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RETURNS AND VOLATILITY SPILLOVER BETWEEN NIGERIA AND SELECTED GLOBAL STOCK MARKETS: A DIEBOLD-YILMAZ APPROACH*

ABSTRACT

This study examines stock return and volatility spillovers between Nigeria and five global markets (China, Hong Kong, Japan, UK, and the US) from January 2000 to August 2021. The study adopts the Diebold-Yilmaz interconnectedness index and concludes that most of the returns generated in Nigeria are due to domestic shocks, implying that the country is less integrated. Also, larger proportion of risks in Nigeria are attributable to global shocks suggesting that the Nigerian stock market is vulnerable to international shocks. The study also showed that the global financial crisis (GFC) is associated with higher and intensified return and volatility spillovers among global markets. The study recommends that investors should consider assets in the Nigerian stock market in their portfolios to benefit from diversification. The study also advocates for policies to stabilize the domestic economy and build buffers to make the market resilient to global uncertainties.

Keywords: Diversification; Integration; International Financial Markets; Portfolio; Stock Returns; Spillovers; Volatility
JEL Classification: G11; G12; G15

RIASSUNTO

Spillover nei rendimenti e nella volatilità tra il mercato azionario della Nigeria ed altri mercati globali: un approccio Diebold-Yilmaz

Questo articolo esamina gli spillover nei rendimenti e nella volatilità tra il mercato della Nigeria e cinque mercati azionari globali (Cina, Hong Kong, Giappone, Regno Unito e Usa) da gennaio

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2000 ad agosto 2021. Lo studio applica l'indice di interconnessione di Diebold-Yilmaz e conclude che la maggior parte dei rendimenti generati in Nigeria sono dovuti a shock interni, da cui si deduce che il paese è poco integrato. Inoltre, gran parte del rischio in Nigeria è attribuibile a shock globali da cui si evince la sensibilità del mercato azionario nigeriano agli shock internazionali. Lo studio ha mostrato anche che la crisi finanziaria globale è associata a più alti e intensi spillover nei rendimenti e nella volatilità tra i mercati internazionali. Si consiglia agli investitori di inserire nel loro portfolio asset del mercato azionario nigeriano per differenziare gli investimenti. L'articolo inoltre raccomanda di applicare delle politiche per stabilizzare l'economia locale e rendere il mercato azionario resistente alle incertezze globali.

1. Introduction

Investors are keen about returns on asset as they always prefer higher returns, however, higher returns come with greater risk (Markowitz, 1952 and 1959). But if one could find a mix of assets with lower degree of co-movements, then it is possible to reduce the level of risk and earn higher returns by investing in such diversified portfolio compared to a portfolio where the assets are considered based only on their inherent individual characteristics (Markowitz, 1952 and 1959). In other words, having assets from markets with shock and volatility spillovers could constitute risky portfolio as events that erodes one's investment in one market could quickly spillover and dissipate the returns in the other market. Thus, portfolio managers do not only assess the risk and associated returns on an asset in selecting their portfolio, but they are also concerned about the co-movements of assets that are potential candidates for the portfolio. Also, monetary authorities are interested in returns and volatility spillover among international markets, due to the inherent capacity of such spillovers to limit the efficacy of domestic monetary policy. Therefore, understanding the degree of connectedness among stock markets is important for both investors and policymakers, hence, the need for a comprehensive study on return and volatility spillovers among stock markets.

This study examines return and volatility spillovers among six international markets – China (CH), Hong Kong (HK), Japan (JP), Nigeria (NG), the United Kingdom (UK), and the United States (US) using the Diebold-Yilmaz approach. The study estimates net total directional volatility spillovers for each of the markets to identify their status as either a net receiver or net distributor of volatility spillovers. The study also examines the dynamics of returns and volatility over time.

There are several approaches to analyzing returns and volatility spillovers in the literature and notable among them are variants of the multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) approach (Bollerslev *et al.*, 1988; Baba *et al.*, 1990; Kroner and Ng, 1998). The MGARCH family of models provides for the interaction among volatility and shocks and allows for the assessment of volatility spillover between markets, though these variants of volatility spillovers do not have the capacity to assess directional movement of volatility spillovers. In other words, they can show the existence and extent of volatility spillovers between markets but not the origin and destination. They cannot also show the net total and pairwise directional spillovers. Hence the need for a more explicit measure of volatility spillovers.

Diebold and Yilmaz (2009, 2012, 2014) proposed measures for total and directional volatility spillovers using a generalized vector autoregressive approach with forecast error variance decompositions that are invariant to variable ordering. These measures of volatility spillovers have gained wide acceptance in the literature due to their inherent capacity to assess the source and destination of volatility spillovers. With the Diebold-Yilmaz approach one can place equity markets in one of two categories, either as a net receiver or a net distributor of volatility spillovers. It is also possible to identify markets from which each individual market receives and distributes returns and volatility.

The identification of directional movement of return and volatility spillovers is important for both policy and investment. For policy, it helps in identifying specific markets to watch out for and allows for proactive measures to mitigate the effects of risks emanating from related markets. For investment, it enables investors select asset portfolio in such a way that minimizes risk and maximizes returns.

The study is motivated by the cornucopia of studies in literature assessing return and volatility spillovers among equity markets (Diebold and Yilmaz, 2009, 2012, 2014; Yilmaz, 2010; Mohammadi and Tan, 2015; Zhou *et. al.*, 2012; Natarajan *et al.,* 2014; Gamba-Santamaria *et al.,* 2019, Bonga-Bonga and Phume, 2022; Atenga and Mougoué, 2021; Mensi *et al.,* 2021). Extant literature mostly focuses on connectedness among developed markets and emerging markets, with little focus on Nigeria. Karimo and Abraham (n.d.) who studied Nigeria, did not assess the directional movement of volatility while Phume and Bonga-Bonga (2018) compare Nigeria with

South Africa. Hence, there is dearth of empirical evidence on the degree of connectedness between Nigeria and global stock markets. A study on the behaviour of stock return and volatility spillovers between Nigeria and the developed economies is important since global shocks could spillover to Nigeria, affecting macroeconomic fundamentals and policy potency in the country, therefore such study could provide useful insight as to the direction of return and volatility spillovers between Nigeria and the developed economies.

Furthermore, the Nigerian stock market has been resilient in recent years making it a potential destination for investment. During the covid-19 pandemic returns on the Nigerian stock exchange (NSE) were the lowest (-8.65%) in March 2020 compared to a pre-pandemic position (3.49%) and pandemic announcement position (3.74%) in April 2020. After the immediate shock from the pandemic stock returns were hardly negative on the NSE. Similar pattern was also observed between August 2008 and February 2009, during the global financial crisis[1]. More so, the Nigerian stock market is one of the largest in Africa and could represent a channel for significant returns and volatility transmission in the continent.

The choice of the US, UK, and JP rest on these markets being the largest and are the most developed stock markets in the world (Liu, 2016). In recent time China has, however, emerged as the largest stock market in Asia followed by Japan and Hong Kong, hence the inclusion of CH and HK in this study.

The rest of the study is organized as follow: in Section 2 the study presents the literature review; the methodology is presented in Section 3; Section 4 has the results and discussion; and finally, Section 5 presents the conclusion and recommendations.

2. Literature Review

2.1 Theoretical Literature

Studies on returns, shock, and volatility spillover/transmission among financial markets are key to understanding the dynamics of international/global financial market integration. On theoretical perspective, financial integration presents opportunities for risk sharing and portfolio diversification, improves capital allocation among investment opportunities, and

[1] Authors computation based on data drawn from Bloomberg terminal available at Bloomberg Terminal | Bloomberg Professional Services

presents potentials for higher economic growth. However, financial integration increases domestic economies vulnerability to external macroeconomic shocks and provides avenue for transmission of financial risks and shocks among financial markets, and to higher output and consumption volatilities.

Markowitz (1952 and 1959) formulated the modern portfolio theory (MPT) to provide the foundation for empirical explanation of portfolio diversification. Since the formulation of the MPT, it has continued to gain attraction from scholars, analysts, and portfolio managers. It has become key in portfolio diversification strategies among analysts and topical in discussions on financial market co-movements and volatility spillovers. By highlighting the importance of the co-movement of returns and risk in portfolio diversification, the MPT allows for evaluation of returns, shocks, and volatility spillovers among financial assets which could be within an economy or among economies. The co-movements provide a way of formulating a portfolio with equal expected return and lower risk relative to one constructed based solely on their individual characteristics.

However, the MPT has come under criticism for being oversimplified. The argument is that, in addition to the mean and variance, considering additional moments could provide better description of the distributions of returns in a portfolio (Tobin, 1958; Lee, 1977; Kraus and Litzenberger, 1976; Fama, 1968; Elton and Gruber, 1974). Albeit the mean-variance theory remains the foundation of MPT. The reasons are that (i) including additional moments does not guarantee improvement of the portfolio performance; (ii) the mean-variance theory is easy to apply, and intuitively appealing since it does not require sophisticated knowledge of quantitative analysis and uses simple summary statistics such as correlations, means and variances to provide a way of understanding the impact of an additional asset to a portfolio.

2.2 Empirical Literature

There is increased interest among scholars, analysts and portfolio managers on returns, and volatility spillovers among equity markets globally. Diebold and Yilmaz (2009) propose an intuitive way to measure asset returns and/or volatility spillovers. The study proposes separate measures of return spillovers and volatility spillovers using the vector autoregression (VAR) framework and facilitates analysis of the dynamic behaviour of spillovers over time. The study deploys the proposed framework to analyzing 19 global equity markets between 1990s and 2008. Findings suggest that return and volatility spillovers are both dynamic and differ over time with mildly increasing trend in return spillovers without burst, and volatility spillovers without trend but with clear bursts. Yilmaz (2010) corroborates these findings in his study of the East Asian equity markets between 1990s and 2009. In addition, Yilmaz (2010) provides evidence that return and volatility spillovers, each peak during the global financial crisis. In their study of US, Hong Kong, and Mainland China, Mohammadi and Tan (2015) did not only corroborate findings from Diebold and Yilmaz (2009), but they also provide additional evidence of return spillover from US to Hong Kong and mainland China with no evidence of return spillover between Hong Kong and mainland China. The study uses daily data from January 2, 2001, to February 08, 2013, and adopts a DCC MGARCH model in addition to the Diebold and Yilmaz (2009) approach.

The Diebold and Yilmaz (2009) approach was fraughted with some frailties as it leans on the Cholesky variable ordering, which means that the forecast error variance decomposition (FEVD) and hence the spillover measures are sensitive to variable ordering. Thus, Diebold and Yilmaz (2012) propose a more robust way of characterizing the spillovers (total and directional spillovers) using generalized VAR framework in which the FEVD, that is, the generalized error variance decompositions (GEVD) are invariant to variable ordering. In a related study, Diebold and Yılmaz (2014) propose another dimension to the spillover measures by introducing the concept of "network topology." The study argues that variance decompositions define weighted and directed networks, and that the measures of interdependence are intrinsically linked to key measures of connectedness in the network literature. The Diebold and Yilmaz (2012, 2014) methods are now widely used in studies on returns and volatility spillovers and there are two main strands in literature on the subject: evidence of increasing intensity of return and volatility spillovers during crisis episodes (contagion effect); and developed markets dominance in return and volatility transmission to developing/emerging markets. For instance, Zhou *et al.* (2012), Natarajan *et al.* (2014), Gamba-Santamaria *et al.* (2019), Atenga and Mougoué (2021), and Mensi *et al.* (2021) all adopt the Diebold and Yilmaz approach to return and volatility spillover among equity markets of different jurisdictions. There is agreement in the findings that crisis episodes are associated with intensified returns, and volatility spillovers, thus, supporting the financial contagion effects.

Also, there is the emergence of studies using approaches different from that of Diebold-Yilmaz but with essentially comparable results. For example, Golosnoy *et al.* (2015), using a four-phase model of CAWF (conditional autoregressive Wishart framework) provides evidence suggesting the increasing intensity of volatility spillovers with the global financial crisis. The study employs intraday data and focus on German, Japan, and US stock markets with specific reference to pre- and subprime crisis. Roni *et al.* (2018) using Granger causality test, and VAR (vector autoregression) after computing volatilities using a GARCH (generalized autoregressive conditional heteroscedasticity) model provides evidence supporting findings from Natarajan *et al.* (2014), and Gamba-Santamaria *et al.* (2019). The study focuses on six Asian emerging markets (Bangladesh, China, India, Malaysia, the Philippine, and South Korea) using monthly data which spans January 2002 to December 2016.

The second strand of literature shows evidence of the relative dominance of developed markets in transmitting volatility spillovers. There are different approaches used in this strand of literature including GARCH family of models and the Diebold-Yilmaz approach. For instance, the study by Zhou *et al.* (2012) focuses on the Chinese and world equity markets and adopts the generalized forecast-error variance decomposition version of the Diebold and Yilmaz approach. The study suggests the dominance of the US market in volatility spillovers to other markets during the subprime mortgage (Global financial) crisis, and significant rise of spillovers from China to other markets since 2005. The study also shows evidence of stronger volatility spillovers among China, Hong Kong, and Taiwan relative to China, Western, and other Asian markets. Kim and Ryu (2015), Mohammadi and Tan (2015), Chow (2017), Lien *et al.* (2018) provide evidence supporting the dominance of US in returns and volatility spillover to Asian markets and that volatility does not always spillover directly from the market where crisis begins. Among twelve European markets Aslam *et al.* (2021) suggests that more developed markets (Mostly German and Dutch markets) are the largest net transmitters of volatility spillovers. The study employs intraday data from December 2, 2019 to May 29, 2020.

Alotaibi and Mishra (2015) provide evidence of return spillover from Saudi Arabia and US to GCC (Gulf cooperation countries of Bahrain, Oman, Kuwait, Qatar, United Arab Emirates) adopting various bivariate GARCH models. Yavas and Rezayat (2016) also show that volatility is transmitted from advanced markets to developing markets but not the other way round. Yavas and Rezayat (2016) investigate the link among returns of equity exchange traded funds (ETF) and volatility spillovers among the USA, Europe, the BRIC (Brazil, Russia, India, and China), MIST (Mexico, Indonesia, South Korea, and Turkey) and South Africa. The study spans from February 3, 2012 to February 28, 2014 and applies a multi-variate autoregressive moving-average (MARMA) and a generalized autoregressive conditional heteroskadasticity (GARCH) models. The study findings suggest increasing interdependence among the global equity markets, though, there exists opportunities for diversification as the US and Europe markets are more integrated and investors will benefit from diversification if they avoid investing in the US and Europe simultaneously but consider the other emerging market equities such as China, South Africa, and Turkey in the portfolio. The study results suggest volatility transmission from the US to India, Russia, Mexico, and Turkey whereas the European volatility spillovers to Mexico and South Korea. Liu (2016) examines volatility spillover among the US, UK, Hong Kong, and Japan stock market returns. Results from VAR model show return spillover from the US to UK, Hong Kong, and Japan. Results from GARCH BEKK model show that post crisis shocks are more persistent in the US compared to Hong Kong and Japan, where past shocks have weaker impact on volatility. Vo and Tran (2020) investigate volatility spillovers between the US equity market and stock markets of ASEAN economies. The study adopts an augmented EGARCH model with ICSS algorithm to control for the excessive volatility break. Findings suggest that volatility spillovers from the US to ASEAN equity markets.

On studies involving Nigeria, evidence suggest that Nigeria is a net recipient of returns and volatility spillovers. For example, Phume and Bonga-Bonga (2018) evaluate the cross-volatility and returns transmission between Nigerian and South African stock markets using a multivariate general autoregressive conditional heteroscedastic (MGARCH) model. The study argues that returns and volatility spillovers from South Africa to Nigeria. Obadiaru *et al.* (2020) distinguish between short-run and long-run spillovers while examining the dynamic interactions between the Nigerian stock market and selected regional and global equity markets. Using daily data for the period 2011-2018 and a generalized impulse response function, and the Toda-Yamamoto Granger causality approach the study provides evidence of volatility spillovers from US to Nigeria in the short run. Results from a normalized Johansen vector error correction model reveal that volatility spillovers from UK and Ghana to Nigeria in the long run. Bonga-Bonga and Phume (2022) evaluate returns and volatility transmission between Nigeria and South Africa stock markets using an asymmetric vector autoregressive-exogenous generalized autoregressive conditional heteroscedasticity (VAR-X GARCH) model. Results suggest that shock spillovers from South Africa to Nigeria. The study also reveals possible portfolio diversification holding assets in the two markets simultaneously. Obadiaru *et al.* (2018) examine volatility spillovers among West African stock markets, the US and UK by applying Exponential Generalized Autoregressive Conditional Heteroscedastic (EGARCH) approach to daily stock returns for the period 2008-2016. The study suggests volatility spillover among stock markets in West Africa and with the US and UK.

The literature review reveals that returns and volatility spillovers from developed markets to developing markets and that crises intensify the transmission of volatility. These studies hardly include Nigeria's stock returns in their analysis, though, the Nigerian stock market is one of the largest in Africa and represents a major source of spillovers in the African context. For the study of Obadiaru *et al.* (2018) which includes Nigeria, it is not clear how the study arrives at the conclusion that volatility spillovers among stock markets in West Africa and from the US and UK to West African markets, since the EGARCH model which the study adopts is a univariate approach for measuring volatility and does not have the capacity to analyze cross volatility transmission. Obadiaru *et al.* (2020) also include Nigeria stock returns data, but the analysis was carried out within the MGARCH framework. The MGARCH framework lacks the capacity to account for net directional spillovers. The current study departs from the existing literature by using the Diebold-Yilmaz approach to account for returns and volatility transmission among global stock markets including Nigeria. The Diebold-Yilmaz approach is preferred for its capacity to measure total, directional (net, and pairwise) spillovers among financial markets. Therefore, the study contributes to extant literature by showing the net directional returns and volatility spillovers from the Nigerian stock market to and from global stock markets.

3. Methodology

3.1 Data

Monthly data on stock market prices of the US Standard & Poors 500 (US), the UK Financial Times Stock Exchange (UK), Chinese Shanghai (CH), Japanese Nikkei (JP), Hong Kong Hang Seng (HK), and the Nigerian all share index (NG) were obtained from Bloomberg terminal[2]. The data spans the period 2000M01 to 2021M08 yielding 260 datapoints. After obtaining the data,

[2]All the data for this study were obtained from the Bloomberg terminal available at the following link Bloomberg Terminal | Bloomberg Professional Services

stock returns were computed using the Liu (2016) continuous compounding stock return formula, stated in equation (1):

$$y_t = 100 * ln\left(\frac{P_t}{P_{t-1}}\right) \tag{1}$$

Where: y_t is stock return, P_t is stock price in the current period (t) and P_{t-1} is stock price in the immediate past one period. We loss one datapoint due to the computation of stock returns reducing the available datapoints for analysis to 259.

3.2 Model Specification

This study estimates volatility spillover index among six global stock markets using Diebold-Yilmaz approach. The method uses the forecast error variance decomposition from a vector autoregressive (VAR) model. An H period-ahead forecast is estimated after fitting the VAR model and the forecast error variance of each variable is then decomposed into shocks from own and other variables at time *t*.

Consider the following covariance stationary VAR(p) process:

$$z_t = \mu + \Phi_1 z_{t-1} + \Phi_2 z_{t-2} + \cdots + \Phi_p z_{t-p} + u_t \tag{2}$$

where z_t is a K x 1 vector of endogenous variables; Φ_is are $K \times K$ coefficient matrices; μ is a $(K \times 1)$ vector of constants; u_t is a $(K \times 1)$ uncorrelated error process with zero mean and constant variance; and p is the lag order of the VAR.

The H-step ahead generalized variance decomposition (GVD) are generated from the MA process proposed by Koop *et al.* (1996) and Pesaran and Shin (1998) as:

$$d_{ij}^{gH} = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' \Psi_{\mathrm{h}} \Sigma e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' \Psi_{\mathrm{h}} \Sigma \Psi_{\mathrm{h}}' e_i\right)^2} \tag{3}$$

Where σ_{jj} is the standard deviation of u_t, and e_i is the selection vector with one on the i^{th} element, and zero otherwise, Ψ_i are $K \times K$ matrices relating to $\Psi(L) = \sum_{i=0}^{p} \Psi_i L^i = \left(I - \Phi_1 L - \Phi_2 L^2 - \cdots - \Phi_p L^p\right)^{-1}$ such that $\Psi_0 = I$ and $\mu = c\left(I - \sum_{i=1}^{p} \Phi_i\right)^{-1}$. The row sums of the variance decomposition matrix are then normalized to unity as proposed by Xiao and Huang (2018) as follows:

$$\tilde{d}_{ij}^{gH} = \frac{d_{ij}^{gH}}{\sum_{j=1}^{K} d_{ij}^{gH}} \tag{4}$$

The total spillover index (C^H) is then obtained using the volatility contributions from the Koop *et al.* (1996) and Pesaran and Shin (1998) variance decomposition as:

$$C^H = \frac{\sum_{i,j=1,i\neq j}^{K} \tilde{d}_{ij}^{gH}}{\sum_{i,j=1}^{K} \tilde{d}_{ij}^{gH}} \times 100 = \frac{\sum_{i,j=1,i\neq j}^{K} \tilde{d}_{ij}^{gH}}{K} \times 100 \tag{5}$$

where K is the number of markets being studied. Equation (5) measures the contributions of return or volatility across related assets to the total forecast error variance. Since the contribution to volatility from each variable is invariant to variable ordering in the GVD, it is possible to obtain directional volatility/return spillover index. Thus, directional spillover from all other variables j to variable i is defined as:

$$C_{i\leftarrow \boldsymbol{j}}^H = \frac{\sum_{j=1,i\neq j}^{K} \tilde{d}_{ij}^{gH}}{\sum_{i,j=1}^{K} \tilde{d}_{ij}^{gH}} \times 100 = \frac{\sum_{j=1,i\neq j}^{K} \tilde{d}_{ij}^{gH}}{K} \times 100 \tag{6}$$

The directional spillover transmission from variable i to all other variables j is defined as:

$$C_{\boldsymbol{i}\rightarrow j}^H = \frac{\sum_{j=1,i\neq j}^{K} \tilde{d}_{ji}^{gH}}{\sum_{i,j=1}^{K} \tilde{d}_{ji}^{gH}} \times 100 = \frac{\sum_{j=1,i\neq j}^{K} \tilde{d}_{ji}^{gH}}{K} \times 100 \tag{7}$$

There are 2K number of total directional spillover. The net total directional spillover for market i is defined as the difference between equation (6) and (7):

$$C_i^H = C_{\boldsymbol{i}\rightarrow j}^H - C_{i\leftarrow \boldsymbol{j}}^H \tag{8}$$

There are K number of net total directional spillovers. Finally, define the net pairwise directional spillover from variable i to variable j to obtain the contribution intensity between the two variables. The net pairwise spillover is defined as the difference between the gross volatility spillover from variable i to j and from j to i:

$$C_{ij}^{H} = \left(\frac{\tilde{d}_{ji}^{gH}}{\sum_{i,m=1}^{K}\tilde{d}_{im}^{gH}} - \frac{\tilde{d}_{ij}^{gH}}{\sum_{j,m=1}^{K}\tilde{d}_{jm}^{gH}}\right) \times 100 = \left(\frac{\tilde{d}_{ji}^{gH} - \tilde{d}_{ij}^{gH}}{K}\right) \times 100 \quad (9)$$

In general, $C_{i\leftarrow j}^{H} \neq C_{i\rightarrow j}^{H}$ therefore, there are $K^2 - K$ number of pairwise directional spillover.

The variance decomposition matrix $\widetilde{D}^{H} = [\tilde{d}_{ij}^{gH}]$ in the K x K block of Table 1 contains the variance decompositions. The $\widetilde{D}^{H}$ table is extended by an additional row containing column sums, and additional column containing row sums and a bottom right element containing the grand average.

TABLE 1 - *Schematic Presentation of the Spillover Indices*

	$\boldsymbol{x_1}$	$\boldsymbol{x_2}$	$\cdots$	$\boldsymbol{x_K}$	**From others**
$\boldsymbol{x_1}$	$\tilde{d}_{11}^{gH}$	$\tilde{d}_{12}^{gH}$	$\cdots$	$\tilde{d}_{1K}^{gH}$	$\sum_{j=1}^{K}\tilde{d}_{1j,j\neq 1}^{gH}$
$\boldsymbol{x_2}$	$\tilde{d}_{21}^{gH}$	$\tilde{d}_{22}^{gH}$	$\cdots$	$\tilde{d}_{2K}^{gH}$	$\sum_{j=1}^{K}\tilde{d}_{2j,j\neq 2}^{gH}$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
$\boldsymbol{x_N}$	$\tilde{d}_{K1}^{gH}$	$\tilde{d}_{K2}^{gH}$	$\cdots$	$\tilde{d}_{KK}^{gH}$	$\sum_{j=1}^{K}\tilde{d}_{Kj,j\neq K}^{gH}$
To others	$\sum_{i=1}^{K}\tilde{d}_{i1,i\neq 1}^{gH}$	$\sum_{i=1}^{K}\tilde{d}_{i2,i\neq 2}^{gH}$	$\cdots$	$\sum_{i=1}^{K}\tilde{d}_{i2,i\neq 2}^{gH}$	$\sum_{j=1}^{K}\tilde{d}_{ij,j\neq i}^{gH}$

Source: Adapted from Xiao and Huang (2018).

Table 1 is the variance decomposition matrix ($\widetilde{D}^{H}$). $x_i's$ represent the stock returns of returns volatility of the i^{th} market. The diagonal elements are the percentages of volatility explained by own innovations. The larger these values, the more domestic factors explain changes in the variance of the asset and the less integrated the market is. The off-diagonal elements are the proportions of the N forecast error variance received (distributed) by each of the corresponding market and they represent the pairwise directional connectedness. The larger these values, the more connected are the corresponding assets/markets.

3.3 Estimation Procedure

The variables were tested for unit root using the augmented Dickey-Fuller (ADF) approach. The return series were also subjected to structural break-based unit root test proposed by Perron and Vogelsand (1992a and 1992b). The procedure endogenously identifies the break dates[3]. The series entered the model after adjusting for observed structural breaks.

We estimate equation (10) using the identified break date as:

$$y_t = \gamma_0 + \gamma_1 DU_t(T_b) + \gamma_2 D_t(T_b) + \gamma_3 DT_t(T_b) + \qquad (10)$$

and obtain the break-adjusted returns ($\tilde{y}_t$) as the residual ($\hat{\varepsilon}_t$). $DU_t(T_b) = 1(t \geq T_b)$ is intercept break dummy that takes the value 0 for all dates before the break date (T_b) and 1 otherwise; $D_t(T_b) = 1(t = T_b)$ is a single date break dummy that takes the value 1 only on the break date and 0 otherwise; $DT_t(T_b) = 1(t \geq T_b)(t - T_b + 1)$ is trend break dummy that takes the value 0 for all dates before the break date, and break date rebased trend for subsequent dates. The generic equation where the return series has breaks in trend and intercept is specified in (11):

$$\tilde{y}_t = \hat{\varepsilon}_t = y_t - (\gamma_0 + \gamma_1 DU_t(T_b) + \gamma_2 D_t(T_b) + \gamma_3 DT_t(T_b)) \qquad (11)$$

If the break is only on the intercept, then (11) reduces to:

$$\tilde{y}_t = \hat{\varepsilon}_t = y_t - (\gamma_0 + \gamma_1 DU_t(T_b) + \gamma_3 DT_t(T_b)) \qquad (11a)$$

and the representation for trend break is:

$$\tilde{y}_t = \hat{\varepsilon}_t = y_t - (\gamma_0 + \gamma_3 DT_t(T_b)) \qquad (11b)$$

In the estimation, a VAR(1) model was empirically selected based on VAR selection criteria. The study uses a 12 month-ahead forecast to generate the GVD. The traditional methods such as the Cholesky-factor identification scheme are sensitive to variable ordering, hence the use of the Diebold and Yilmaz (2014), GVD that is invariant to ordering, proposed by Koop *et al.* (1996) and Pesaran and Shin (1998).

[3]See Perron (1989, 1990); Perron and Vogelsand (1992a, 1992b); Vogelsang and Perron (1998) for detailed derivation and discussion of the unit root test models with structural breaks.

4. Results and discussion

4.1 Pre-estimation Results

In Table 2 the study presents the descriptive statistics of stock returns for the six markets. The mean values are all positive suggesting average monthly gains in the markets.

TABLE 2 – *Descriptive Statistics*

	US	UK	JP	HK	CH	NG
Mean	0.19	0.02	0.06	0.13	0.13	0.32
Median	0.45	0.33	0.28	0.55	0.27	0.2
Maximum	5.19	5.06	6.09	7.17	10.59	14.33
Minimum	-8.06	-6.45	-11.82	-11.13	-12.26	-15.88
Std. Dev.	1.9	1.74	2.43	2.67	3.2	3.03
Skewness	-0.74	-0.71	-0.72	-0.7	-0.53	-0.45
Kurtosis	4.55	4.27	4.51	4.37	5.15	7.64
Jarque-Bera	49.24	39.43	47.26	41.27	62.07	241.55
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Sum	49.86	5.61	15.23	34.71	34.77	82.97
Sum Sq. Dev.	929.03	778.41	1523.16	1835.26	2648.13	2364.54
Observations	259	259	259	259	259	259

Note: US is the US Standard and Poor 500 stock returns; UK is the UK Financial Times Stock Exchange returns; JP is Japanese Nikkei stock returns; HK is Hong Kong Heng Seng stock returns; CH is Chinese Shanghai stock returns; and NG is the Nigerian stock exchange returns.

The NG dominates having the largest expected monthly return, followed by the US, CH, and HK. The average monthly return was least for the UK and JP, in that order. The marked difference between the NG returns and those of the developed economies could be attributed to the global financial crisis which hit the world most developed stock markets more severely. Another factor could be the less developed nature of the Nigerian stock market, it leaves room for investors to consistently predict the direction of the market and make higher profits. The CH (3.2) and NG (3.03) stock returns show the largest volatilities suggesting that they suffered uncertainty more and were most risky, which could also explain the large expected returns reported in these markets. The UK has the least standard deviation, indicating that it is the least volatile and risky market. The Jaque Bera statistics were all statistically significant, which suggest that the series are not normally distributed. This is attributable to Leptokurtic kurtosis (that is, the Kurtosis are all greater than 3) distribution in the series.

In Table 3, we have the unconditional correlation coefficients. In the last row we report the correlation between the NG and other markets returns. The all positive and less than 0.5 coefficients are indication that assets in the Nigerian stock market can form a good portfolio with assets in each of the markets. However, including assets in the US, UK, JP, and HK markets in a portfolio makes it riskier. This could be indicative of a more segregated Nigerian stock market and more integrated global stock markets.

TABLE 3 – *Unconditional Stock Returns Correlation*

	US	UK	CH	JP	HK	NG
US	1.00					
UK	0.82	1.00				
CH	0.33	0.26	1.00			
JP	0.66	0.60	0.33	1.00		
HK	0.67	0.63	0.57	0.59	1.00	
NG	0.25	0.21	0.18	0.22	0.31	1.00

Note: US is the US Standard and Poor 500 stock returns; UK is the UK Financial Times Stock Exchange returns; JP is Japanese Nikkei stock returns; HK is Hong Kong Heng Seng stock returns; CH is Chinese Shanghai stock returns; and NG is the Nigerian stock exchange returns.

Table 4 presents the unit root test results with and without structural breaks. The test statistics and larger when we account for structural break, though, the statistical properties are similar for the ADF test and the PV test with break. The KPSS test could reject the null hypothesis of stationarity. Thus, the three approaches to the test for unit root suggest that all the return series are stationary as expected. All the stock returns (except UK) exhibited structural breaks during the global financial crisis between October 2008 and January 2009. The US, CH, JP, and HK showed structural breaks in October 2008 during the peak of the crisis while NG showed structural break in January 2009, which is also attributable to the GFC. The UK structural break occurred in March 2020, after the declaration of Covid-19 as a pandemic and could be attributed to the resulting lockdown measures taken to forestall the spread of the virus. During this period, most firms were shutdown except for those in the food and health industries, as well as information technology services, thus, stock prices of most firms went down.

TABLE 4 – *Stock Returns Unit Root Test Results*

Variable	Model Type (C, T)	Augmented Dickey-Fuller			KPSS		Perron and Vogelsang unit root test with break		
		ADF-Stat	Included Lags	~I(d)	Stat.	~I(d)	test-Stat	Break date	~I(d)
US	(1,0)	-14.801***	0	I(0)	0.051	I(0)	-15.983***	2008M10	I(0)
UK	(1,0)	-15.900***	0	I(0)	0.089	I(0)	-16.778***	2020M03	I(0)
CH	(1,0)	-5.932***	13	I(0)	0.042	I(0)	-14.949***	2008M10	I(0)
JP	(1,0)	-14.142***	0	I(0)	0.067	I(0)	-15.530***	2008M10	I(0)
HK	(1,0)	-14.259***	0	I(0)	0.067	I(0)	-15.175***	2008M10	I(0)
NG	(1,0)	-5.755***	4	I(0)	0.103	I(0)	-14.538***	2009M01	I(0)

Note: US is the US Standard and Poor 500 stock returns; UK is the UK Financial Times Stock Exchange returns; JP is Japanese Nikkei stock returns; HK is Hong Kong Heng Seng stock returns; CH is Chinese Shanghai stock returns; and NG is the Nigerian stock exchange returns; C and T represent constant and Trend, respectively; KPSS is Kwaitkowski-Philips-Schmidt-Shin stationarity test.

4.2 Estimation Results

The study estimates a VAR(1) model based on the VAR lag order selection results. The VAR(1) model is dynamically stable as indicated by the VAR characteristic polynomial. The model residuals show no autocorrelation and a normally distributed as indicated by the VAR residual Portmanteau test for autocorrelations and the Jarque-Bera normality test. Results for all the diagnostic tests are presented in Appendix. Since the VAR passed all the diagnostic tests the spillover indices were therefore estimated from the GVD of the VAR(1) model.

4.2.1 Spillovers under Full Sample (Static Analysis)

This study estimates the Diebold-Yilmaz spillover index to characterize the net recipient and distributors of return and volatility spillovers among the markets. Tables 5 and 6 report the returns and volatility spillovers, respectively.

TABLE 5 - Returns Spillover

	CH	HK	JP	NG	UK	US	From Others
CH	62.6	20.2	5.4	2.3	3.5	6.0	37.4
HK	12.3	37.9	13.1	4.2	15.3	17.2	62.1
JP	5.0	16	42.6	2.9	15.5	18	57.4
NG	3.7	8.7	6.3	68.6	5	7.7	31.4
UK	2.7	16	13.8	2	39	26.5	60.9
US	4.1	17.1	15.2	3.1	24.2	36.3	63.7
Contribution to others	27.8	78	53.8	14.5	63.4	75.5	312.9
Net directional spillover	-9.6	15.9	-3.6	-16.9	2.5	11.8	52.20%

The total connectedness index measures the overall degree of system connectedness. The result on the bottom right corner of Table 5 indicates that 52% of returns generated during the study period results from spillovers among the markets. This suggests that about 52% of returns made in the global stock market is due to markets' interconnectedness.

The total directional returns spillovers from other markets ranges between 31.4% and 63.7% (see the right most column of Table 5). It turns out that, NG is the least recipient (31.4%) and distributor (14.5%) of returns, though, it receives more than it distributes, NG is a net recipients of return spillovers. The largest share of variations in returns in NG (68.6%) results from domestic shocks suggesting that domestic policies and fluctuations play the most important roles in this market, and that it is the least integrated.

On volatility spillovers, Table 6 presents the results. About 53% of forecast error variance arises from volatility spillovers among the markets suggesting that on average, uncertainties observed in these markets result from uncertainty spillovers across the markets. The "from others" column indicates that NG (54.5%) is one of the highest recipients of volatility spillovers, suggesting that larger proportion of uncertainties and risk generated in other markets are transmitted to Nigeria, thus making it susceptible to international shocks that increase uncertainties and risk.

TABLE 6 - *Volatility Spillover*

	CH	HK	JP	NG	UK	US	From Others
CH	69.8	18.2	3.4	4.5	1.8	2.3	30.2
HK	10.1	50.2	10.5	1.9	13.7	13.6	49.8
JP	5.7	23	33.5	1.9	18.5	17.4	66.5
NG	4.5	13.8	11.9	45.5	11.8	12.5	54.5
UK	2.7	11.2	8.4	1.3	52.6	23.8	47.4
US	2.9	16.7	16.3	1.8	31.4	30.9	69.1
Contribution to others	25.9	82.9	50.5	11.4	77.2	69.6	317.5
Net directional spillover	-4.3	33.1	-16	-43.1	29.8	0.5	52.90%

The "contribution to others" is the directional spillovers from each market. The results show that Nigeria is the least distributor of uncertainties, distributing 11.4 per cent of risks generated in the market. These results, like return spillovers in Table 5, affirm that NG is a less integrated market. It turns out that Nigeria has one of the least percentage of uncertainties due to domestic shocks (about 46%), suggesting that larger proportion of the risks experienced in this market are risks coming from international markets. This means that Nigeria is susceptible to uncertainties and risks due to international shocks. The findings are in consonance with extant literature indicating that returns and volatility transmit from developed to developing markets (Kim and Ryu, 2015; Lien *et al.,* 2018; Mohammadi and Tan, 2015; Alotaibi and Mishra, 2015; Vo and Tran, 2020; Phume and Bonga-Bonga, 2018; Obadiaru *et al.,* 2020; Bonga-Bonga and Phume, 2022).
These results have implications for investment decisions relating to global portfolio diversification. Specifically, the results suggest that markets in Hong Kong, Japan, UK, and the US are more integrated, thus provide less opportunities for portfolio diversification. In contrast, markets in China and Nigeria are less integrated (more segregated) to the rest of the world, hence, provide better opportunities for portfolio diversification.

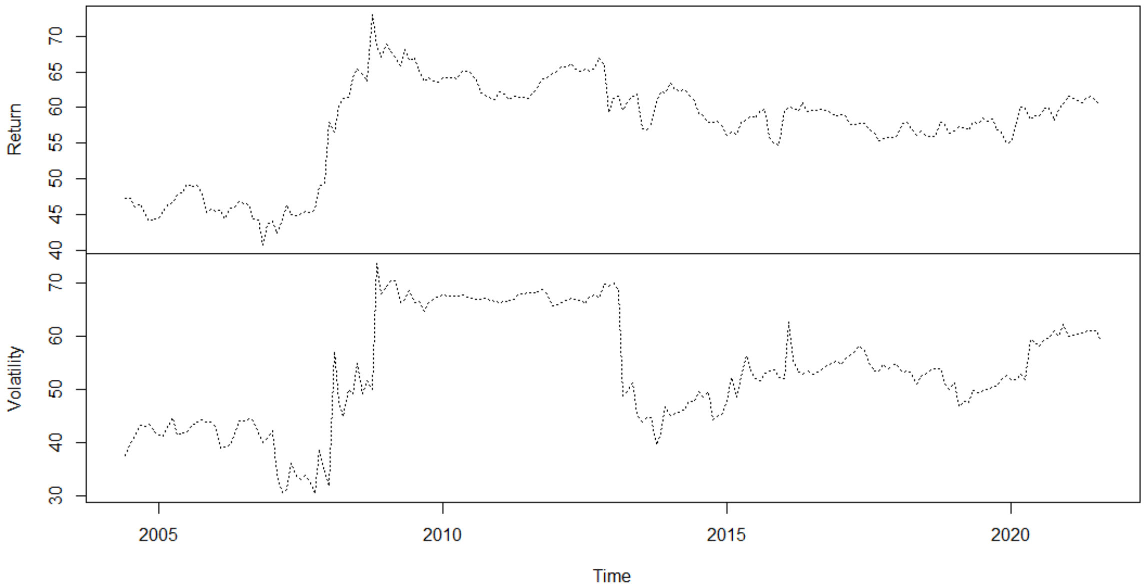
The results also have implications for policy formulation and efficacy. Nigeria, Japan, and the US are more vulnerable to global shocks, hence, policy makers in these markets must be well abreast with events in global markets to take policy decisions that would be resilient to global uncertainties.

4.2.2 Spillover under Rolling Sample (Dynamic Analysis)

Total Spillover

Figure 1 presents the dynamic total return and volatility spillovers. Return spillover is in the upper segment and the lower segment is volatility spillover.

FIGURE 1 - *Total Return and Volatility Spillovers*



The dynamics of return spillover can be partitioned into three phases: the low spillover phase; the transition to high spillover phase; and the high spillover phase. The low spillover phase [May 2004 (47.21%) to October 2007 (45.75%)] predates the global financial crises. During this period, return spillover among the markets was low and larger proportion of returns generated were due to own activities with 40.72% to 48.96% spilling over among the markets. The transition to high spillover (persistence) phase [November 2007 (48.98%) to October 2008 (73.02%)] coincides with the onset of the global financial crisis.

During this period, the markets witnessed a rapid and continuous rise in return spillovers. Return spillovers rose from 45.75% in October 2007 to 73.02% in October 2008 at the peak of the GFC, indicating that the GFC is associated with rising return spillovers among the markets. The high spillover phase [November 2008 (67.81%) to August 2021 (60.31%)] coincides with the period after the GFC. The continuous rise in return spillovers witnessed during the GFC was consolidated during this period, though, returns spillovers declined to 67.02% in March 2009, it largely remains above 55% from thereon, hovering between 68.74% and 54.79%. This means that the global financial crisis is not only associated with higher intensity of return spillover among the markets but also shifted the degree of spillover among the markets permanently to a higher pedestrian.

The dynamic volatility spillover shows similar behaviour to returns spillover prior to and during the global financial crisis, indicating that when returns spillovers gain momentum there is the tendency that the associated risk/uncertainty are also distributed alongside. However, after the global financial crisis, volatility spillovers declined significantly from 77.21% in November 2008 to 28.63% in September 2013, which is marginally greater than the pre-crises low (28.06%) observed in October 2007. Returns and volatility spillovers are both dynamic corroborating Diebold and Yilmaz (2009). They both transit from low regime prior to the GFC to higher intensity regime and peaked during the GFC suggesting financial contagion effects and supports findings from Yilmaz (2010) and Mohammadi and Tan (2015), Zhou *et al.* (2012), Natarajan *et al.* (2014), Gamba-Santamaria *et al.* (2019), Atenga and Mougoue (2021) and Mensi *et al.* (2021) all of which adopted the Diebold and Yilmaz approach but focused on different jurisdictions. Comparable results have also been reported by studies using approaches other than the Diebold and Yilmaz such as Golosnoy *et al.* (2015) and Roni *et al.* (2018).

Total Directional Spillovers

Results on total directional spillovers show the dynamics of both returns and volatility spillovers from other markets to each of the selected markets and from each of the markets to other markets. Figures 2a and 2b present the returns and volatility spillovers for Nigeria (see Appendix for other markets). Over the study period, returns spillovers to Nigeria from other markets remain larger than spillovers from Nigeria to these markets, suggesting that more returns generated from the global markets is transmitted to Nigeria compared to returns transmitted from Nigeria to the global markets. The transmission of returns to and from Nigeria were low prior the GFC, though, they became intensified with the GFC and remained larger after the crisis.

Figure 2b indicates that the Nigerian market is also a net recipient of volatility spillovers suggesting that the market in Nigeria is susceptible to global shocks, though, prior to the GFC, the market was a net distributor of volatility.

FIGURE 2a - *Total Directional Return Spillover to and from Nigeria*

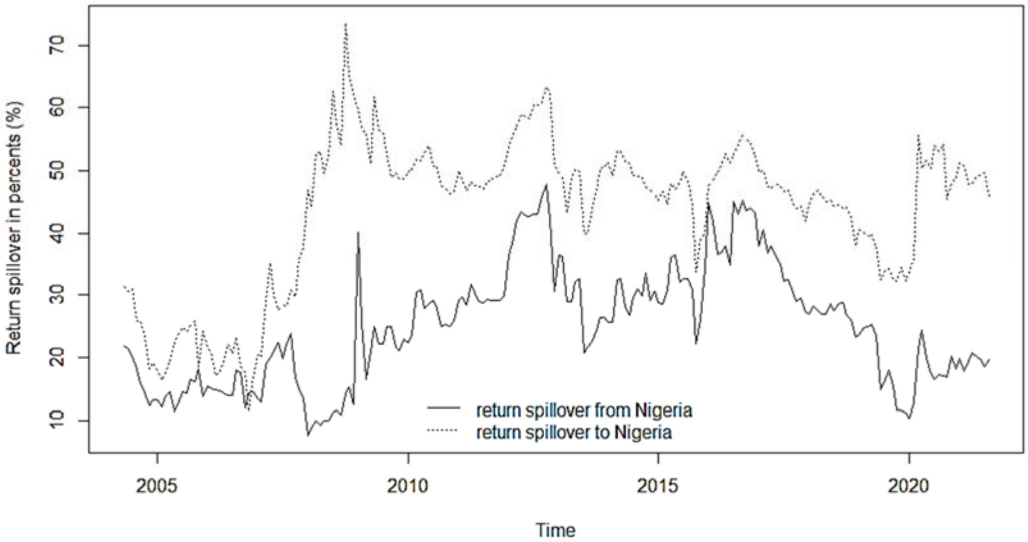
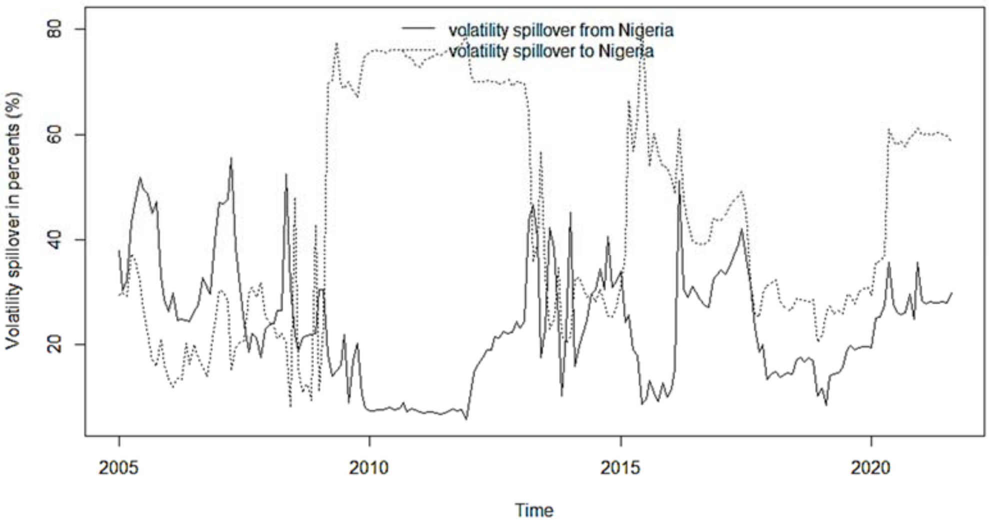


FIGURE 2b - *Total Directional Volatility Spillover to and from Nigeria*



Pairwise spillovers between Nigeria and each of the selected markets

Results for pairwise returns and volatility spillovers are presented in Figures 3a and 3b, respectively. The results indicate that Nigeria is a net receiver of returns spillovers from each of the global markets as the net return spillovers are mostly below the zero line, though, they remained constant since the GFC. However, Nigeria receives more returns from China between January 2007 and December 2008 coinciding with the GFC compared to other countries, suggesting that Nigeria-China tie was relatively stronger during the GFC, which has since diminished. This may suggest that during the GFC, when the major global markets were highly volatile, Nigerians switched to China to hedge against the crisis, which could explain why the Nigerian stock market was not severely affected by the GFC.

On volatility spillovers (Figure 3b), Nigeria, like in the case of returns spillovers, is a net recipient from all the markets, especially between October 2008 and August 2021 coinciding with the peak of the GFC and the period after it. This suggests that the Nigerian market has been vulnerable to shocks from each markets since the GFC. Prior to the crisis Nigeria was a net distributor only to Japan and UK, but that has changed since the end of the GFC. The country became a net distributor to China only from December 2011 to January 2015.

FIGURE 3a - *Net Pairwise Return Spillovers to Nigeria*

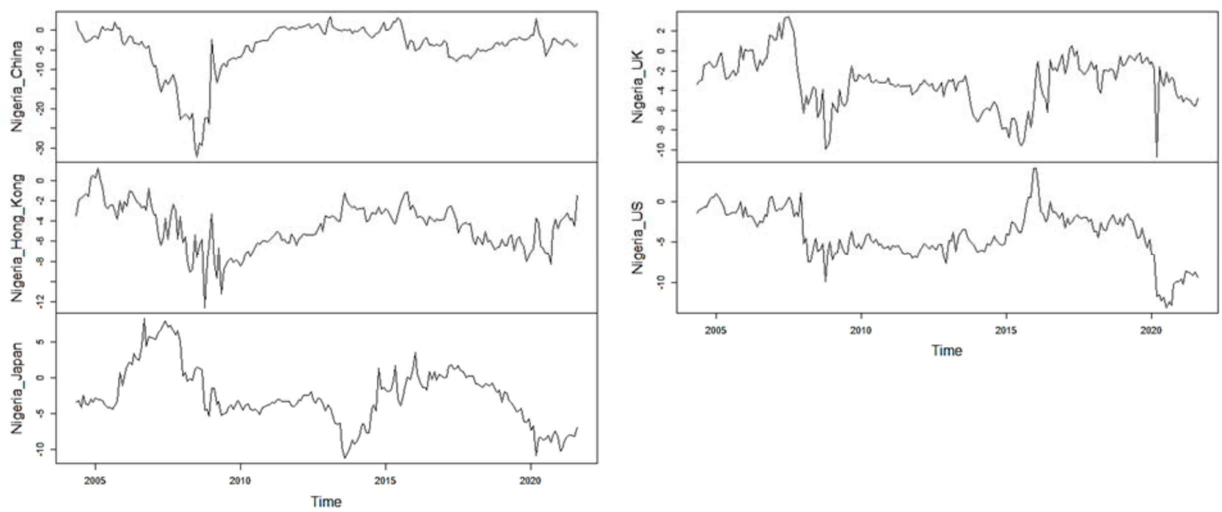
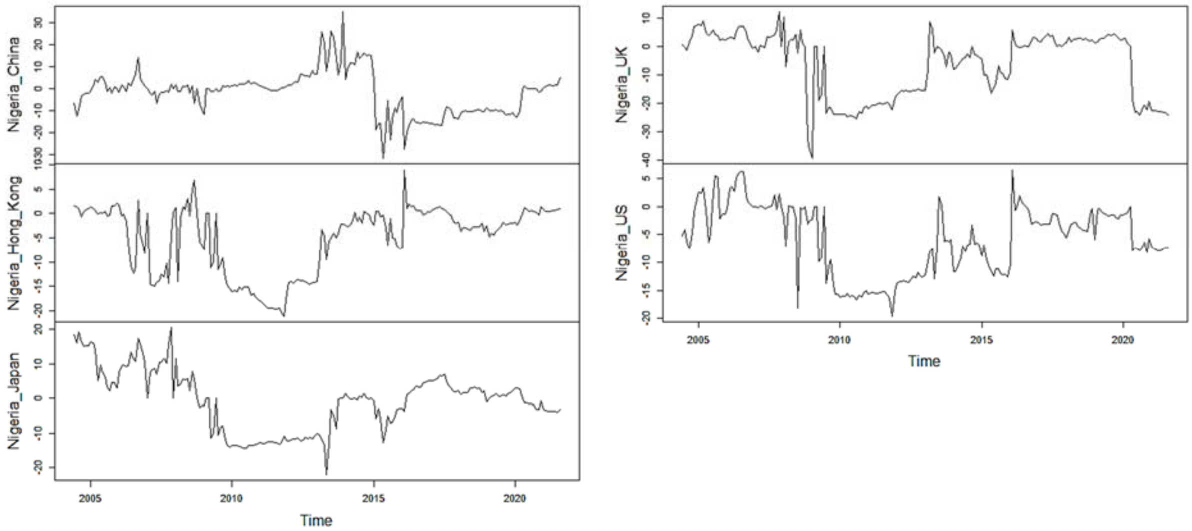


FIGURE 3B - *Net Pairwise Volatility Spillovers to Nigeria*



5. CONCLUSION AND RECOMMENDATIONS

The advent of the GFC brought about the realization/consciousness that shocks in a market can quickly spiral and spillover to other markets within a country and across international boundaries. For investors, diversifying their portfolios is one way to safeguard against such unforeseen events. For policy makers, the resilience of the domestic economy to such international shocks is paramount, as such shocks have the capacity to render domestic policy impotent.

This study examines stock returns and volatility spillovers between Nigeria and five global markets (China, Hong Kong, Japan, UK, and the US) from January 2000 to August 2021 using monthly data. The study adopts the Diebold-Yilmaz interconnectedness index and inferred that most of the returns generated in Nigeria are attributable to domestic policy and shocks, hence Nigeria is less integrated. In terms of volatility, larger proportion of shocks generated in the international markets explain more of the uncertainties and risks in Nigeria, suggesting the country's susceptibility to international shocks. In fact, Nigeria became vulnerable to international shocks during the GFC in 2008 and, as of August 2021, this position has not changed. This suggests that the GFC has had a lasting effect on the Nigerian stock market.

Nigeria is also a net recipient of both returns and volatility spillovers. Also, the GFC is associated with higher and intensified returns and volatility spillovers among the markets. While returns spillovers never return to the pre GFC levels volatility spillovers did.

These conclusions are important for investment and policy decisions. For investors, the less integrated a market I,s the more opportunity it provides for diversification gains, hence, the Nigerian market provides opportunities for portfolio diversification. For policy makers, the more susceptible a market is to global shocks, the more difficulties it presents for the domestic policy makers, hence, the need for buffers and accelerated efforts towards building resilient markets. Therefore, policy makers in Nigeria must be weary of the susceptibility of this market to international shocks.

The study recommends that investors should list assets in the Nigerian stock market in their portfolios to benefit from diversification. Policy makers in the country should formulate policies to build buffers that would make the market resilient to global uncertainties. Since domestic factors explains more of the returns generated in the market, policy makers should focus on stabilizing the domestic economy through policies that lower and stabilize inflation and the Naira exchange rate, build investors' confidence and support economic growth.

A major limitation to the study is the limited number of stock markets and continents represented. The stock markets (China, Hong Kong, Japan, the UK, and US) represented in the study to benchmark the Nigerian stock exchange are those of three continents only (America, Asia, and Europe) and may not be a good representation of the global stock markets. These markets were selected because they are some of the largest and most developed in the world.

This limitation notwithstanding, the study has achieved its objectives. To the best of our knowledge, existing studies did not empirically examine the connectedness of the Nigerian stock market to the rest of the world, at best they have only studied spillovers between Nigeria and South Africa using the MGARCH family of models which do not capture directional spillovers. This study, by showing that Nigeria is a net recipient of returns and volatility spillovers from international stock markets; susceptible to international shocks; and most of the returns generated in the market are explained by domestic factors contributes to extant literature.

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APPENDIX

TABLE A1 - *VAR Lag Order Selection*

Lag	AIC	HQ	SC	FPE
1	7.762*	8.001*	8.355*	2349.263*
2	7.880	8.323	8.981	2644.068
3	8.025	8.673	9.635	3060.503
4	8.083	8.936	10.202	3252.817
5	8.190	9.247	10.817	3631.453
6	8.241	9.504	11.377	3844.975
7	8.308	9.775	11.953	4143.588
8	8.351	10.023	12.504	4369.528
9	8.431	10.308	13.093	4797.609
10	8.530	10.610	13.700	5384.010

Note: * denotes the lag selected by the criterion; AIC, HQ, SC, and FPE are Akaike, Hannan-Quinn, Schwarz, and Final prediction error information criteria, respectively.

TABLE A2 - *VAR Residual Portmanteau Test for Autocorrelations*

Lags	Q-Stat	Prob.*	Adj Q-Stat	Prob.*	df
1	1.671333	---	1.677836	---	---
2	39.21441	0.3277	39.51422	0.3158	36
3	72.08755	0.4749	72.7741	0.4523	72

Note: Null Hypothesis: no residual autocorrelations up to lag h; *Test is valid only for lags larger than the VAR lag order; df is degrees of freedom for (approximate) chi-square distribution

TABLE A3 - *Roots of Characteristic Polynomial*

Root	Modulus
0.190029	0.190029
-0.182014	0.182014
0.080508 - 0.101471i	0.12953
0.080508 + 0.101471i	0.12953
-0.075703	0.075703
-0.003054	0.003054

Note: No root lies outside the unit circle; VAR satisfies the stability condition.

TABLE A4 - *VAR Residual Normality Tests*

Component	Skewness	Chi-sq	df	Prob.
1	-0.15	1.04	1	0.31
2	-0.17	1.37	1	0.24
3	-0.13	0.80	1	0.37
4	-0.36	1.54	1	0.32
5	-0.58	2.19	1	0.05
6	-0.02	0.02	1	0.88
Joint		6.96	6	0.54
	Kurtosis			
1	2.71	2.43	1	0.18
2	3.71	5.30	1	0.02
3	3.00	0.03	1	0.86
4	4.76	6.17	1	0.02
5	4.21	1.53	1	0.22
6	4.01	1.41	1	0.07
Joint		16.87	6	0.06
	Jarque-Bera			
1	3.47		2	0.25
2	6.67		2	0.13
3	0.83		2	0.61
4	7.72		2	0.19
5	3.71		2	0.14
6	1.43		2	0.65
Joint	23.83		12	0.30

FIGURE A1a - *Total Directional Return Spillover to and from China*

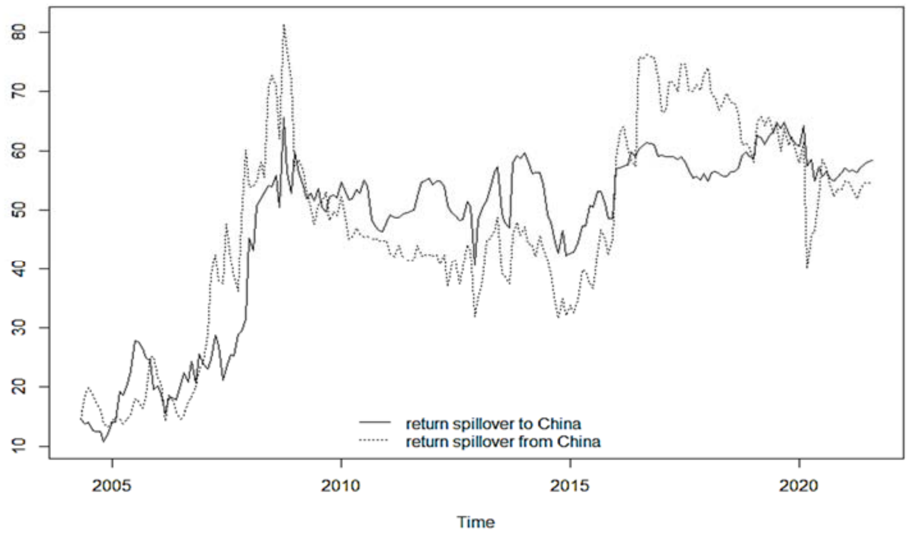

FIGURE A1b - *Total Directional Volatility Spillover to and from China*

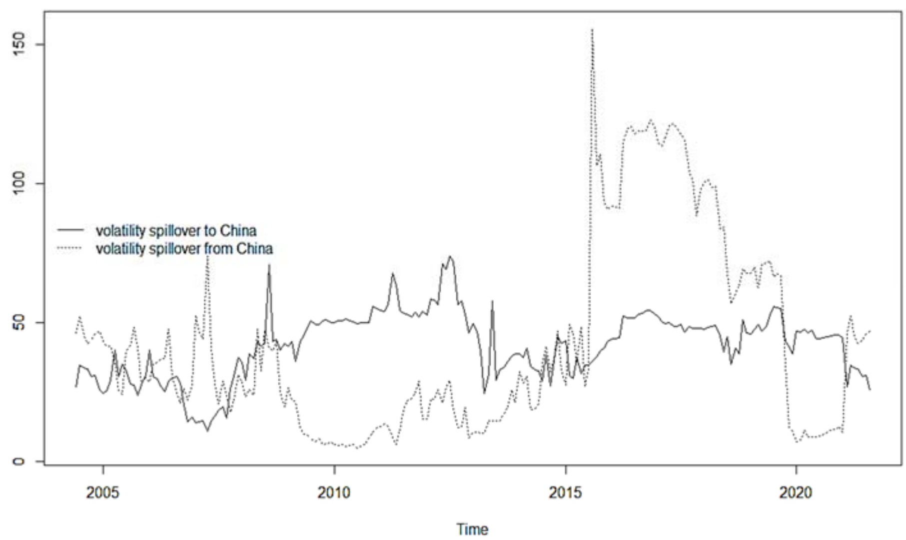

FIGURE A2a - *Total Directional Return Spillover to and from Hong Kong*

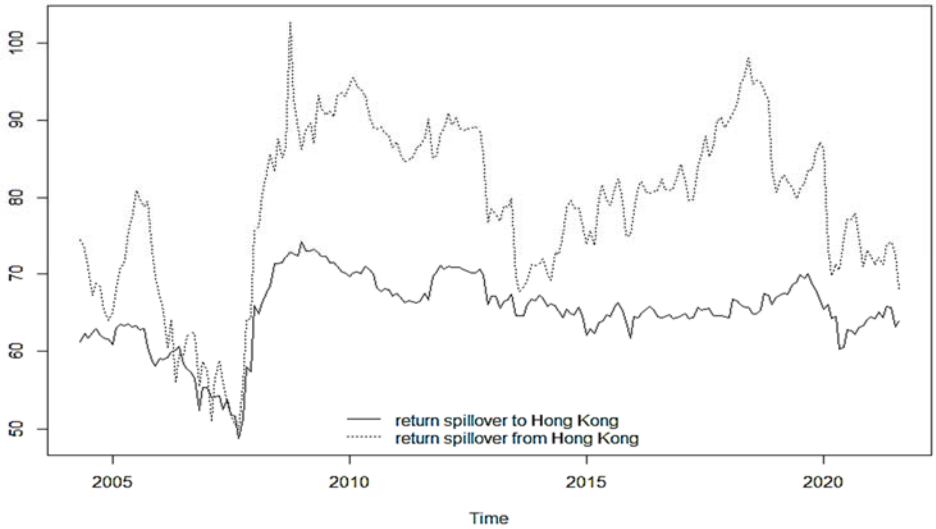

FIGURE A2b - *Total Directional Volatility Spillover to and from Hong Kong*

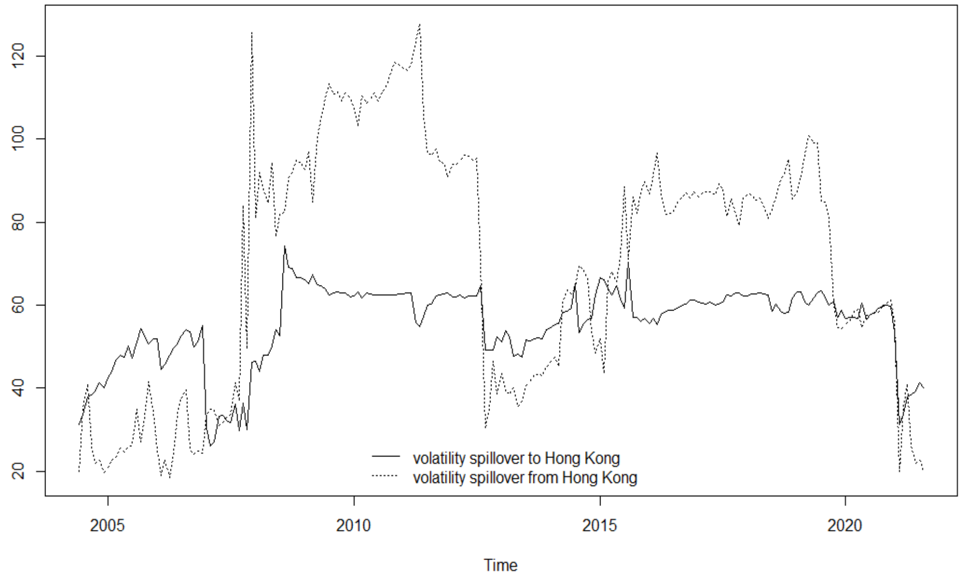

FIGURE A3a - *Total Directional Return Spillover to and from Japan*

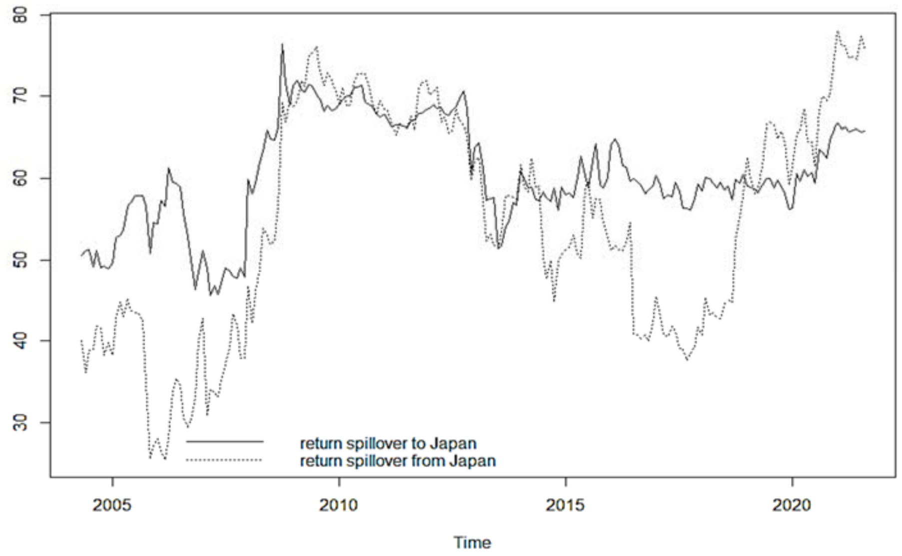

FIGURE A3b - *Total Directional Volatility Spillover to and from Japan*

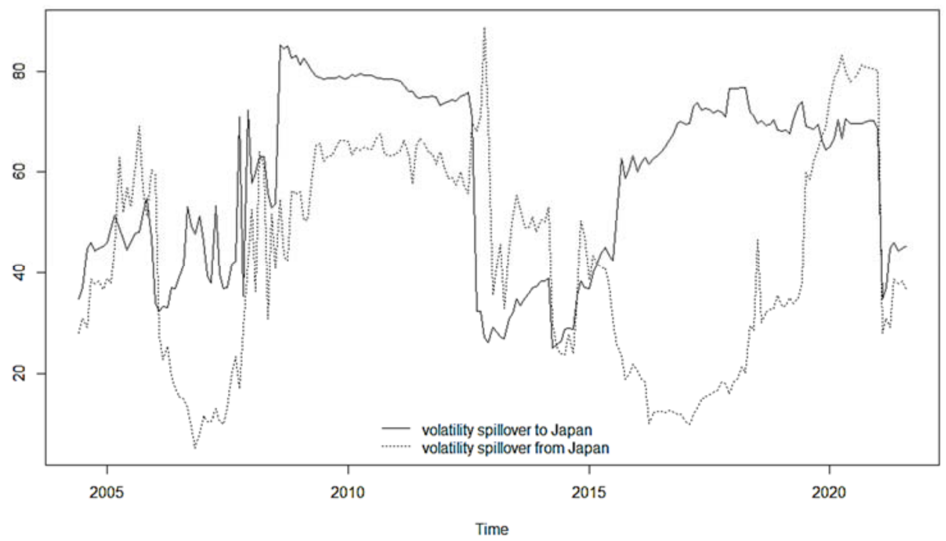

FIGURE A4a - *Total Directional Return Spillover to and from the United Kingdom*

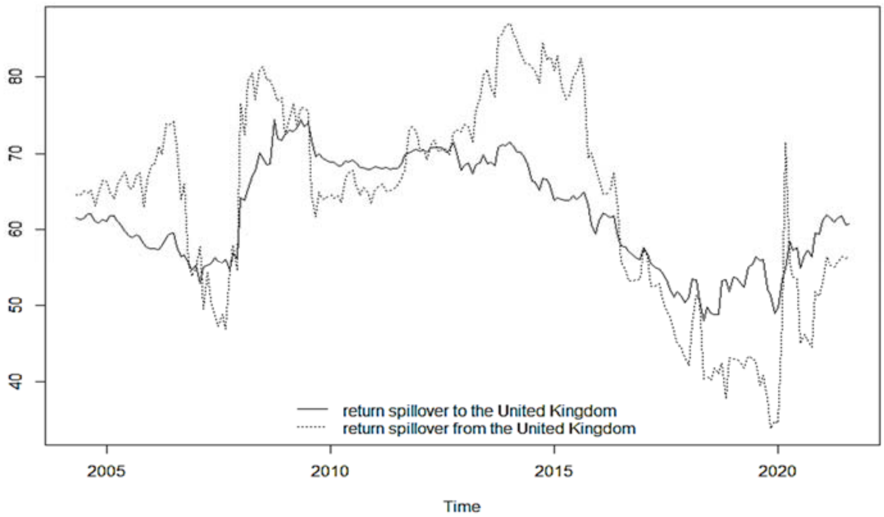

FIGURE A4b - *Total Directional Volatility Spillover to and from the United Kingdom*

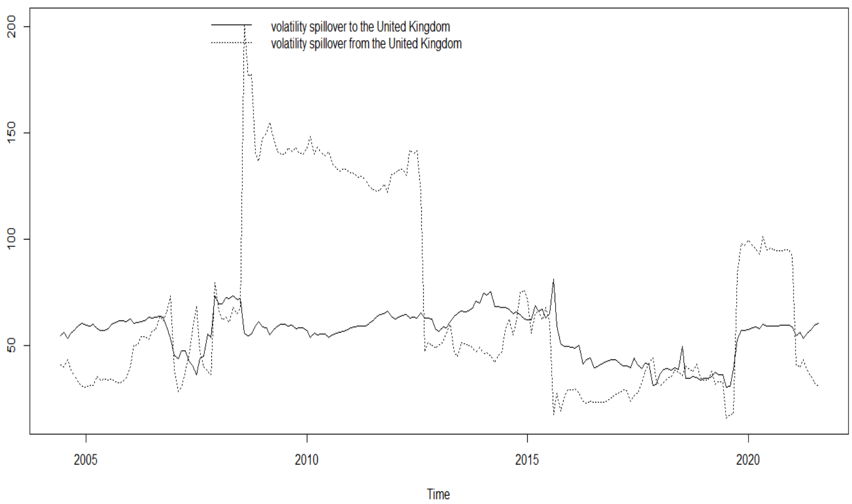

FIGURE A5a - *Total Directional Return Spillover to and from the United States*

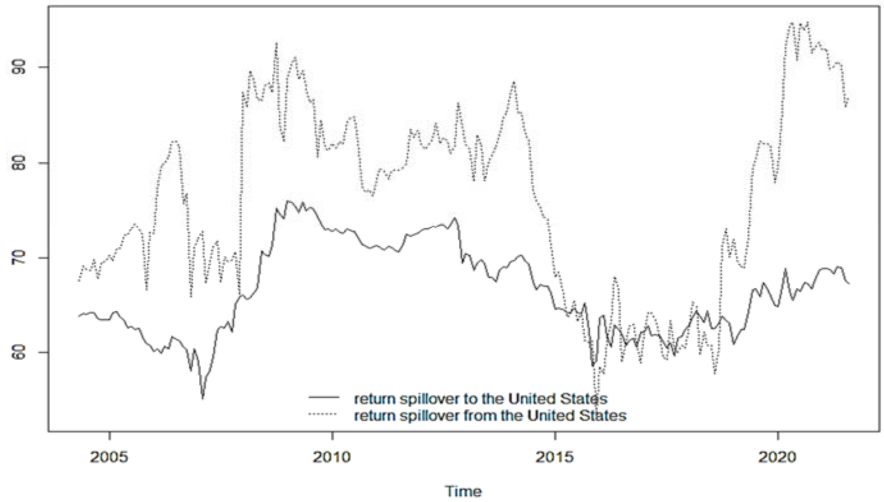

FIGURE A5b - *Total Directional Volatility Spillover to and from the United States*