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Assessing Systemic Risk in the Nigerian Interbank Money Market

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Abstract

The interbank market is an important platform for strengthening financial integration. It also represents a medium for risk sharing among banks through the linkages and common exposures. Exposure between banks leads to a direct asset relation through borrowing from each other at the interbank market while banks are associated indirectly through ownership and sharing of similar portfolio exposures, that connects them, through a web of transaction network. The paper analysed the systemic risk implied in the Nigerian interbank network, based on various network measures using data on individual banks' bilateral exposures. The findings showed that few banks featured prominently in the analysis, owing to their level of exposures and the effect of these varying exposures on their capital base. In addition, the linkages between two prominent banks and other banks were exposed. Moreover, a scenario of two banks failing was observed, which could spark up the chain of other failures with contagion second-round effects. The study could be useful in the development of a monitoring system by the supervisory authorities, as well as in strengthening the bank-internal stress tests of default contagion.

Keywords: Interbank Markets, Financial Stability, Contagion

JEL Classification Numbers: D85, G21, G28

I. Introduction

The widespread impact of the 2007/2008 global financial crisis including the role of the interbank market, underscored the importance of understanding the interconnectedness in the financial system, particularly the need for a better assessment of systemic risk. Generally, financial institutions, especially the operators and regulators, have an interest in a well-functioning and robust interbank market. Central banks, as regulators, leverage on the efficient functioning of the interbank market to influence market interest rates, in a way that reflects the stance of monetary policy. For

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the operators, the interbank market helps in the reallocation of liquidity, but poses a common exposure to risks. The interbank market, not only allows intermediary financial institutions to pool and spread their risk, but also creates the possibility of one bank's crisis propagating through the system. This was the experience in the case of default of the Lehman Brothers (an American investment bank) in 2008 and the resultant chaos in the US interbank market. Similarly, the experience of the 2009 Nigerian banking crisis, due mainly to the second-round effect of the 2007/2008 global financial crisis, underscored the tendency for the crisis in a banking system to spread from one bank to another.

Though a robust and well-functioning interbank market is important for the reliability of the financial system, the aftermath of the failure of a single bank may cause a system failure through interbank exposures. This risk of contagion amongst banks, in terms of a problem in one bank spreading to another, has therefore, been recognised as an important form of systemic risk. Systemic risk of this form connotes the likelihood of a bank's failure or disruption in service in the banking system, leading to the failure or disruption of services of other banks. Therefore, understanding interbank exposure and, thus, systemic risk has received increased attention among policymakers and researchers. It has been established that at the heart of systemic risk are contagion effects, and various forms of external effects (De Bandt and Hartmann, 2000; Smaga, 2014; Gauthier and Souissi, 2012). However, the factors that contribute to the build-up of systemic risk and the eventual spreading of contagion are not definite, as systemic risk in banks appear to be driven by different factors, even in the US and European banks (Varotto and Zhao, 2014).

Blåvarg and Nimander (2002) asserted that the risk of contagion in the banking system could be driven directly, via financial exposure or where crisis with one bank is a possible cause of the problem with other banks. Studies on banks' systemic risk, however, have not only centred around the interconnectedness of financial institutions and their financial robustness, but have also considered firm size, vulnerability, and default probability (Varotto and Zhao, 2014; Inaoka et al., 2014; Langfield et al., 2014; Kanno, 2014; Black et al., 2012; Puhr et al., 2012; Soramaki et al., 2007). Perhaps some important policy questions, supervisors or regulators of financial institutions, especially financial intermediaries would want to ask include: what are the factors that could potentially cause systemic risk in the banking sector or the interbank market?

Could the failure of a bank, owing to those factors, trigger the subsequent failure of other banks? These are the issues examined in this study.

This study is similar to previous studies in understanding the systemic risk in the Nigerian banking sector, specifically the interbank market. It is, however, different regarding the choice of factors that contribute to the build-up of systemic risk and the eventual spreading of contagion in the Nigerian interbank market. In assessing systemic risk in the Nigerian interbank market, we assumed a default state for a bank by shocking it with credit default; credit and funding; and risk transfer in terms of contingent liabilities, after establishing interconnectedness among the banks. Since the financial crisis had put systemic risk firmly on the policy agenda, this study would aid in the identification of the major triggers of systemic risk and enhance an understanding of the potential resilience to contagion in the Nigerian interbank market. With such knowledge, policymakers can provide appropriate preventive macroprudential measures to mitigate systemic risk by reducing the externalities. This study, therefore, examined the interconnectedness (linkages) in the Nigerian interbank market and the various level of financial exposure to specific shocks (from 2014 to 2016), with a view to highlighting potential systemic risk and contagion effects. The study provided evidence of potential risks of a chain reaction in the interbank market in which the failure of one bank could lead to the default of other bank creditors. The study adopted the dynamic approach to Network Analysis framework for the simulation.

The rest of the paper is organised as follows: Section 2 provided a brief review of the conceptual issues and empirical literature, while Section 3 presented the trend in the Nigerian interbank market. Section 4 estimated and discussed the results of the simulation. Section 5 highlighted policy implications and recommendations of the study, while Section 6 concluded the paper.

II. Literature Review

II.1 Conceptual Literature

The interbank market is an important platform for strengthening financial integration. It represents a medium for risk sharing among banks, through the linkages and common exposures. The linkages and interconnectedness of the interbank market operations may serve as a channel of contagion through which problems affecting one bank, or one country, may spread to other banks or other countries (Degryse and Nguyen, 2004). Iori et al., (2006) identified sources of systemic failure already documented in the literature as follows:

- a bank run may arise from an attempt by depositors to draw funds, which lead to a collapse of the system, otherwise self-fulfilling panic;
- where banks invest in similar types of assets, significant fall in the price of the asset, which causes a bank's failure, may affect the solvency of other banks that hold the same asset; and
- inter-locking (interbank) exposures among financial institutions, which serve the purpose of mutual support but, also, create the potential for one institution's failure to have a ripple effect on the financial health of other institutions.

The last source of systemic risk underscores the dangers of contagion in the interbank market, which arise from short-term, mainly overnight interbank lending. Iori et al., (2006) further emphasised the trade-off between mutual insurance and systemic risk on the overall stability of the system under interbank lending.

II.1.1 Systemic Risk

Systemic risk comprises the risk to the proper functioning of the system as well as the risk created by the system (Zigrand, 2014). Put differently, it refers to the possibility that a triggering event like bank failure or market disruption could cause widespread disruption of the stability of the entire financial system. Systemic risk could be classified according to various groups, dimensions, or general types as shown in Table 1.

Table 1: Classification of Systemic Risk

Classes			References
Groups	Common exposure to asset price bubbles		Allen and Carletti (2011)
	Liquidity provision and mispricing of assets		
	Multiple equilibria and panics		
	Contagion		
	Sovereign default		
	Currency Mismatch		
Dimensions	Macroeconomic	When the financial system becomes exposed to aggregate risk resulting from exposures.	Nier 2009
	Microeconomic	When the failure of an individual institution has an adverse impact on the system as a whole.	
Type	Macro shocks	Negative external disturbance, preventing financial system from properly fulfilling its functions	Bancarewicz (2005)
	Failure chains	Losses incurred by one institution, leading to losses in related institution (Spreading of risk)	
	Reassessment failures	Based on the increase in information asymmetry concerning the correlation in institutions risk exposure and limited possibility of differentiating them.	

Author's compilation based on Smaga, 2014.

II.1.2 Contagion

A financial contagion could be defined as the diffusion of either eeconomic crises throughout a geographic region. According to Investopedia (online), this could occur at the international and domestic levels, but it had become more noticeable as the global economy grows, and economies within certain geographic regions became more connected with one another. At the domestic level, it could occur if one large bank sells most of its assets quickly and the confidence in other large banks, drops accordingly[1].

To estimate the danger of contagion, owing to exposures in the interbank loan market, Upper (2011) provided a summary of the results of other works done by various researchers in Table 2. He presented a critical assessment of the

[1] *www.investopedia.com*

modeling assumptions on which they were based and discussed their use in financial stability analysis. He noted further that, though contagion due to interbank exposures might be rare, when it happens, it could destroy a sizable proportion of the banking system's total assets and that contagion could happen through a multitude of channels.

Table 2: Channel of Contagion in the Banking System

	Channel	References
Liability-Side	Bank runs – Multiple equilibria/fear of other withdrawals	Diamond and Dybvig (1983), Temzelides (1997), Goldstein and Pauzner (2004)
	Common pool of liquidity	Aghion et al. (2005), Acharya et al., (2008), Diamond and Rajan (2005), Brunnermeier and Pedersen (2009)
	Information about asset quality	Chen (1999), Acharya et al.,(2008)
	Portfolio rebalancing Fear of direct effects	Kodres and Pritsker (2002), Dasgupta (2004), Iyer and Peydró-Alcalde (2005), Lagunoff and Shreft (2001), Freixas et al. (2000)
	Strategic behaviour by potential lenders	Acharya et al. (2008)
Asset side – Direct Effects	Interbank Lending	Rochet and Tirole (1996)
	Payment System	Humphrey (1986), Angelini, et al. (1996), Bech and Garratt (2006)
	Security Settlement	Northcott (2002)
	FX Settlement	
	Derivative exposures	Blavarg and Nimander (2002)
	Equity cross-holding	
Asset side – Indirect Effects	Asset prices	Cifuentes et al. (2005), Fecht (2004)

Adapted from: Upper, 2011

II.2 Empirical Literature

In the years following the 2007/2008 global financial crisis, many studies had focused on the analysis of the financial system with a view to understanding the various sources and transmission processes of systemic risks, especially in the banking system. Economists studying contagion have resorted to simulation methods to test whether, given a set of exposures; failures could have knock-on effects or not (Upper, 2011). In assessing systemic risk in the interbank market, network analysis is often applied (Kanno,2015). Applying the network analysis allows one, not only to look beyond the immediate "point of impact" of a shock, but also to see the likely spillovers, arising from the inter-linkages in the system. Thus, the use of the interbank network analysis aids in alerting supervisory authorities on possible contagion risk and the channels through which shocks spread within the system. It serves as a resilience test of network and a means of identifying systemically significant nodes. The network model could be analysed using the static and the dynamic approaches.

The static network approach describes the network structure of the financial system, using topological indicators, while the dynamic approach measures the strength of the contagion channels and network resilience by observing the responses of financial structure to shocks. Some of the studies that adopted the network approach included Inaoka et al., (2014), Soramaki et al., (2007), Puhr et al., (2012), Langfield et al., (2014) and Masayasu (2015). Many studies have analysed systemic risk in interbank market from a network perspective. However, a sizeable number of studies had also attempted to analyse the dynamics of systemic risk in the market, from different points of view.

Allen and Gale (2000) introduced interbank liquidity market into the model of Diamond and Dybvig (1983) and found that the system was more resilient when every bank was connected to all other banks, due to wider risk-sharing effect. However, where the network structure was incomplete, such market was fragile because banks were unable to have a wider platform for risk sharing and diversify their portfolio structure against idiosyncratic shocks. Nier et al., (2008) investigated how the interactive features of the interbank network could be related to the financial stability of the system. They found out that the higher the risk-sharing among banks, the greater the size of the domino effect. This was usually in a situation where one of the banks, in the system was hit by a shock, although higher capitalisation level might reduce the number of defaults in case the shock permeated the system.

Iori et al., (2006) investigated the potential for the interbank market to act as a propagation mechanism for liquidity crises. Using a dynamic model, in which banks interacted in the interbank market, they showed that the market played a stabilising role. The study found that interbank market unambiguously stabilised a system with homogeneous banks, while chances of contagion effect were more apparent with heterogeneous banks, notwithstanding that the interbank market still played the stabilising role. In other words, they observed that through fluctuations in liquid assets and stochastic investment opportunities that mature with delay, creating the risk of liquidity shortages, banks activities in the market created interconnections in the market that might turn out to be channels for the propagation of initial bank-specific shocks.

Generally, the first of the two popular approaches to measuring contagion tries to isolate contagion from other shocks affecting the economy. To examine the issue of systemic risk in the Swiss interbank market, Sheldon and Maurer (1998) simulated the outcomes of the failure of one bank, based on estimated interbank exposures, and looked at the potential domino effects. They x-rayed the first round and potential contagion effects. They found that the potential of contagion, arising from interbank linkages in Switzerland, was quite low, although the failure of a large Swiss bank would have serious implications.

Using a similar approach to study the German interbank market, Upper and Andreas (2002) observed that contagion risk of failure in a bank could trigger domino or contagion that would affect a substantial part of the banking system. The study identified the role of the safety net as a veritable measure to mitigate the spread of systemic risk from interbank activities. Overall, the consensus among authors[2], based on the findings in their separate studies, emphasised that the interbank system was necessary to pool idiosyncratic risk and ensure an efficient system. However, the system could also be a source for the propagation of systemic risk. In other words, the findings emphasised the dualism of interbank connections and, thus, underscored the need for proper risk management in the financial system, in order to forestall over-exposure and ensure an adequate safety net.

Other studies on systemic risk in the banking sector include Varotto and Zhao (2014); Laeven et al., (2014); Black et al., (2012); Gauthier and Souissi (2012); Huang et al., (2012); and De Brandt and Hartmann (2012). Varotto and Zhao

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[2] *Gai and Kapadia (2010) and Cifuentes (2003),*

(2014) analysed aggregate and firm-level systemic risk for the US and European banks from 2004 to 2012. They observed that common systemic risk indicators were driven primarily by firm size, which implied an overriding concern for "too-big-to-fail" institutions. They, however, posited that smaller banks might still pose considerable systemic threats, as exemplified by the Northern Rock debacle in 2007. By introducing a simple standardisation, they obtained a new risk measure that identified Northern Rock as a top ranking systemic institution, up to 4 quarters before its bailout.

In a similar study on bank size and systemic risk, Laeven et al., (2014) revealed that large banks tended to be riskier and create more systemic risk, when they have lesser capital and less-stable funding. This was because the failure of large banks tended to be more disruptive to the financial system than failure of small banks, as it generated liquidity stress in the banking system. However, Black et al., (2012) examined the systemic risk of banks, using a hypothetical distress insurance premium. Economically integrating the main characteristics of systemic risk, which included size, default probability, and interconnectedness, the authors designed a systemic risk measure for the European banking system and showed that European banking systemic risk reached its height in late 2011, while the sovereign default factor was the dominant driver of the European debt crisis. Huang et al., (2012) also measured the systemic risk of a portfolio of twenty-two major banks in Asia and the Pacific, illustrating the dynamics of the spillover effects of the global financial crisis to the region. Their findings revealed that the increase in the perceived systemic risk was driven mainly by the heightened risk aversion and the liquidity squeeze, particularly after the failure of the Lehman Brothers. The result from Huang et al. (2012) analysis of the marginal contribution of individual banks to systemic risk, suggested that "too-big-to-fail" was a valid concern from a macroprudential perspective of bank regulation.

Gauthier and Souissi (2012) employed the macro-financial risk assessment framework (MFRAF) in facilitating the understanding of systemic risk in the Canadian banking system. They found that failure to account for either liquidity risk or network spillover effects could cause a significant underestimation of the extent of systemic risk in an undercapitalised banking system that relies extensively on the short-term funding market. Thus, they posited that any regulatory framework that intends to control for systemic risk should consider the bank's capital, holdings of liquid assets and short-term liabilities, comprehensively.

III. The Nigerian Interbank Money Market

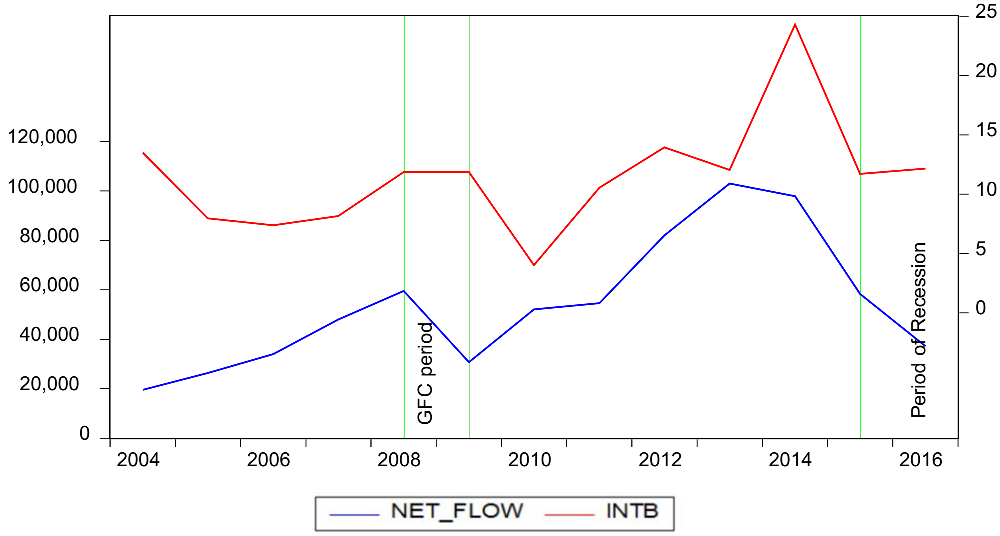
The Interbank market, as an integral part of the money market, is the market where banks and discount houses trade unsecured overnight loans. In the market, impulses, which influence the dynamics of interest rate determination and structure, are generated. The market also provides the platform for banks to take care of daily imbalances, either as fund-takers or as fund-givers. Hence, the market, as in many other countries, plays a critical role in the conduct and transmission mechanism of monetary policy. When banks extend credit, they do so with the belief that their debtors would be committed to repaying the loans at the due date. These debtors, in some cases, however, may fail to honour their debts obligations. This potentially causes severe contagious events, resulting in the loss of equity (Gai and Kapadia, 2010).

If a bank wants to minimise its risk when advancing such credit, the bank would need to have sufficient information regarding the financial situations of the bank it extends credit to, including all the bank's exposures. However, no bank can peep so deeply into the interbank credit network to evaluate the probability of defaults due to contagion effects. If a single bank fails, only those banks to which it owes money suffer directly, the remainder of the system is unaffected. The direct impact, however, may cause one or more of the bank's counter-party to fail, destroying further institutions within the interbank market. Since the creation of the interbank market in the 1970s, the market has grown to be very efficient and thus continue to serve as a veritable platform for facilitating the efficiency of a central bank's monetary policy. It is a subset of the money market for unsecured placements and borrowings of finance, amongst players in the economy.

Transactions on the Nigerian interbank market, as in other countries, involve placement of funds on a short-term basis, ranging from overnight, up to a period of three years. Most of the trading in the Nigerian interbank market are carried out directly between pairs of banks over-the-counter (OTC), as opposed to a centralised location. Some banks need to borrow money in the interbank market to cover temporary shortfalls in liquidity or regulatory reserve requirements, while others, on the other hand, hold excess liquid assets beyond their liquidity requirements, and lend money in the interbank market earning interest on the assets. The interbank market trades in all the money market instruments, using them as security or collateral.

Over the years, the Nigerian monetary authority had adopted policies aimed at ensuring the stability of the interbank market and the financial system. However, the 2007/2008 global financial crisis affected the domestic interbank market, mainly through trade and capital flows from other countries because of the openness of the economy and the massive dependence on the export of crude oil for government revenue and foreign exchange earnings (Figure 1).

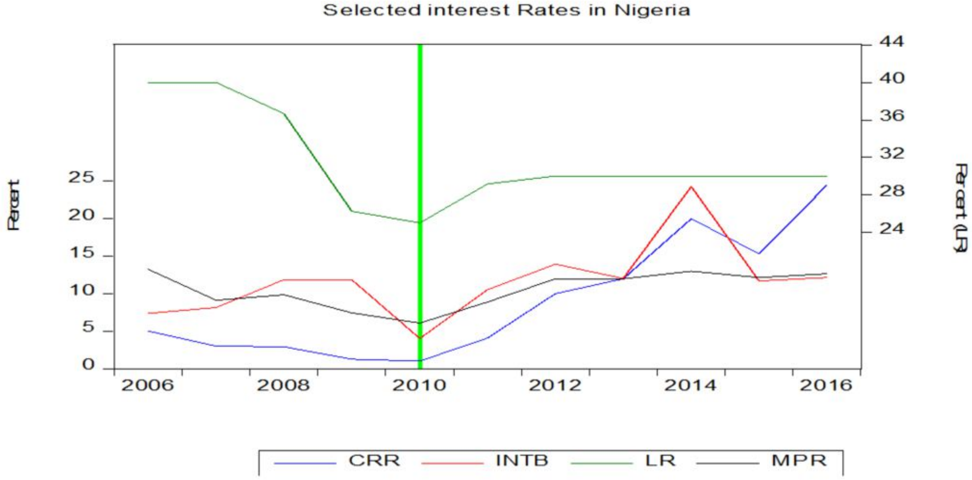
Figure 1: Forex flows and Interbank Money Market Rate (2004-2016)



At a time, the banks were unable to carry out their statutory function, due to the tightening of liquidity because of rising capital outflow, and lower monetisation of oil earnings. Furthermore, a special audit of the banking industry revealed that banks had large volumes of non-performing loans (heavily exposed to oil & gas, margin lending), capital erosion, poor risk management, illiquidity and poor corporate governance practices, among others. This led to liquidity pressures, thereby pushing up domestic interest rates that posed a threat to systemic risk.

However, in a bid to mitigate the effects of these negative developments, the regulatory authorities took active steps to infuse more liquidity into the market. The measures included reduction of the monetary policy rate from 10.25 per cent to 9.75 per cent in 2008; cutting down the liquidity ratio from 40.0 per cent in 2008 to 25.0 per cent in 2009; and reducing the cash reserve requirement from 4.0 per cent in 2008 to 1.0 per cent in 2009 (Figure 2). The Monetary Authority injected N620 billion into some of the banks, removed their top executive management and appointed interim ones (Sanusi,2010).

Figure 2: Selected Interest Rates in Nigeria



The Central Bank of Nigeria (CBN) also guaranteed interbank transactions by Nigerian banks that were denominated in the local currency and allowed banks to buy back their securities, while extending the discount window to 365 days (1 year), as opposed to overnight lending. As part of the Bank's efforts to meet the resolution cost of restoring financial stability, while guarding against further risk, the Asset Management Corporation of Nigeria (AMCON) was established in 2010 to resolve the issues of non-performing loans in banks and recapitalise the technically-insolvent banks. Furthermore, the Financial Stability Fund (FSF) was also set up in 2010 by the Bank, in collaboration with the banks, to ensure that future bailouts of these banks could be achieved with minimum delay and little contribution, if at all, from taxpayers' money. The Fund had an initial target of N1.5 trillion (about US$10 billion). The CBN was to contribute N50 billion annually to the Fund, while each bank was to contribute 0.4 per cent of its total assets annually for ten (10) years. These actions stabilised the interbank rates and restored confidence in the financial system.

IV. Methodology

IV.1 The Network Model

Globalisation has expanded trade beyond borders and links markets across countries. As a result, cross-border financial flows have increased affecting financial institutions through various assets and liabilities on their balance sheets. Exposure between banks leads to a direct asset relation through borrowing from each other at the interbank market, while banks are associated indirectly through ownership and sharing of similar portfolio exposures that connects them through a web of transaction network. A network representation of financial system can conveniently capture the complex structure of linkages between financial institutions. The network concept depicts a set of nodes and links between them that may represent objects, individuals, firms or countries. A link for instance, is a social setting, which could mean a bond between friends or family members. While in the financial system context, the links indicate financial obligations among banks that are created through mutual exposures in the interbank market, owing to ownership or dealing with the same bulk of depositors. The creation of risk assets, in the interbank market, has exposed banks thereby endangering their capital on a different magnitude.

To prevent a local financial crisis from expanding into a global concern, the network analysis is imperative as it is instrumental in identifying the vulnerabilities of an institution and the negative externalities it may create for other related institutions within the system. Moreover, an understanding of network externalities may lead to the appreciation of macroprudential framework adopted for financial supervision. This regulatory framework takes into consideration vulnerabilities of an individual institution that may pose a systemic risk to the entire financial system. The concept of network analysis is relevant in explaining the impact of network formation and structure of a financial system. On the formation of the network in the interbank market, the driving force is predicated on the need to share risk aimed at curtailing the evolving threat of contagion. The network structure provides an insight on how the financial system responds to the risk of contagion either promptly or with a lag. Financial institutions that play more of the role of intermediation benefit more and are saddled with more risks. When the risk associated with lending funds on the interbank market becomes too high and the links are too costly relative to their benefits, freezes occur in network formation.

IV.2 Theoretical Application of Network Model

The network concept has been applied to a wide range of scenarios. According to Allen and Ana (2008), various research work from Calvó-Armengol and Jackson (2004), Arrow and Borzekowski (2004) and Loannides and Soetevent (2006) have established the behavioural pattern of employers, using the social network of their current employees to hire recommended applicants. Corominas-Bosch (2004) explained transaction dynamics between buyers and sellers are connected through a web of network links. Transactions occured only between parties that were connected by a link and multiple links indicate multiple transactions. Allen and Gale (2000), Diamond and Dybvig (1983), Leitner (2005), Vivier-Lirimont (2004), Masayasu (2015) applied network analysis to a financial system, focusing on financial stability, interbank market, and contagion.

IV.3 The Interbank Network Model

The lending relationship in the interbank market was modelled with links and the banks represented by nodes. Time periods were indexed by $t \in N$ Banks are indexed by $i \in \{1, \ldots, N\}$. In each period, banks were subjected to funding shocks that occasionally crystalised into credit shocks and consequently influenced banks' payment accounts in their daily business operations. Banks wished to smoothen these shocks by borrowing and lending funds from each other in an over-the-counter market. As an outside option, banks had unlimited recourse to the central bank's standing facilities (discount window) with deposit rate r_d and lending rate r_l with $r_l \geq r_d$ Banks entered the market with the objective to maximise expected discounted interbank market profits from lending and borrowing funds by: (i) choosing which banks to approach for bilateral bargaining on loan and interest rates with other banks; and (ii) setting bilateral monitoring expenditures to mitigate uncertainty about counterparty credit risk.

The first set of simulations probed the likely impact of the assumed credit default from an institution, which was tagged as credit shocks. The second set of simulations captured the potential effect of credit-plus funding scenario, whereby the defaulting institution creates liquidity squeeze for other institutions that relied on it for funding. Following from Espinosa-Vega and Sole (2011), the potential systemic implications of interbank linkages could be assessed through a network of N institutions. The balance sheet identity of the bank can be shown as:

$$\sum_j x_{ji} + a_i = k_i + b_i + d_i + \sum_j x_{ij} \quad (1)$$

Where x_{ji} represented bank i loans to the bank j, a_i indicated bank i other assets, k_i stood for bank i's capital, b_i were long-term and short-term borrowing (excluding interbank loans), d_i denoted deposits, and x_{ij} stands for bank i borrowing from bank j.

In assessing systemic risk in the interbank market, we assumed a default state for a bank, by shocking it with credit default, credit-plus funding shocks, and shocks emanating from risk transfer, regarding contingent liabilities.

IV.3.1 Credit Default Shocks

The default of each of the 23 banks, captured for this study, was simulated. The likely loss from the default was denoted by the parameter λ. Borrowing from Espinose-Vega and Sole (2011), it was assumed that banking system capital absorbed losses from the default. Taking into consideration the assumed default of say bank h, the balance sheet identity of bank i transformed to:

$$a_i + \sum_{j \neq h} x_{ji} + (1 - \lambda) x_{hi} = (k_i - \lambda x_{hi}) + b_i + d_i + \sum_j x_{ij} \quad (2)$$

However, bank i is said to have failed, if its capital is insufficient to fully cover its losses (i.e., if $k_i - \lambda x_{hi} < 0$).

IV.3.2 Credit-Plus-Funding Shocks

Liquidity in the money market influences the extent to which a bank can replace an unforeseen withdrawal of interbank funding. With liquidity surfeit in the market, bank-funding sources are assured at an affordable cost of fund. However, in a scenario of liquidity squeezes, and the absence of alternative sources of funding, a bank may resolve into a fire sale of assets to mend its balance sheet identity. For ease of analysis, we assumed that the bank's capital absorbed the loss induced by a funding shortfall and the possibility of the bank raising new capital was not considered. Consequently, a bank's vulnerability not only emanates from the credit exposure but also from funding sources, through its inability to roll over its funding.

The simulations were premised on the assumption that bank i was able to replace only a fraction $(1-\rho)$ of the lost funding from bank h, and its assets traded at a discount, so that bank i was forced to sell assets worth $(1+\delta)\rho x_{ih}$ in book value terms. The funding shortfall induced loss, $\delta\rho x_{ih}$, was absorbed by bank $i's$ capital, and thus the new balance sheet identity for bank i was given by

$$a_i + \sum_j x_{ji} - (1+\delta)\rho x_{ih} = (k_i - \delta\rho x_{ih}) + b_i + d_i + \sum_j x_{ij} - \rho x_{ih} \quad (3)$$

IV.3.3 Risk Transfers Shocks

Contingent liabilities deserve special consideration in times of stress as its crystallisation activates dormant linkages across banks and bring new exposures onto the balance sheet of the bank. However, owing to data constraints, we were unable to cover this segment of the analysis.

IV.4 Data

In this study, we used data from FinA, produced on the platform of Central Bank of Nigeria. FinA is a database containing information about all banks operating in Nigeria. Each of the 23 banks' reports contains detailed unconsolidated and or consolidated, balance sheet and income statements. Given that the variables of interest, namely: interbank exposure, which was a combination of both secured and unsecured lending in the market and total qualifying capital of banks were all stock variables, a point analysis was conducted for the end periods December 2014, June 2015, December 2015, and June 2016.

V. Simulation Results

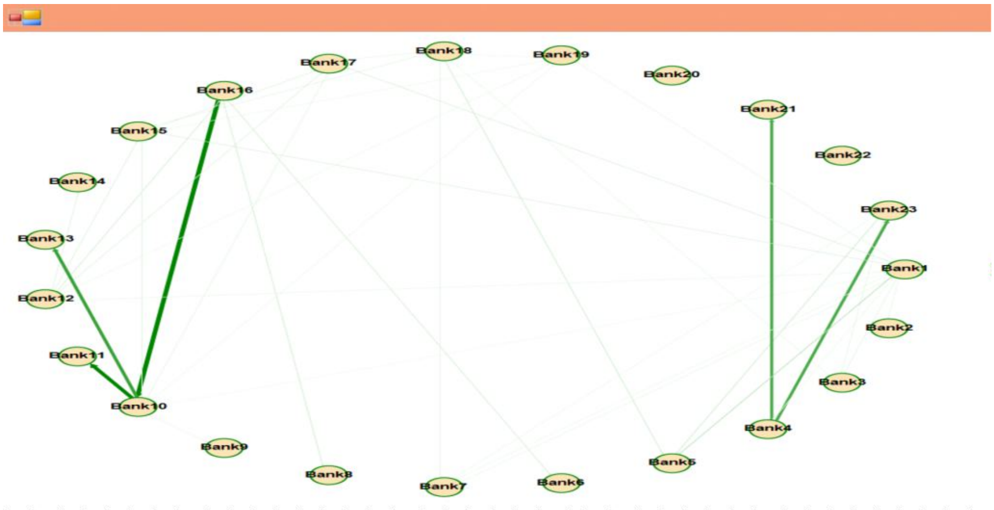
V.1 Bank Network Exposures

The analysis began with the interconnectedness of financial institutions in the interbank market, based on their credit exposures. The network can transmit systemic risk bilateral exposures, possibly causing contagion defaults that are triggered by a bank's stand-alone default. Figure 3 presented network exposure for the period end-December 2014 among the sampled Nigerian banks.

V.1.1 Network Exposures for Period End-December 2014

The network diagrams displayed the exposures of various banks within the interbank market. From the analysis, the exposure between bank 16 and 10 was the largest[3], as bank 16 owed bank 10, 238.5 per cent of bank 10's capital. This was followed by the exposure of bank 10 to bank 11, which was 114.5 per cent of bank 11's capital. Others were: the exposure of bank 10 to bank 13 (75.7 per cent of bank 13 capital); bank 4 to bank 23 (69.0 per cent of bank 23's capital) and bank 4 exposure to bank 21 (66.4 per cent of bank 21 capital).

Figure 3: Interbank Exposure Network Diagram for End-December 2014



Source: Authors' Computation

V.1.2 Network Exposures for Period End-June 2015

The Network exposures for the half-year period of 2015, as shown on Figure 4, indicated a huge exposure between bank 20 and 10, where bank 20 owed bank 10 (200,000 per cent of bank 10's capital that had a negative capital base as at that period). The lack of capital, on the part of bank 10, could be attributed to either real loss of capital or a situation of merger and acquisition, whereby bank 10 capital was absorbed by bank 20. Similarly, bank 1 owed bank 2, 20.9 per cent of bank 2 capital, while bank 7 owed bank 2 (13.2 per

[3] *The thickness of the network lines indicates the level of exposure, the thicker the line the greater the level of exposure.*

cent of bank 2's capital) and bank 7 owed 15 (10.4 per cent of bank 15's capital). A systemic crisis might emerge if bank 20 or 2 decides to recall their funds, given that the exposure between bank 10 and 20 was quite substantial as indicated by the thickness of the link among the banks. The intuition here was not the amount but the percentage of the borrowed funds on the capital of the creditor.

Figure 4: Interbank Exposure Network Diagram for End-June 2015

Source: Authors' Computation

V.1.3 Network Exposures for Period End-December 2015

For the end-December 2015, exposures activities among the banks were at its lowest ebb. The exposure between bank 14 and 21 was dominant, as indicated in Figure 5. Bank 14 owed bank 21,928.9 per cent of bank 21's capital). This was followed by the exposure of bank 18 to 21, whereby bank 18 owed bank 21 (13.4 per cent of bank 21's capital). Likewise, bank 23 owed bank 21 (5.3 per cent of bank 21's capital), bank 9 owed bank 2,093.1 per cent of bank 20's capital), while bank 16 owed bank 14 (2.9 per cent of bank 14's capital). Other noticeable exposures included bank 15 owed bank 19 (2.2 per cent of bank 19's capital); bank 4 owed bank 16 (2.2 per cent of bank 16's capital) and bank 20 owed bank 19 (2.0 per cent of bank 19's capital). Also, bank 10 owed bank 19 (1.2 per cent of bank 19's capital); and bank 16 owed bank 3 (1.1 per cent of bank 3's capital).

Figure 5: Interbank Exposure Network Diagram for End-December 2015

Source: Authors' Computation

V.1.4 Network Exposures for Period End-June 2016

As shown in Figure 6, the exposure between bank 16 and 10 was the dominant one, not in terms of the amount borrowed but rather the percentage of the borrowed fund on the capital of the lender. Bank 16 owed N18.27 billion to bank 10 and given that bank 16 had no capital as at the period of the simulation, making the exposure more pronounced. Other exposures are bank 10 owed (105.7 per cent of bank 11's capital); and bank 4 owed bank 23 (64.0 per cent of bank 23's capital). Similarly, bank 4 owed bank 21(48.1 per cent of bank 21's capital); and bank 10 owed bank 13 (48.4 per cent of bank 13's capital); and bank 1 owed bank 5 (25.0 per cent of bank 5's capital). Bank 1 owed bank 17 (11.5 per cent of bank 17's capital) and bank 1 owed bank 15 (9.8 per cent of bank 15's capital).

Figure 6: Interbank Exposure Network Diagram for End-June 2016

Source: Authors' Computation

V.2 Credit Shock Transmission

Simulating the transmission of credit shocks, we adapted a scenario in which institutions could rollover their debt obligations and do not necessarily have to resort to fire sales of assets. The credit shock analysis focused on a hypothetical default of a bank to other banks within the interbank market.

V.2.1 Credit Shocks Transmission for the Period End-December 2014

The simulation results were reported in Table 3. It was indicated in the Table that banks 7, 22, 9, 1 and 19 were systemic players in the market. As at end-December 2014, the default of these banks would have led to losses – after all contagion rounds of effects – of 13.9, 12.5, 9.6, 8.3 and 7.6 per cent, for bank 7, 22, 9, 1 and 19, respectively.

Induced failures and number of contagion rounds of the aftershocks, triggered by each hypothetical failure, were shown in columns 1 and 3 in Table 3. The failure of bank 10 would trigger distress in only one round contagion. Likewise, the failure of Bank 16 would trigger the failure of two additional banks in two round contagion.

The analysis further revealed the recognition of institutions whose stress posed systemic risk and institutions that became vulnerable because of such risks. At the end of December 2014, banks 1, 10, 12, 16 and 18 were systemic institutions that triggered light contagion within the market, while bank 7 and 22 experienced high capital losses, because of the induced failures. For the absolute hazard, also known as vulnerability, level indicated that out the 23 simulations, banks 10 and 11 were affected once and twice, respectively, in scenarios in which they were not the trigger institutions.

Table 3 – Simulation Results for Credit Shocks Transmission for the Period End-December 2014

Banks	Induced Failures	% of Failed Capital	Contagion Rounds	Index of Contagion	Index of Vulnerability
Bank 1	0	8.33	0	2.03	0.47
Bank 2	0	2.35	0	0	0.12
Bank 3	0	6.17	0	0	0.46
Bank 4	0	6.56	0	0.7	0.04
Bank 5	0	1.18	0	0	2.39
Bank 6	0	5.15	0	0	0.53
Bank 7	0	13.91	0	0.34	0.2
Bank 8	0	4.68	0	0	0.58
Bank 9	0	9.63	0	0	0.31
Bank 10	1	0.54	1	1.36	4.55
Bank 11	0	0.29	0	0	9.09
Bank 12	0	3.80	0	1.46	0
Bank 13	0	0.44	0	0	6.88
Bank 14	0	4.46	0	0	0.3
Bank 15	0	2.53	0	0.47	1.47
Bank 16	2	2.94	2	2.87	0.55
Bank 17	0	2.38	0	0	1.99
Bank 18	0	3.16	0	1.02	0
Bank 19	0	7.57	0	0	0.63
Bank 20	0	1.31	0	0	0
Bank 21	0	0.49	0	0	3.02
Bank 22	0	12.50	0	0	0
Bank 23	0	0.47	0	0.53	3.14

Source: Authors' Computation

V.2.2 Credit Shocks Transmission for the Period End-June 2015

The result of credit shocks simulation output for the period ended June 2015, presented on Table 4, indicated that an induced failure of bank 20 that consequently triggered capital loss of 9.04, 7.39, 15.46, 9.97, 8.06 and 12.71, respectively, to banks 1, 4, 7, 9,19 and 22. Capital erosion of banks 7 and 22 was quite significant, owing to the systemic impact of bank 20 on these two banks. The contagion round of effects was also limited to one round, implying that there was no second-round contagion effect from the induced failure of bank 20. Apart from identifying bank 20 as a systemic player, the simulation also detected bank 10 as the most vulnerable in the system with a high 4.55 per cent index of vulnerability. However, the capital impairment of bank 10 was zero because it had a status of negative capital before the simulation.

Table 4: Simulation Result for Credit Shock Transmission for the Period End-June 2015

Banks	Induced Failures	% of Failed Capital	Contagion Rounds	Index of Contagion	Index of Vulnerability
1	0	9.04	0	0.15	0.88
2	0	1.38	0	0.27	0.6
3	0	6.64	0	0	0
4	0	7.39	0	1.12	0.34
5	0	1.03	0	0	3.38
6	0	5.14	0	0	0
7	0	15.46	0	0.57	0.18
8	0	4.88	0	0	0
9	0	9.97	0	0	0.07
10	0	0.00	0	0.67	4.55
11	0	0.29	0	0.03	0
12	0	0.00	0	0	0
13	0	0.64	0	0	0
14	0	3.25	0	0.91	0
15	0	2.90	0	0.42	0.47
16	0	2.75	0	1.61	0.1
17	0	2.46	0	0	0.11
18	0	3.27	0	0.96	0
19	0	8.06	0	0	0.96
20	1	1.62	1	1.19	0
21	0	0.63	0	0	1.51
22	0	12.71	0	0	0.66
23	0	0.48	0	0.64	0

Source: Authors' Computation

V.2.3 Credit Shocks Transmission for the Period End-December 2015

Table 5 presented showed the simulation result of credit shock transmission for the period end-December 2015. Owing to the low exposures activities observed from the network diagram, the simulator did not induce failure for any bank, as depicted on column 2 of Table 5. However, the possible erosion of capital was captured more for bank 7 with 14.43 per cent. This was followed by bank 22, 1, 19, 4, 3, 23, 8 and 6 with 11.49, 9.19, 7.72, 7.21, 6.0, 5.13, 5.13 and 4.69 per cent levels of capital failure, respectively.

On the other hand, bank 20 tended to have more contagion as exhibited by more lines, linking it to other banks as shown in Figure 5, with 0.52 per cent, while bank 18 with 0.34 per cent, came second with the largest volume of activities within the network. Other likely cases of contagion were bank 14, 16, 7, 15, 23, 10, 4 and 9 with 0.23, 0.20, 0.18, 0.17, 0.17, 0.09, 0.06 and 0.05 per cent, respectively. Bank 19 was the most vulnerable in the system.

Table 5: Simulation Results for Credit Shocks Transmission for the Period End-December 2015

Banks	Induced Failures	% of Failed Capital	Contagion Rounds	Index of Contagion	Index of Vulnerability
1	0	9.19	0	0	0
2	0	1.34	0	0	0
3	0	6.00	0	0	0.05
4	0	7.21	0	0.06	0.13
5	0	0.00	0	0	0
6	0	4.69	0	0	0
7	0	14.43	0	0.2	0.06
8	0	5.13	0	0	0
9	0	9.41	0	0.05	0.05
10	0	0.70	0	0.09	0
11	0	0.42	0	0	0
12	0	0.00	0	0	0
13	0	0.60	0	0	0
14	0	3.80	0	0.23	0.13
15	0	2.70	0	0.17	0
16	0	2.59	0	0.18	0.1
17	0	2.41	0	0	0
18	0	2.98	0	0.34	0
19	0	7.72	0	0	0.32
20	0	1.49	0	0.52	0.14
21	0	0.58	0	0	2.16
22	0	11.49	0	0	0.06
23	0	5.13	0	0.17	0.16

Source: Authors' Computation

V.2.4 Credit Shocks Transmission for the Period End-June 2016

Three induced failures were simulated for the credit shocks, one for bank 10 and two for bank 16. This, however, produced one round contagion effect for bank 10 and a second-round effect for bank 16. Contagion index of 2.47 per cent for bank 16 was the highest, followed by 1.91, 1.31 and 1.29 per cent for bank 1, 12 and 10, respectively. The result also indicated bank 11 as the most vulnerable with vulnerability index of 9.09 per cent, trailed closely by bank 10 and 23 with 4.55 and 2.91 per cent index of vulnerability, respectively.

Table 6: Simulation Results for Credit Shocks Transmission for the Period End-June 2016

Banks	Induced Failures	% of Failed Capital	Contagion Rounds	Index of Contagion	Index of Vulnerability
1	0	9.04	0	1.91	0.41
2	0	1.38	0	0	0.18
3	0	6.64	0	0	0.4
4	0	7.39	0	0.66	0.03
5	0	1.03	0	0	2.55
6	0	5.14	0	0	0.49
7	0	15.46	0	0.33	0.17
8	0	4.88	0	0	0.52
9	0	9.97	0	0	0.28
10	1	0.29	1	1.29	4.55
11	0	0.29	0	0	9.09
12	0	0.00	0	1.31	0
13	0	0.64	0	0	4.4
14	0	3.25	0	0	0.38
15	0	2.90	0	0.44	1.2
16	2	3.04	2	2.47	0.45
17	0	2.46	0	0	1.81
18	0	3.27	0	0.95	0
19	0	8.06	0	0	0.55
20	0	1.62	0	0	0
21	0	0.63	0	0	2.18
22	0	12.71	0	0	0
23	0	0.48	0	0.5	2.91

Source: Authors' Computation

V.3 Funding Shocks Transmission

The effect of funding shocks was considered based on the assumption that banks were unable to roll over credit arrangements, thereby falling back to a fire sale of their assets to meet due obligations. Given the fact that such assets disposal would be done with some level of desperation, we further assumed that a discount value of 35 per cent, implying that such assets would be disposed at a market rate less the discount value (i.e., at 65 per cent).

V.3.1 Funding Shocks Transmission for the Period End-December 2014

From the simulation results, in Table 7, the funding shock exhibited a similar pattern like the credit shocks transmission, except for bank 10 and 16, where the percentage of failed capital were 0.25 and 2.40 per cent, which were less than 0.54 and 2.94, respectively, recorded for 10 and 16 under the credit shocks transmission. The vulnerability of banks was more pronounced in the preceding analysis of credit shock when compared to the funding shocks transmission analysis, except for bank 4,7, 8 and 10.

Table 7 – Simulation Result for Funding Shocks Transmission for the Period End-December 2014

Banks	Induced Failures	% of Failed Capital	Contagion Rounds	Index of Contagion	Index of Vulnerability
Bank 1	0	8.33	0	0.28	0.35
Bank 2	0	2.35	0	0.02	0
Bank 3	0	6.17	0	0.23	0
Bank 4	0	6.56	0	0.02	0.16
Bank 5	0	1.18	0	0.22	0
Bank 6	0	5.15	0	0.22	0
Bank 7	0	13.91	0	0.25	0.03
Bank 8	0	4.68	0	0.22	0
Bank 9	0	9.63	0	0.13	0
Bank 10	0	0.25	0	0.21	8.93
Bank 11	0	0.29	0	0.12	0
Bank 12	0	3.80	0	0	0.59
Bank 13	0	0.44	0	0.12	0
Bank 14	0	4.46	0	0.11	0
Bank 15	0	2.53	0	0.26	0.29
Bank 16	0	2.40	0	0.11	1.18
Bank 17	0	2.38	0	0.34	0
Bank 18	0	3.16	0	0	0.5
Bank 19	0	7.57	0	0.36	0
Bank 20	0	1.31	0	0	0
Bank 21	0	0.49	0	0.11	0
Bank 22	0	12.50	0	0	0
Bank 23	0	0.47	0	0.11	1.79

Source: Authors' Computation

V.3.2 Funding Shocks Transmission for the Period End-June 2015

For the funding shocks, the induced failed banks were 1 and 19, triggering the same pattern of capital loss, as with the case of credit shocks. The index of contagion and vulnerability differed, slightly with the credit shocks; bank 10 stood as one of the most vulnerable banks, with vulnerability index of 13.64 per cent, followed by bank 23 with vulnerability index of 2.14. While the index of contagion was just one round effect, implying that the effect of the induced failures wore off with the first-round effect.

Table 8 – Simulation Results for Funding Shocks Transmission for the Period End-June 2015

Banks	Induced Failures	% of Failed Capital	Contagion Rounds	Index of Contagion	Index of Vulnerability
Bank 1	1	9.04	1	0.56	0.02
Bank 2	0	1.38	0	0.06	0.31
Bank 3	0	6.64	0	0	0
Bank 4	0	7.39	0	0.21	0.22
Bank 5	1	1.03	1	0.03	0
Bank 6	0	5.14	0	0	0
Bank 7	0	15.46	0	0.26	0.05
Bank 8	0	4.88	0	0	0
Bank 9	0	9.97	0	0.06	0
Bank 10	0	0.00	0	0.02	13.64
Bank 11	0	0.29	0	0	0.16
Bank 12	0	0.00	0	0	0
Bank 13	0	0.64	0	0	0
Bank 14	0	3.25	0	0	0.43
Bank 15	0	2.90	0	0.11	0.23
Bank 16	0	2.75	0	0.02	0.9
Bank 17	0	2.46	0	0.02	0
Bank 18	0	3.27	0	0	0.45
Bank 19	1	8.06	1	0.58	0
Bank 20	0	1.62	0	0	0.74
Bank 21	0	0.63	0	0.07	0
Bank 22	0	12.71	0	0.74	0
Bank 23	0	0.48	0	0	2.14

Source: Authors' Computation

V.3.3 Funding Shocks Transmission for the Period End-December 2015

The likely percentage of failed capital from funding shock transmission simulation for the period end- December 2015 mimicked the credit pattern for the same period, ascribable to low exposures activities within the network. Bank 19 came first on the contagion index with 0.21 per cent, while bank 20 with 0.54 per cent was the most vulnerable.

Table 9 – Simulation Results for Funding Shocks Transmission for the Period End-December 2015

Banks	Induced Failures	% of Failed Capital	Contagion Rounds	Index of Contagion	Index of Vulnerability
Bank 1	0	9.19	0	0	0
Bank 2	0	1.34	0	0	0
Bank 3	0	6.00	0	0.02	0
Bank 4	0	7.21	0	0.08	0.01
Bank 5	0	0.00	0	0	0
Bank 6	0	4.69	0	0	0
Bank 7	0	14.43	0	0.08	0.02
Bank 8	0	5.13	0	0	0
Bank 9	0	9.41	0	0.04	0.01
Bank 10	0	0.70	0	0	0.2
Bank 11	0	0.42	0	0	0
Bank 12	0	0.00	0	0	0
Bank 13	0	0.60	0	0	0
Bank 14	0	3.80	0	0.04	0.09
Bank 15	0	2.70	0	0	0.1
Bank 16	0	2.59	0	0.02	0.11
Bank 17	0	2.41	0	0	0
Bank 18	0	2.98	0	0	0.18
Bank 19	0	7.72	0	0.21	0
Bank 20	0	1.49	0	0.02	0.54
Bank 21	0	0.58	0	0.1	0
Bank 22	0	11.49	0	0.05	0
Bank 23	0	5.13	0	0.07	0.05

Source: Authors' Computation

V.3.4 Funding Shocks Transmission for the Period End-June 2016

The outcome of the funding shocks transmission presented in Table 10 mimicks the pattern of failed capital exhibited in the interbank market for the period end-June 2015. There were eight induced failures, for banks 1, 15 and 19 the induced failure was twice but the effect was just one round, while banks 9,11,13,14 and 16 had one induced failure with only one round contagion effect. The index of contagion for the period was equally mild with 0.46 per cent as the highest; this also reflected the contagion round that lie between zero and one. The index of vulnerability indicated bank 10 as the most vulnerable in the system with 31.82 per cent level of vulnerability, followed by 12 with 27.27 per cent level. Similarly bank 16, 23, 18, 11, 5, 4 and 7 had 3.22, 1.66, 0.45, 0.31, 0.23, 0.13 and 0.03 per cent level of vulnerability, respectively.

Table 10 – Simulation Result for Funding Shocks Transmission for the Period End-June 2016

Banks	Induced Failures	% of Failed Capital	Contagion Rounds	Index of Contagion	Index of Vulnerability
Bank 1	2	9.04	1	0.32	0.31
Bank 2	0	1.38	0	0.02	0
Bank 3	0	6.64	0	0.22	0
Bank 4	0	7.39	0	0.02	0.13
Bank 5	0	1.03	0	0.2	0
Bank 6	0	5.14	0	0.21	0
Bank 7	0	15.46	0	0.24	0.03
Bank 8	0	4.88	0	0.2	0
Bank 9	1	9.97	1	0.22	0
Bank 10	0	0.00	0	0.19	31.82
Bank 11	1	0.29	1	0.2	0
Bank 12	0	0.00	0	0	27.27
Bank 13	1	0.64	1	0.2	0
Bank 14	1	3.25	1	0	0
Bank 15	2	2.90	1	0.36	0.23
Bank 16	1	2.75	1	0	3.22
Bank 17	2	2.46	1	0.43	0
Bank 18	0	3.27	0	0	0.45
Bank 19	2	8.06	1	0.46	0
Bank 20	0	1.62	0	0	0
Bank 21	0	0.63	0	0.11	0
Bank 22	0	12.71	0	0	0
Bank 23	0	0.48	0	0.11	1.66

Source: Authors' Computation

VI. Conclusion

The paper appraised the effect of bank lending relationships in the Nigerian interbank market for the four periods namely: end-December 2014, end-June 2015 end-December 2015 and end-June 2016, using network model. We analysed the systemic risk implied in the Nigerian interbank network, based on various network measures. In our analysis, we represented the interbank market exposures as a network consisting of nodes (banks) and time-varying number of weighted and directed links between them (representing interbank exposures or loans). The direction of the links followed the flow of money from lenders to borrowers. We further established (with network diagram) the systemic risk inherent in the interbank market exposure. Our dataset included a sample of 23 banks in Nigeria. For each bank, we included information about the total qualifying capital and the interbank exposures (both secured and unsecured). Data on individual banks bilateral exposures were extracted from the FinA.

The main findings showed that few banks, namely: bank 1,2, 4, 10, 13, 15, 17, 20, 21 and 23 featured prominently in the analysis, owing to the level of exposures and the effect of these varying exposures on their capital base. Also, the analysis exposed the linkages between bank 10 and 16 and among other banks and these two banks as systemic to the market, regarding the magnitude of the exposure, effect on capital and vulnerability. A scenario of these two banks failing would spark up the chains of other failures with contagion second-round effects. Globally, bank supervisors use a combination of both on-site examination and off-site surveillance in their supervisory tasks. While on-site examinations are recognised as the cornerstone of bank supervision, regulators usually support their on-site examinations with off-site surveillance, which entails quarterly reviews of banks' financial data. This analysis or usage of network analysis would assist the supervisors in:

- taking prompt actions in response to emerging supervisory issues before such issues exacerbate into major concerns, and
- focusing on the institutions presenting the greatest risk to the financial system.

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