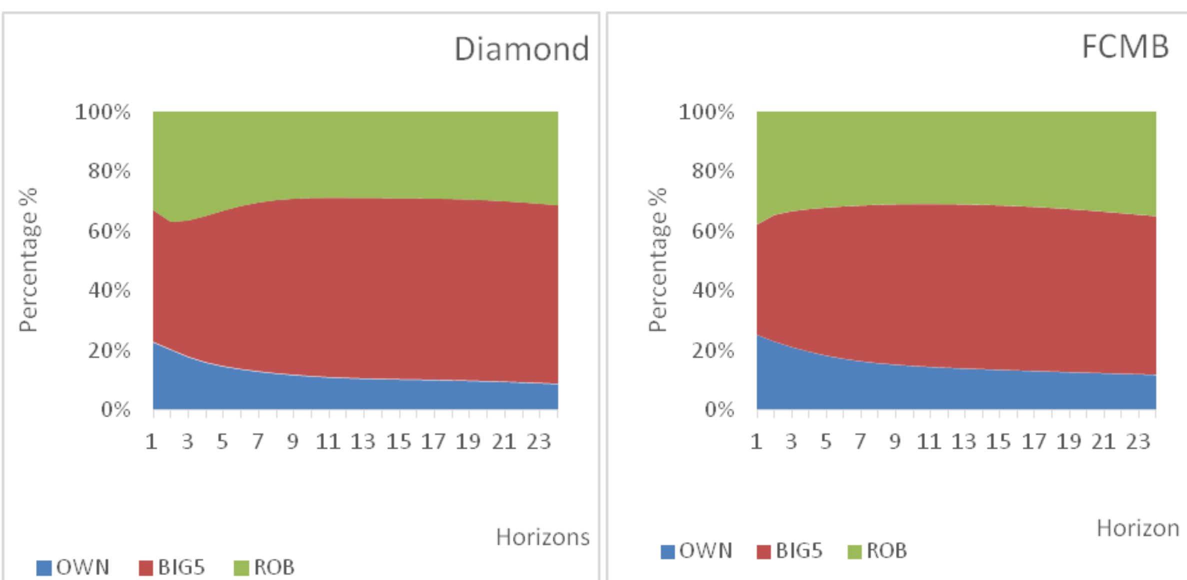
$$\boldsymbol{O_j^{own}} = \frac{F_j^{own}}{F_j^{own} + F_j^{Big5} + F_j^{ROB}}; \quad \boldsymbol{O_j^{Big5}} = \frac{F_j^{Big5}}{F_j^{own} + F_j^{Big5} + F_j^{ROB}} \text{ and } \boldsymbol{O_j^{ROB}} = \frac{F_j^{ROB}}{F_j^{own} + F_j^{Big5} + F_j^{ROB}} \qquad (14)$$

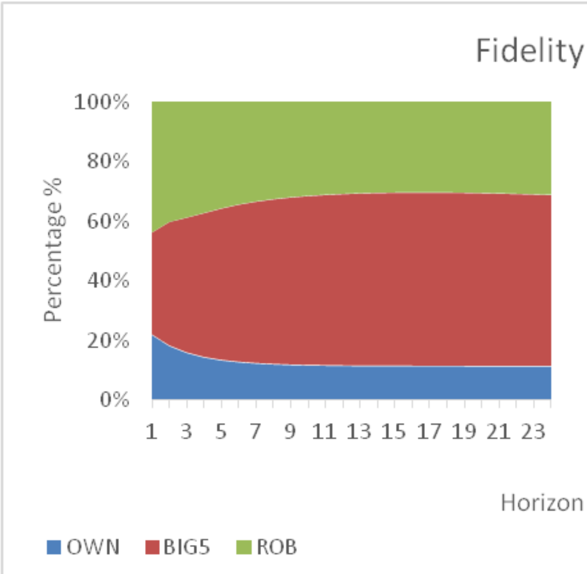
where $\boldsymbol{F_j^{own}}$captures own-spillovers, akin to $\boldsymbol{H_j}$ of equation (5); $\boldsymbol{F_j^{Big5}}$ captures the spillovers from the Big5 while $\boldsymbol{F_j^{ROB}}$ captures the spillovers from the rest of the banks in the system. Following the normalization procedure in equation (4), it is easily seen that $\boldsymbol{F_j^{own}} + \boldsymbol{F_j^{Big5}} + \boldsymbol{F_j^{ROB}} = \boldsymbol{100}\%$.

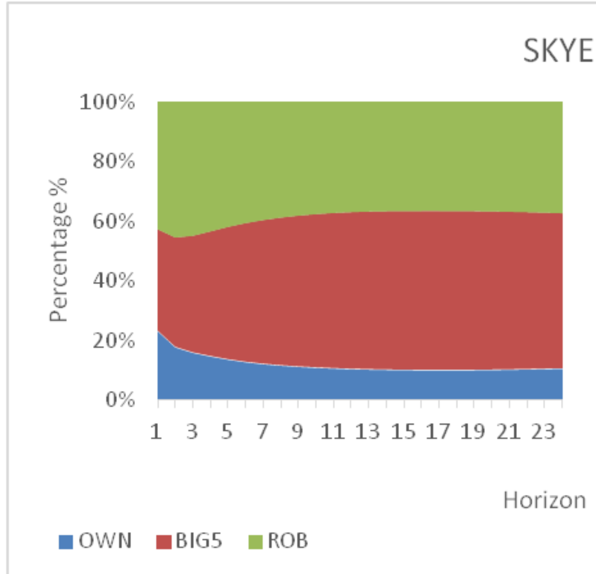
Using this GCM in equation (14), this study estimated the role of the Big5 in each individual bank operating in the system over the full sample. The results are presented in Figure 3. The patterns in Figure 3 indicate that: *own-effects* are dominant mainly in the short-run (i.e. at horizon 1) but diminish towards the long run (i.e. towards horizon 24); *Big5-effects* (i.e. contributions from the Big5 banks) are quite significant both in the short-run and long run (even though this effect started from 15% at horizon 1 in the case of Wema, which is still non-negligible, it rapidly rose to 52% at horizon 24); while the *ROB-effects* (i.e. contributions from the rest of the banks in the system) consistently remained important both in the short-run and long run. These facts further reinforce the earlier conclusions in this study that the banking system in Nigeria is deeply interconnected and that the Big5 exert dominant influence on the system. The findings here also support the earlier findings that other banks in the system are vulnerable to the systemic risks (particularly the risk of contagion) emanating from the connectedness of the banking system in Nigeria.

Let us briefly consider the first deposit money bank appearing in Figure 3 (which is Diamond), since the rest of the banks follow similar patterns. We find that for Diamond, the *own-effect* started from 23% at horizon 1 and declined gradually to 9% at horizon 24. The *Big5-effect* began from 44% at horizon 1 and rose continuously until it reached 60% after 24 months, with UBA, Access and FBN making the highest contributions of 14.16%, 14.10% and 12.41%, respectively. The *ROB-effect* declined slightly from 33% in the short-run to 32% in the long-run, with FCMB and Fidelity making modest contributions of 7.13% and 5.47% to its GFEVDs, respectively. For FCMB, Fidelity, Skye, Sterling, UBN, Unity, and Wema**,** the overall patterns in Figure 3 are similar to those of Diamond, such that *own-effects* are more pronounced at horizon 1 (i.e. the short-run) than at horizon 24 (i.e. towards the long-run) while the *Big5-effects* and *ROB-effects* consistently remained important both in the short-run and long-run.

Figure 3: Connectedness of Each Individual Bank over the Full Sample




Fidelity
100%
80%
60%
40%
20%
0%
Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
OWN
BIG5
ROB


SKYE
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20%
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Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
OWN
BIG5
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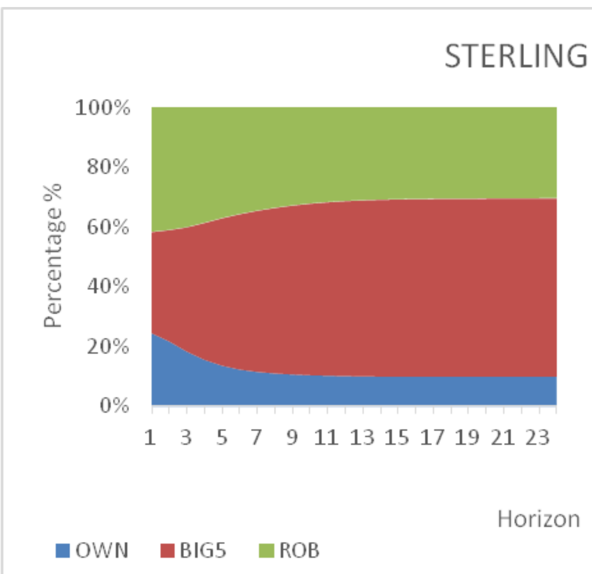
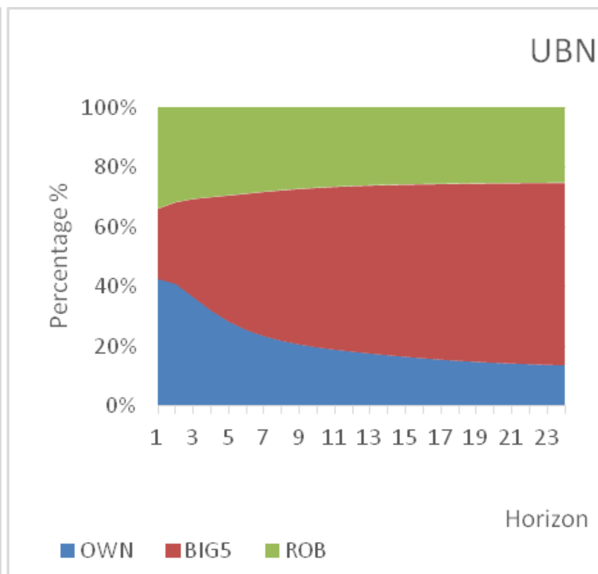

STERLING
100%
80%
60%
40%
20%
0%
Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
OWN
BIG5
ROB


UBN
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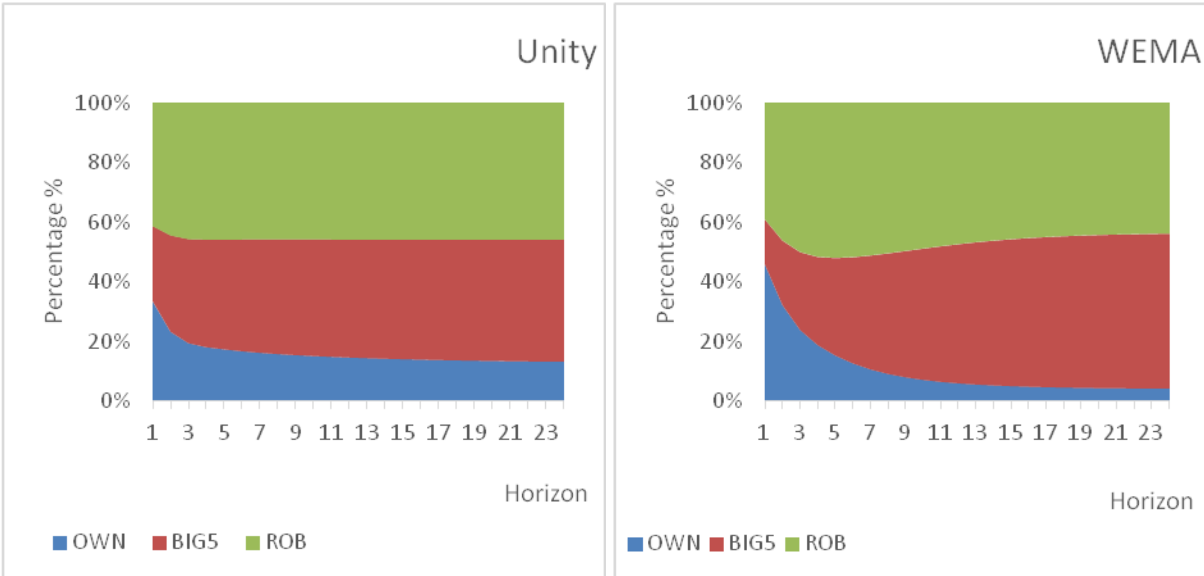


Source: Author's computation. **Notes**: This figure reports the connectedness of each individual bank in the system over the full sample across all horizons. *Own* means proportion of the bank's forecast error variance (FEV) explained by the bank itself; *Big5* means proportion explained by the Big5 banks; while *ROB* means proportion explained by the rest of the banks in the system. These GCMs were computed following the *own-Big5-ROB effect* in equation (14). Notice that the *Big5* play dominant role in all cases, both in the short-run and long-run.

At this point, what remains to be seen is whether these findings are consistent with the reference sample. To do this, recall that the study had earlier established that up till August 2009, Intercontinental, Oceanic and UBN generally showed positive net-effects, indicating that they were also exerting some influence on the system. Accordingly, this study brings these three banks into one basket called *group of three* or G3 for short. Thus, for the sub-sample period, this study constructs a GCM called the *own-Big5-G3-ROB effect*. This GCM measures how sensitive each individual bank in the system is to its own internal conditions (i.e. own or idiosyncratic conditions) as well as conditions in the Big5 (i.e. Big5 conditions), conditions in the G3 (i.e. G3 conditions) and conditions in the rest of the banks in the system (i.e. *ROB* conditions).

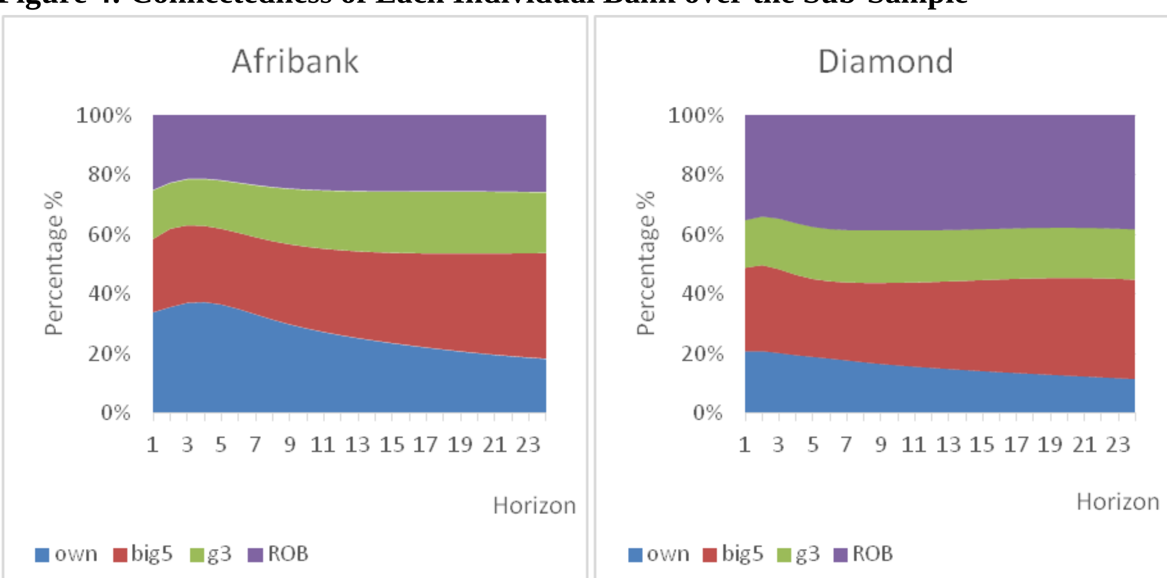
To construct this GCM, let $\boldsymbol{O_j^{own}}$, $\boldsymbol{O_j^{Big5}}$, $\boldsymbol{O_j^{G3}}$ and $\boldsymbol{O_j^{ROB}}$ denote the *own effect*, *Big5 effect*, *G3 effect* and *ROB effect* for the $\boldsymbol{j^{th}}$ bank in the system. Then:

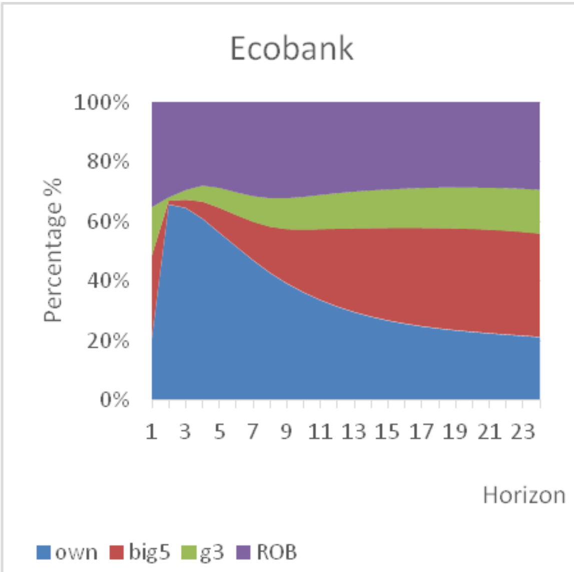
$$\boldsymbol{O_j^{own}} = \frac{\boldsymbol{F_j^{own}}}{\boldsymbol{F_j^{own} + F_j^{Big5} + F_j^{G3} + F_j^{ROB}}};\ \boldsymbol{O_j^{Big5}} = \frac{\boldsymbol{F_j^{Big5}}}{\boldsymbol{F_j^{own} + F_j^{Big5} + F_j^{G3} + F_j^{ROB}}};\ \boldsymbol{O_j^{G3}} = \frac{\boldsymbol{F_j^{G3}}}{\boldsymbol{F_j^{own} + F_j^{Big5} + F_j^{G3} + F_j^{ROB}}} \text{ and } \boldsymbol{O_j^{ROB}} = \frac{\boldsymbol{F_j^{ROB}}}{\boldsymbol{F_j^{own} + F_j^{Big5} + F_j^{G3} + F_j^{ROB}}} \quad (15)$$

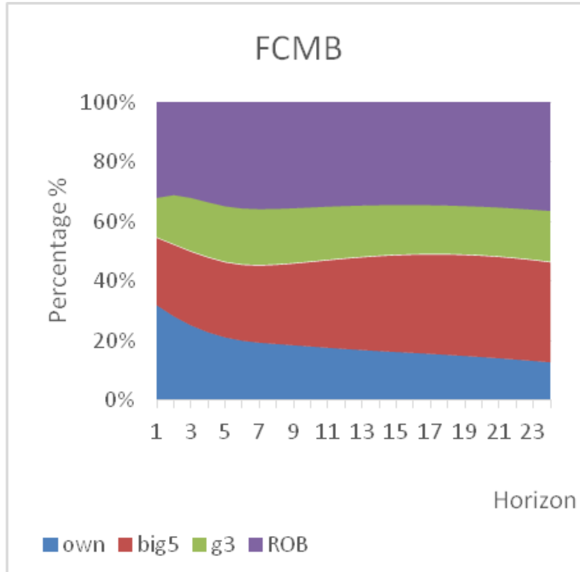
where $\boldsymbol{F_j^{own}}$ captures own-spillovers, akin to $\boldsymbol{H_j}$ of equation (5); $\boldsymbol{F_j^{Big5}}$ captures the spillovers from the Big5, $\boldsymbol{F_j^{G3}}$ captures the spillovers from the G3 while $\boldsymbol{F_j^{ROB}}$ captures the spillovers from the rest of the banks in the system. By construction, $\boldsymbol{F_j^{own}} + \boldsymbol{F_j^{Big5}} + \boldsymbol{F_j^{G3}} + \boldsymbol{F_j^{ROB}} = \mathbf{100}\%$.

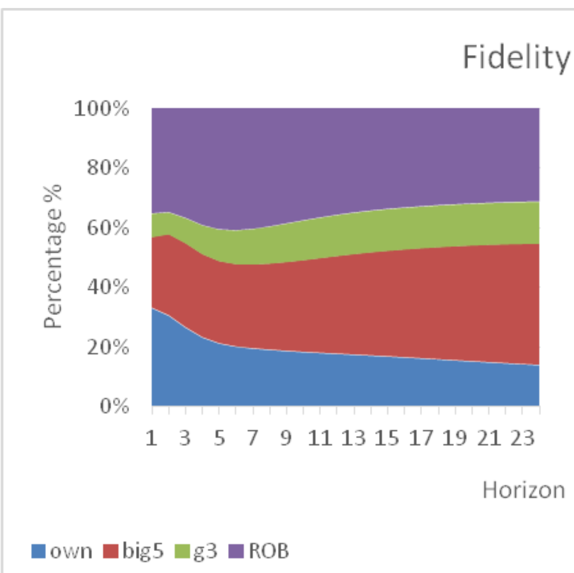
Using the GCM in equation (15), this study estimated the roles of the Big5 and G3 in each individual bank operating in the system over the reference sample (i.e. January 2006 to August 2009). The results are presented in Figure 4. The same patterns observed earlier in Figure 3 are also present in Figure 4. These patterns indicate that: *own-effects* are dominant mainly in the short-run (i.e. at horizon 1) but diminish rapidly towards the long run (i.e. towards horizon 24); *Big5-effects* (i.e. contributions from the Big5 banks) are quite significant both in the short-run and long run, except for Ecobank, Spring and Wema for which this effect is muted at horizon 1 but rapidly becomes important towards horizon 24; *G3-effects* cannot be called unimportant both in the short-run and long-run, except for Ecobank, Finland, Platinum, Spring, and Wema for which the effect appears minimal in the short-run; while the *ROB-effects* (i.e. contributions from the rest of the banks in the system) consistently remained important both in the short-run and long run. These facts further reinforce the earlier conclusions in this study. They support the results that: (i) the banking system in Nigeria is deeply interconnected; (ii) the Big5 exert dominant influence on the system; (iii) the roles of the G3 prior to their take over by the CBN cannot be called unimportant, thereby calling to question the decision of the monetary authority to intervene in these banks; (iv) other banks in the system are vulnerable to systemic risks (particularly the risk of contagion) emanating from the connectedness of the banking system in Nigeria.

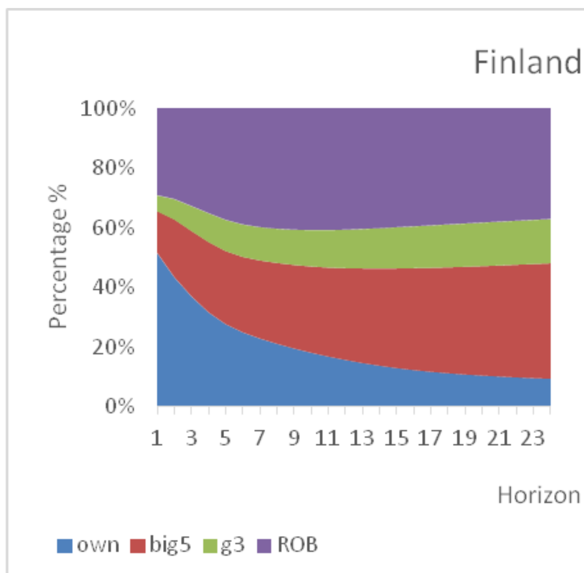
Figure 4: Connectedness of Each Individual Bank over the Sub-Sample

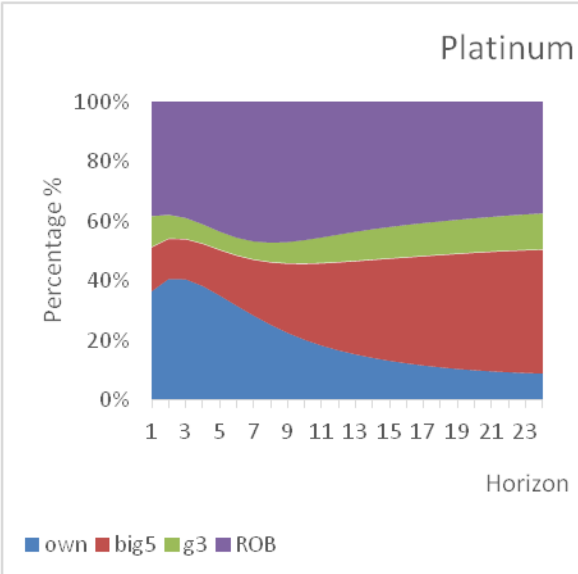


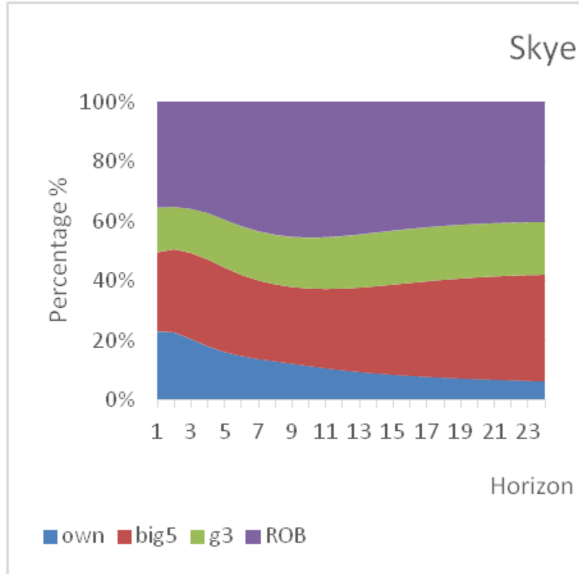

Ecobank
100%
80%
60%
40%
20%
0%
Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
own big5 g3 ROB

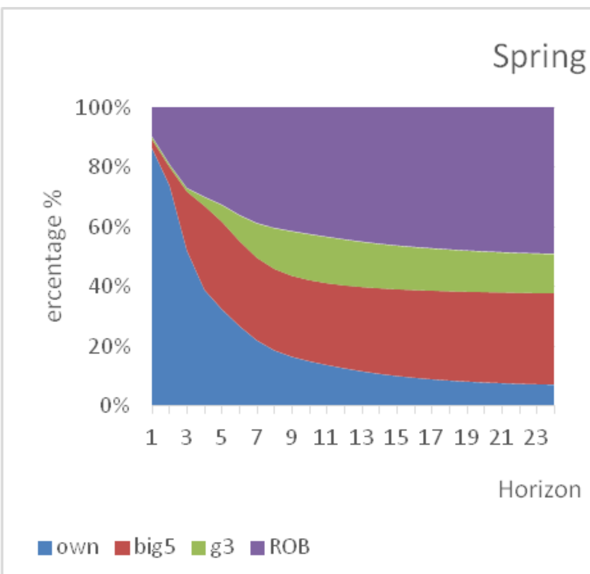

FCMB
100%
80%
60%
40%
20%
0%
Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
own big5 g3 ROB

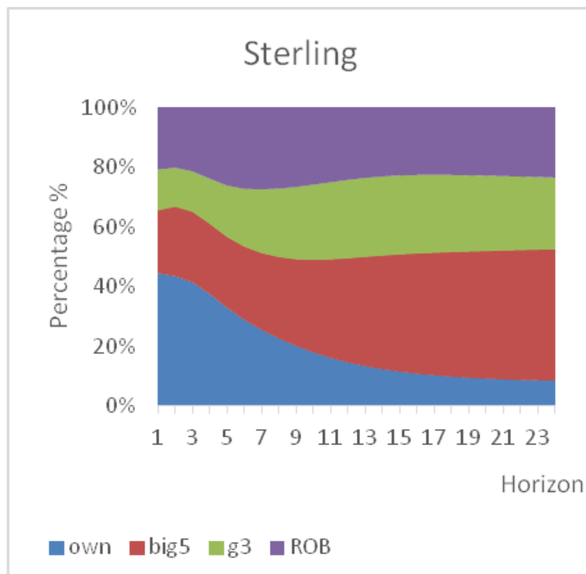

Fidelity
100%
80%
60%
40%
20%
0%
Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
own big5 g3 ROB

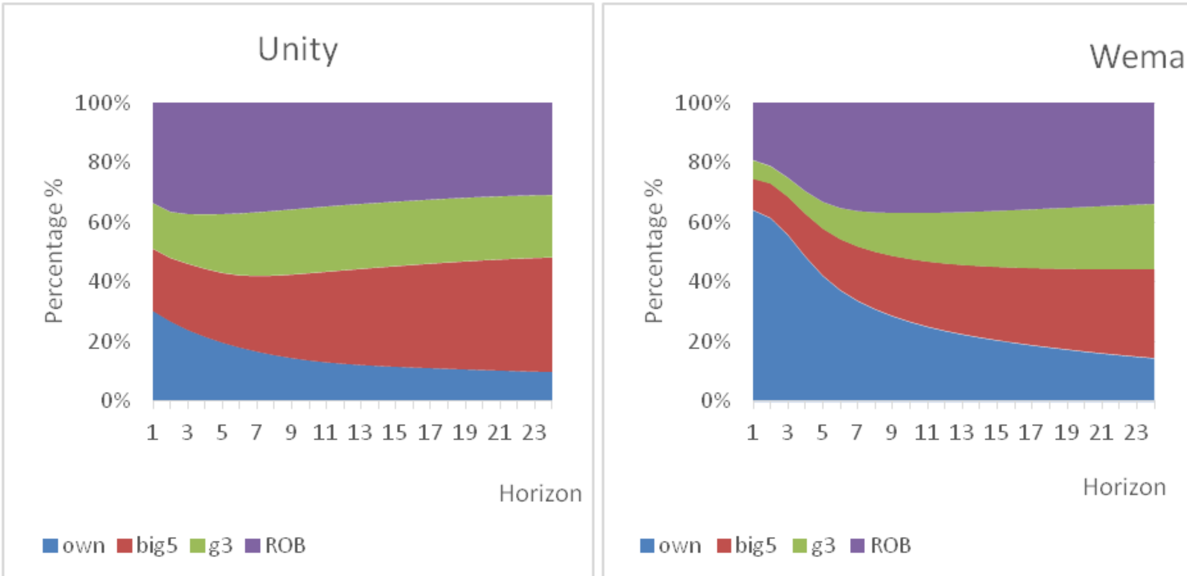

Finland
100%
80%
60%
40%
20%
0%
Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
own big5 g3 ROB


Platinum
100%
80%
60%
40%
20%
0%
Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
own big5 g3 ROB


Skye
100%
80%
60%
40%
20%
0%
Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
own big5 g3 ROB


Spring
100%
80%
60%
40%
20%
0%
ercentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
own big5 g3 ROB

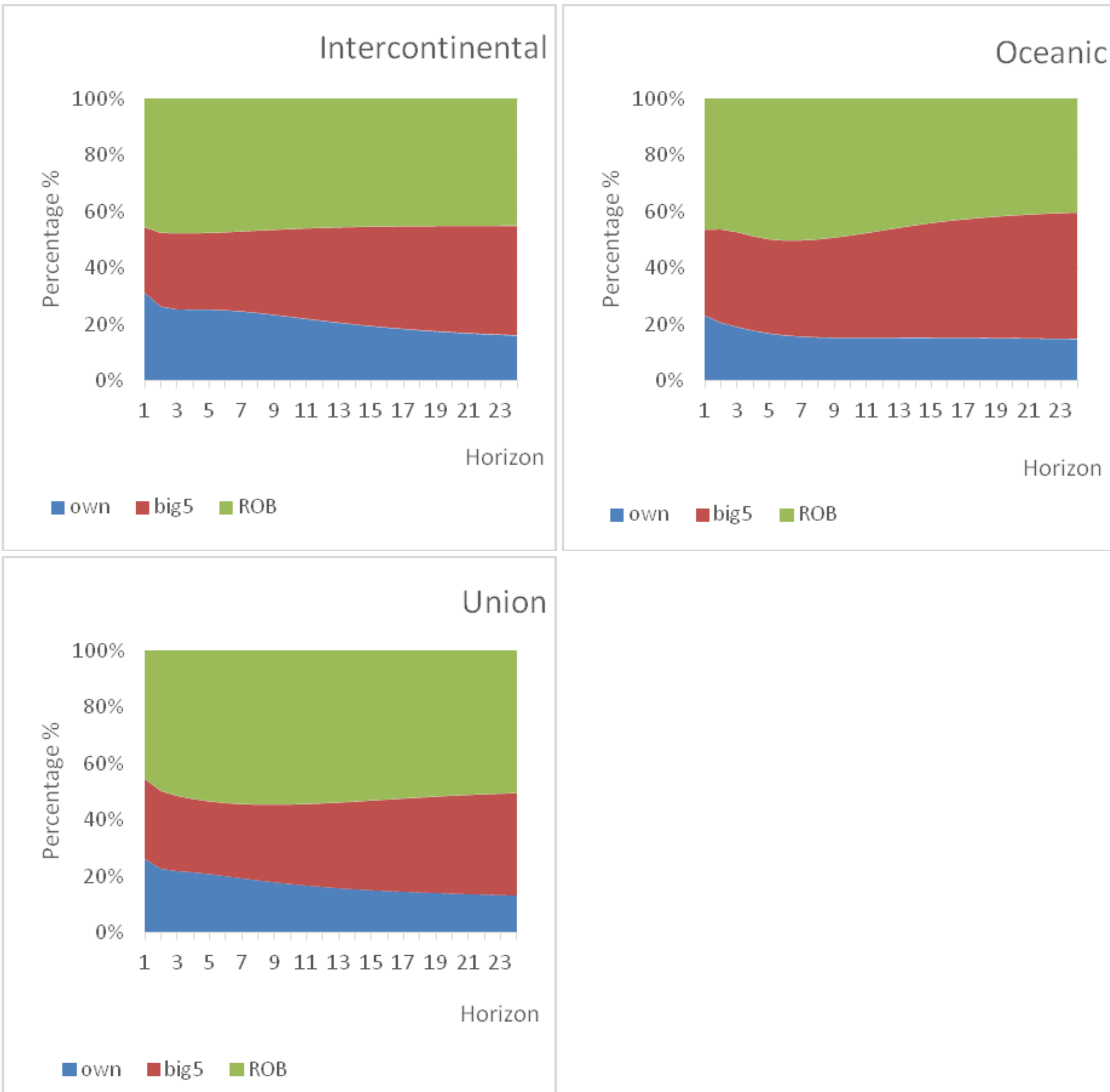

Sterling
100%
80%
60%
40%
20%
0%
Percentage %
1 3 5 7 9 11 13 15 17 19 21 23
Horizon
own big5 g3 ROB



Source: Author's computation. **Notes**: This figure reports the connectedness of each individual bank in the system over the sub-sample across all horizons. *Own* means proportion of the bank's forecast error variance (FEV) explained by the bank itself; *Big5* means proportion explained by the Big5 banks; *G3* means proportion explained by the G3 banks; while *ROB* means proportion explained by the rest of the banks in the system. These GCMs were computed following the *own-Big5-G3-ROB effect* in equation (15). Notice that the *Big5* and the *G3* play important roles in all cases, especially in the long-run.

In order to subject the finding that the roles of the G3 banks prior to their take over by the CBN cannot be called unimportant to further sensitivity check, this study considered the connectedness of these three banks using the GCM defined in equation (14). In doing this, the GFEVDs of these three banks were decomposed into *own-effects, Big5-effects* and *ROB-effects*. The results of these decompositions are shown in Figure 5. The results indicate that all the effects are important both in the short-run and long run. This shows that even though these banks were deeply interconnected, idiosyncratic conditions remained quite important, thereby limiting their vulnerability to contagion. Specifically, the *ROB-effects* show that the G3 banks play important roles in the system given their modest contributions to the GFEVDs of the other banks in the system. Indeed, their *ROB-effects* indicate that they were systemically important.

Figure 5: Connectedness of the G3 Banks over the Sub-Sample



Source: Author's computation. **Notes**: This figure reports the connectedness of each G3 bank over the sub-sample across all horizons following equation (14). *Own* means proportion of the bank's forecast error variance (FEV) explained by the bank itself; *Big5* means proportion explained by the Big5 banks; while *ROB* means proportion explained by the rest of the banks in the system. Notice that all the effects are important in all cases, both in the short-run and long-run.

6. Conclusion and Policy Implications

This study was motivated by the fact that there has hardly been any period during which a single bank failed in isolation in Nigeria, suggesting that the Nigerian banking system may be deeply interconnected. The study was also motivated by the need to provide evidence that can assist monetary authorities to appreciate how connectedness measurement can be used to improve systemic risk management, public policy and overall regulatory oversight. The specific objectives of the study include: (i) to estimate the degree of the connectedness of the Nigerian banking system; (ii) to determine the banks that exert dominant influence and therefore have the potential to spread systemic risks in the Nigerian banking industry; (iii) to determine the banks that are most vulnerable to systemic risks arising from connectedness of banks in Nigeria; (iv) to determine if the banks taken over by the CBN in August 2009 were vulnerable or otherwise; and (v) to examine the impact of the 2016 economic recession on the connectedness of the banking system in Nigeria. This study used the normalized generalized forecast error variance decompositions (NGFEVDs) distilled from an underlying VAR model to build generalized connectedness measures (GCMs) for the Nigerian banking system.

The study found that the connectedness of banks in Nigeria is deeply interconnected as demonstrated by the total connectedness index which averaged 84% and 80% in the full sample and the reference sample, respectively. The findings also indicate that FBN, Access, GTB, UBA and Zenith exert dominant influence on the system and therefore have the potential to propagate systemic risks; while Wema, Unity, Diamond, UBN, Skye, Sterling, FCMB and Fidelity were found to be vulnerable to systemic risks arising from the connectedness of banks in Nigeria since they generally showed negative *net-effect* connectedness. Furthermore, the findings also indicate that three of the banks taken over by the CBN in August 2009 (namely: Intercontinental, Oceanic and UBN) generally showed positive *net-effects*, indicating that they were not vulnerable at the point of take-over. However, the results consistently showed that Afribank and Finland had negative *net-effects* connectedness, suggesting that the CBN decision to intervene in them was quite plausible. Lastly, the study found that the 2016 recession episode increased the connectedness of the banking system beyond its pre-crisis levels.

The foregoing findings have some important policy implications. For instance, an important finding of this study is that the Nigerian banking system is deeply interconnected both in the short run and in the long run. The implication of this finding is that a negative shock that affects any of the banks in the system will likely spread to the other banks, thereby resulting in domino effect. This study therefore recommends that the CBN should take this potential threat into account by interminably and strictly monitoring the system to avoid the crystallization of this systemic risk. Hence, the CBN should ensure that its regulatory activities are properly coordinated not only to safeguard the entire system from future crisis but also to increase the confidence of the banking public in the system. Another key finding of the study is that First Bank of Nigeria Plc, Access Bank Plc, Guaranty Trust Bank Plc, United Bank for Africa Plc and Zenith Bank Plc exert dominant influence on the banking system in Nigeria and therefore have the potential to propagate systemic risks. A major implication of this finding is that the stability of the system depends somewhat on the actions of these five banks. Thus, this study recommends that the CBN should not allow any form of lax supervision to be associated with these banks as the consequences would be dire. The CBN should pursue policies that support the stability of these banks since any shock that affects any of them would most likely results in the domino effect.

The findings of this study show that Wema is most vulnerable to systemic risks arising from the connectedness of banks in Nigeria, followed by Unity, Diamond, UBN, Skye, Sterling, FCMB and Fidelity in that order. This study therefore recommends that the CBN should review the operations of these banks in order to strengthen them. For instance, their corporate governance and risk management structures should be properly scrutinized and fortified, and lax supervision should be avoided since the failure of any of these banks will further weaken the system. Where there are opportunities for mergers that can lead to the emergence of bigger and stronger banks, this study recommends that the CBN should encourage such mergers as a means of limiting systemic risk. As a lender of last resort, this study recommends that the CBN should not withhold its emergency liquidity support from these banks whenever the need arises as doing so could cause more harm than good in view of the connectedness nature of the system.

Another finding of the study indicate that three of the banks taken over by the CBN in August 2009, which are Intercontinental, Oceanic and UBN, exhibited positive *net-effects* connectedness, suggesting that they were not vulnerable at the point of take-over. A key implication of this finding is that the takeover of these banks may not be plausible after all. This study therefore recommends that subsequent takeover of banks by the CBN should be done more transparently to avoid the challenges of possible litigations and increased uncertainties in the system. In addition, this study recommends that the CBN should extend its monitoring and regulatory framework to include connectedness measurement and dynamics as a means of improving regulatory oversight and achieving more transparent supervision and regulation. This study also established that the 2016 economic recession in Nigeria significantly increased the connectedness of the Nigerian banking system, showing that the connectedness of the banking system in Nigeria is also time-varying. This finding further reinforces our earlier recommendation that the CBN should interminably but rigorously monitor the banking system, especially during crisis episodes in order to limit contagion.

References

Adegbaju, A. A., & Olokoyo, F. O. (2008). Recapitalization and Banks' Performance: A Case Study of Nigerian Banks. *African Economic and Business Review*, ***6***(1), 1 – 17.

Ademola, O. G., Olusegun, J. O. & Kehinde, O. (2013). Bank Distress in Nigeria and the Nigeria Deposit Insurance Corporation Intervention. *Global Journal of Management and Business Research Finance*, ***13***(8), 51 – 60.

Ahmad, B. D. (2004). An Examination of Ethical Dilemmas in the Nigerian Banking Sector. MPRA Paper No.23162. Retrieved from: https://mpra.ub.uni-muenchen.de/23162/.

Ajide, F.M. (2014). The effect of bank competition and stock market on economic growth in Nigeria. Unpublished Thesis, Department of Economics, Obafemi Awolowo University.

Ajide, F.M. & Aderemi, A.A. (2015). Market Power of Nigerian Deposit Money Market: Evidence from Bresnahan-Lau's Approach. *American Journal of Economics*, ***5***(1), 21–28.

Ajisafe, R.A. & Akinlo, A.E. (2014). Competition and efficiency of commercial banks: empirical evidence from Nigeria. *American Journal of Economics, **4***(1), 18-22.

Allen, F. & Babus, A. (2009). Networks in Finance. In Kleindorfer, P. & Wind, J. (Eds), *The Network Challenge* (Chapter 21). London: Pearson Education. ISBN: 9780137015511.

Allen, F. & Gale, D. (2000). Financial Contagion. *Journal of Political Economy*, ***108*** (1), 1–33.

Andrada-Félix, J., Fernandez-Perez, A. & Sosvilla-Rivero, S. (2018). Fear connectedness among asset classes. *Applied Economics*, ***50***(39), 4234 – 4249.

Babalola, A. (2011). Corporate governance in banks: The Nigerian experience. *Corporate Ownership and Control International Journal*, ***7***(4), 34 – 41.

Barattieri, A., Eden, M., & Stevanovic, D. (2013). The Connection between Wall Street and Main Street: Measurement and Implications for Monetary Policy. *SSRN Electronic Journal*. DOI: 10.2139/ssrn.2342217.

Barunik, J., & Krehlik, T. (2016). Measuring the frequency dynamics of financial and macroeconomic connectedness. FinMaP-Working Paper 54, http://hdl.handle.net/10419/125824.

Bikker, J.A. (2003). Testing for imperfect competition on EU deposit and loan markets with Bresnahan's market power model. *De Netherlandsche Bank Research Series*, Amsterdam

Billio, M., Getmansky, M., Lo, A.W., & Pelizzon, L. (2012). Econometric Measures of Connectedness and Systemic Risk in the Finance and Insurance Sectors. *Journal of Financial Economics*, ***104***(3), 535-559.

Bostanci, G. & Yilmaz, K. (2020). How Connected is the Global Sovereign Credit Risk Network? *Journal of Banking & Finance*. https://doi.org/10.1016/j.jbankfin.2020.105761

Bu, S., Kim, Y. and Shin, Y. (2013). *Measuring the Connectedness of the Korean Financial System: The GVAR-GCM Modelling Approach*. Mimeo, University of York, United Kingdom.

Brunetti, C., Harris, J.H., Mankad, S. & Michailidis, G. (2019). Interconnectedness in the Interbank Market. *Journal of Financial Economics*, ***133***(2), 520 – 538.

CBN (2015). Central Bank of Nigeria: List of Financial Institutions - Commercial Banks. Available at: http://www.cbn.gov.ng/Supervision/Inst-DM.asp, Access 3 December, 2016.

Cipollini, A., Cascio, I. L., & Muzzioli, S. (2014). Volatility Risk Premia and Financial Connectedness. Dipartimento Economia Marco Biagi (DEMB) Working Paper Series, No 47.

Claessens, S. & Laeven, L. (2003). Competition in the financial sector and growth: A cross-country perspective. Being a paper presented at the Money, Finance and Growth workshop, organized by Charles Good hart, in Salford on September 8 and 9, year 2003.

Cohen-Cole, E., Patacchini, E., & Zenou, Y. (2011). *Systemic Risk and Network Formation in the Interbank Market*. CEPR Discussion Paper No. DP8332, Department of Economics, Stockholm University. Available at: https://ideas.repec.org/p/hhs/sunrpe/2011_0006.html, Accessed 20 April, 2018.

Demirer, M., Diebold, F. X., Liu, L. & Yilmaz, K. (2018). Estimating Global Bank Network Connectedness. *Journal of Applied Econometrics*, ***33***(1), 1 – 15.

Diebold, F.X., & Yilmaz, K. (2009). Measuring financial asset return and volatility spillovers, with application to global equity markets. *The Economic Journal*, ***119***(534), 158-171.

Diebold, F. X., & Yilmaz, K. (2012). Better to Give than to Receive: Predictive Directional Measurement of Volatility Spillovers. *International Journal of Forecasting*, ***28***(1), 57 – 66.

Diebold, F. X., & Yilmaz, K. (2014). On the Network Topology of Variance Decompositions: Measuring the Connectedness of Financial Firms. *Journal of Econometrics*, ***182***(1), 119-134.

Diebold, F.X., & Yilmaz, K. (2015a). Trans-Atlantic equity volatility connectedness: U.S. and European Financial Institutions, 2004 - 2014. *Journal of Financial Econometrics*, ***14***(1), 81–127.

Diebold, F.X., & Yilmaz, K. (2015b). *Financial and macroeconomic connectedness: A network approach to measurement and monitoring*. New York: Oxford University Press.

Diebold, F.X., & Yilmaz, K. (2016). Measuring the Dynamics of Global Business Cycle Connectedness. In S.J. Koopman & N. Shephard (Eds.), *Unobserved Components and Time Series Econometrics: Essays in Honor of Andrew C. Harvey*, Oxford University Press, Oxford.

Dornbusch, R., Park, Y.C. & Claessens, S. (2000). Contagion: understanding how it spreads. *The World Bank Research Observer*, ***15***(2), 177 - 197.

Ebhodaghe, J.U. (1997). *Concept and Activities of the Financial Services Regulation Coordinating Committee (FSRCC) in Nigeria: 1994-1996*. Lagos: Nigeria Deposit Insurance Corporation.

Echevarria-Icaza, V., & Rivero, S. S. (2016). *Connectedness of Stress in EMU Bank and Sovereign CDS: The Role of Policy Measures 2008-2014*. Documentos de Economíay Finanzas Internacionales Working Papers on International Economics and Finance, DEFI 16-01, http://dx.doi.org/10.2139/ssrn.2726494

Egbo, O. P. (2012). Universal Basis of Bank Failure: The Nigeria case. *Developing Country Studies*, ***2***(10), 119 – 131.

Eichengreen, B., Hale, G., & Mody, A. (2001). Flight to Quality: Investor Risk Tolerance and the Spread of Emerging Market Crises. In S. Claessens & K. J. Forbes (eds.), *International Financial Contagion*. Boston: Kluwer, 129–156.

Elegbe, A. (2013). Bank Failure and Economic Development in Nigeria: An Empirical Approach. *British Journal of Economics, Finance and Management Sciences*, ***8***(1), 46 – 63.

Gätjen, R. & Schienle, M. (2015). *Measuring Connectedness of Euro Area Sovereign Risk*. SFB 649 Discussion Papers 2015-019, ISSN:1860-5664, DOI: 10.18452/4576

Greenwood-Nimmo, M., Nguyen, V. H. & Shin, Y. (2015). *Measuring the Connectedness of the Global Economy*. Melbourne Institute Working Paper No. 7/15, Melbourne Institute of Applied Economic and Social Research, The University of Melbourne, Australia, http://dx.doi.org/10.2139/ssrn.2586861

Guimarães-Filho, R., & Hong, G. H. (2016). *Dynamic Connectedness of Asian Equity Markets*. IMF Working Paper No. 16/57, International Monetary Fund, Washington, DC, ISBN/ISSN: 9781513572451/1018-5941

Kaminsky, G. L., Reinhart C. M., & Vegh, C. A. (2003). The Unholy Trinity of Financial Contagion. *Journal of Economic Perspectives*, ***17***(4), 51-74.

Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse Response Analysis in Nonlinear Multivariate Models. *Journal of Econometrics*, ***74***(1), 119 – 147.

Kose, M. A., Prasad, E. S., & Terrones, M. E. (2003). How Does Globalization Affect the Synchronization of Business Cycles? *American Economic Review*, ***93***(2), 57-62.

Laeven, L., & Valencia, F. (2008). Systemic Banking Crises: A New Database. *IMF Working Paper*, WP/08/224.

Magknonis G., & Tsopanakis, A. (2019). The Financial Connectdness between Eurozone Core and Periphery: A Disaggregated View. *Macroeconomic Dynamics*. DOI: https://doi.org/10.1017/S1365100518000998.

Merton, R. C. (2014). Measuring the connectedness of the financial system: Implications for risk management. *Asian Development Review*, ***31***(1), 186–210.

National Bureau of Statistics, NBS (2017). *Nigerian Gross Domestic Product Report (Q4 2016)*. Abuja: NBS.

Nigeria Deposit Insurance Corporation, NDIC (2018). *Case Study of Bank Failures in Nigeria.* Volume 7. Abuja: NDIC.

Ogbuabor, J. E., Orji, A., Aneke, G. C., & Erdene-Urnukh, O. (2016). Measuring the Real and Financial Connectedness of Selected African Economies with the Global Economy. *South African Journal of Economics*, ***84***(3), 364 – 399.

Ogbuabor, J.E., Eigbiremolen, G.O., Aneke, G.C., & Manasseh, C.O. (2018). Measuring the Dynamics of APEC Output Connectedness. *Asian-Pacific Economic Literature*, ***32***(1), 29 – 43.

Onaolapo, A. A. (2008). Implication of capitalization on bank financial health. *Journal of Economic Thought*, ***2***(5), 4 – 19.

Onu, E. (2010). *Nigeria: FG Demands CBN's Blueprint on Bank Reforms*. Thisday, 12 February, 2010. Available at: http://allafrica.com/stories/201002120374.html, Accessed 16 March, 2018.

Paseda, O. (2012). Banking Regulation in Nigeria: A Review Article. Department of Finance, University of Lagos. Available at: https://ssrn.com/abstract=2900252

Pesaran, M. H. & Shin, Y. (1998). Generalized Impulse Response Analysis in Linear Multivariate Models. *Economics Letters*, ***58***(1), 17 – 29.

Rauch, J., Weiss, M. A. & Wende, S. (2015). *Default Risk and Contagion in the US Financial Sector: An Empirical Analysis of the Commercial and Investment Banking, and Insurance Sectors*. Available at: http://www.wriec.net/wp-content/uploads/2015/07/4E3_Rauch.pdf, Accessed: 20 April, 2018.

Rodríguez, F. F., & Sosvilla-Rivero, S. (2016). *Volatility Transmission between Stock and Exchange-Rate Markets: A Connectedness Analysis*. Bath Economics Research Papers, No. 54/16

Shakya, S. (2016) Interbank Connections and Financial Stability. PhD Thesis, Department of Finance, Smeal College of Business, The Pennsylvania State University.

Sims, C. A. (1980). Macroeconomics and Reality. *Econometrica*, ***48***, 1 – 48.

Soludo, C. C. (2004). Consolidating the Nigerian banking industry to meet the development challenges of the 21st century. An address presented at the Special Meeting of the Bankers' Committee, Abuja, 6 July.

Trevino, I. (2014). Channels of Financial Contagion: Theory and Experiments. New York University. Retrieved from: http://www.igier.unibocconi.it/files/Isabel_Trevino_jmp20140120180129.pdf, Accessed 20 April, 2018.

Wang, G., Jiang, Z., Lin, M., Xie, C., & Stanley, E., (2018). *Interconnectedness and systemic risk of China's financial institutions*. *Emerging Markets Review*, ***35***, 1 – 18.

Yilmaz, K. (2014). *Volatility Connectedness of Bank Stocks Across the Atlantic*. Koç University-TÜSİAD Economic Research Forum Working Paper Series 1402, http://hdl.handle.net/10419/108641.

Zigrand, J-P. (2014). *Systems and Systemic Risk in Finance and Economics*. Systemic Risk Centre Special Paper No 1, The London School of Economic and Political Science, January 23.