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Measuring Return and Volatility Spillovers among Sectoral Stocks in Nigeria

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Abstract: *This paper examines the return and volatility spillovers of different sectoral stock prices in Nigeria using monthly data from January 2007 to December 2016. We employ the Diebold and Yilmaz (2012) spillover approach and rolling sample analysis to capture the inherent secular and cyclical movements in the sector stocks market.We show that there is substantial difference between the behaviour of the sectoral stock return and volatility spillover indices over time. We find evidence of interdependence among sector stocks given the spillover indices. While the return spillover index reveals increased integration among the sectoral stocks, the volatility spillover index experiences significant bursts during major market crises. Interestingly, return and volatility spillovers exhibit both trends and bursts respectively.*

Keywords: Stocks; Returns; Volatilities; Vector autoregression; Forecast error variance; Spillover

JEL Classification: C32, C67, G12

Introduction

A plethora of studies have examined movements of aggregate stock market volatility, with most often focusing on developed economies like the US and European stock markets. However, the literature on volatility co-movement among sectoral stocks within an economy is sparse.While there is a substantial literature on the analysis of volatility spillovers between stock returns and domestic exchange rates, surprisingly, little or no study have been carried out on returns and volatility spillovers at the sectoral level in the stock markets of developing economies. It is the limited nature and

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paucity of such work in existing literature that has spurred us to investigate the returns and volatility spillovers among sectoral stocks in Nigeria. Our choice of Nigeria is motivated by the fact that Nigeria is Africa's largest economy and her importance as an investment destination cannot be underestimated; policy makers must therefore develop an in depth understanding of returns and volatility spillovers among sectors in the Nigerian stock market to enable policy to focus closely on smoothing out the effects of shocks to the transmission channel (Kpughur et al., 2017).

Stock markets have become increasingly integrated and liberalized, largely due to rapid technological developments and financial deregulations (Jebran et al., 2017). However, as stock markets become increasingly integrated and global, there may be some downsides such as; volatile capital flows which may result in increased stock market volatility and vulnerability to fluctuation of global financial markets which may be particularly harmful for emerging economies (Prasad et al., 2005). Moreover, it is plausible that integration within stock markets may indicate the absence of potential diversification opportunities and this may pose an exposure to risk, as the integrated market are more susceptible to greater loss due to financial contagion in a crisis situation (Jebran et al., 2017). This study is therefore very significant and timely as information about linkages between the emerging markets will provide valuable information to investors, which may help in portfolio formulation.

From the policy perspective, there are compelling reasons for the analysis of volatility transmissions among sectoral stocks in the Nigerian stock market. First, "information about the intensity of these spillovers provides useful insights to portfolio investors on how to diversify their portfolio investments in order to maximize returns" (Salisu et al., 2018). Second, information about volatility transmissions would prove useful to policy makers in identifying likely sectors within the Nigerian Stock Market which may be vulnerable to higher risks (Fasanya and Akinde, 2019). Third, as pointed out by Diebold and Yilmaz (2012), it would be useful in measuring and monitoring such interactions among sectors, to provide early warning signs for budding crises, and to track the evolvement of existent crises. Motivated by these concerns, this study measures the return and volatility spillovers among sectoral stocks within the Nigerian stock market.

Of the few studies that have empirically considered returns and volatility transmissions among sectoral stocks and global stock markets, many cover different markets and regions, adopting varying methodologies. We review quite a reasonable number of them in this paper and discover findings are mixed. This is probably due to differing methodologies, use of different proxies, data coverage and variable measurement (see Table 1 for a survey of literature).

This study makes a methodological contribution by adopting the approach of Diebold and Yilmaz (2012) to quantify the returns and volatility transmissions among sectoral stocks in the Nigerian Stock Market. To the best of our knowledge, no previous study has adopted the Diebold and Yilmaz (2012) methodology to investigate this dynamic relationship among sectoral stocks in the Nigerian stock market. The Diebold and Yilmaz (2012) approach provides a simple and intuitive measure of interdependence of asset returns and volatilities by exploiting the generalized vector autoregressive framework of Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998), which produces variance decompositions that are unaffected by ordering. This is an improvement on the Diebold and Yilmaz (2009) approach. We also investigate the stability of our analysis over time by subjecting the results to robustness checks. Our results offer some useful generalizations relevant to volatility transmissions among sectoral stocks. This is the contribution of our paper.

Following this introductory section, we structure the rest of the paper as follows. Section 2 provides the literature review of the study. In section 3, the methodology for our analysis is pursued. Section 4 describes the data and also provides some preliminary analyses. Section 5 discusses the empirical results including diagnostics and robustness tests. In Section 6, we discuss policy implications and conclude the study.

Literature Review

This section presents a review of literature on returns and volatility spillovers among sectoral stocks. A lot of studies have examined the returns and volatility transmissions in several stock markets, offering mixed and inconclusive findings (see Table 1). Most of these studies already include literature reviews up to the date of their publication (see, e.g., Jebran et al., 2017) for a complete literature survey. However, to the best of the authors' knowledge, no empirical investigation has been carried out on returns and volatility spillovers at the sectoral level in the stock markets of developing economies. It is because of the paucity of such work in existing literature that this study examines Nigeria. A study on returns and volatility transmissions among sectoral stocks in Nigeria is therefore essential as Nigeria's importance as an investment destination cannot be overemphasized being Africa's largest economy. Therefore, an in depth understanding of the returns and volatility spillovers among sectors in the Nigerian stock market would be useful to policy makers in formulating policies focused on smoothing out the effects of shocks to the transmission channel (Kpughur et al., 2017).

Of the papers surveyed in this study, just one study have examined volatility transmissions in the Nigerian stock market (see, Kpughur er al,, 2017) however, it adopts aggregate data and examines transmissions between the naira exchange rate and the stock market using approaches different from this study. There are also studies for other regions, worthy of mention is China (see, e.g., Wang and Zhang, 2011; Sharma, 2017; Jebran et al., 2017), BRICS (see, e.g., Ramaprasad and Biljana, 2007; Boubaker and Raza, 2017; Nareshet al., 2018), U.S (see, e.g., Arouri et al., 2011; Ghouse and Khan, 2017; Kinnunen, 2017; Oh, 2017; Bekiros et al., 2016), Europe (see, e.g., Arouri et al., 2011; Chang et al., 2013; Sharma, 2017; Blau, 2017), South America (see, e.g., Vasco and Agudelo, 2014; Gamba-Santamaria et al., 2016)among others. Furthermore, we notice that there are few or no studies on returns and volatility transmission at the sectoral level in Sub Saharan African regions, this is probably due to data inadequacies or constraints.

In the literature, differing methods have been used to examine returns and volatility transmissions in stock markets. Some of the prominent techniques include; General Autoregressive Conditional Heteroscedasticity (GARCH) models (see, e.g., Ramaprasad and Biljana, 2007; Arouri et al., 2011; Chang et al., 2013; Jebran, et al., 2017; Kpughur et al., 2017; Ghouse and Khan, 2017; Apergis and Gupta, 2017;Boubaker and Raza, 2017), Vector Autoregression (see, e.g., Andrikopoulos et al., 2014; Baoko and Alagidede, 2017; Sharma, 2017; Kinnunen, 2017), Regression analysis (see, e.g., Wang and Zhang, 2011; Vasco and Agudelo, 2014; Fauzi and Wahyudi, 2016;Blau, 2017) to mention a few.

In terms of empirical findings, the results appear mixed. Particular attention has been paid to presence of transmission mechanism between markets. Many studies report unidirectional volatility spillovers between markets (for example, see; Arouri et al., 2011; Ghouse and Khan, 2017; Kpughur et al., 2017) while some others reported a bidirectional relationship between markets (see, e.g., Du and He, 2015; Majdoub and Sassi, 2016; Jebran et al., 2017; Boubaker and Raza, 2017). On the contrary, some studies report no evidence of significant comovement (see, e.g.,Chang et al., 2013; Bekiros et al., 2016; Kinnunen, 2017). However, in some cases we notice differing result from studies from similar regions and countries, this is probably due to differing methodologies, use of different proxies, data coverage and variable measurement.

Table 1: Survey of Literature

S/N	Year	Author(s)	Title	Region /Market	Methodology	Data / Scope	Findings and Conclusion
1	2004	Bala and Premaratne	Volatility Spillover and Co-movement: Some New Evidence from Singapore	Singapore stock market and the markets of US, UK, Hong Kong and Japan.	Univariate GARCH; Vector Autoregression and a Multivariate and Asymmetric Multivariate GARCH model with GJR extensions.	Daily returns from 1992 to 2002,	High degree of volatility co-movement between Singapore stock market and that of Hong Kong, US, Japan and UK. Results support small but significant volatility spillover from Singapore into Hong Kong, Japan and US markets despite the latter three being dominant markets
2	2007	Ramaprasad and Biljana	Analysis of Mean and Volatility Spillovers Using BRIC Countries, Regional and World Equity Index Returns	BRIC	Two-stage GARCH-in-mean approach (GARCH-M)	Daily equity index level data for the period between January 1995 and December 2004	Regional trends are found to have a much greater influence than world trends upon the stock return process of the BRIC countries. The world index returns, and most likely the US equity market returns, have a significant influence upon the variance of returns seen across Brazil, Russia and India. China is the only country where there exists a negative relationship between volatility spillover effects on a regional and global basis.
3	2011	Wang and Zhang	The spillover effect of disclosure rules and materiality thresholds: Evidence from profit warnings issued in Hong Kong market	Chinese Stock Market	Logistic Regression	Daily data from 2003 to 2009	Spillover effect increases with the market capitalization of Chinese duallisted firms and increases with the market share of these firms before they dominate the industry.
4	2011	Arouri et al.	Volatility spillovers between oil prices and stock sector returns: Implications for portfolio management	Stock markets in Europe and US at sectoral level	VAR-GARCH models	Weekly data from January 01,1998, to December 31, 2009, covering seven industrial sectors in Europe and the US	Existence of significant volatility spillover between oil and sector stock returns. The spillover is usually unidirectional from oil markets to stock markets in Europe, but bidirectional in the United States

S/N	Year	Author(s)	Title	Region /Market	Methodology	Data / Scope	Findings and Conclusion
5	2013	Chang et al.	Conditional correlations and volatility spillovers between crude oil and stock index returns	FTSE100 (London Stock Exchange: FTSE), NYSE composite (New York Stock Exchange: NYSE), S&P500 composite (Standard and Poor's: S&P), and Dow Jones Industrials (Dow Jones: DJ)	CCC, VARMA-GARCH, VARMA-AGARCH, and DCC models	Daily data from 2 January 1998 to 4 November 2009	Result suggests no evidence of constant conditional correlations. Also, empirical results from the VARMA-GARCH and VARMA-AGARCH models provide little evidence of volatility spillovers between the crude oil and financial markets. The evidence of asymmetric effects of negative and positive shocks of equal magnitude on the conditional variances suggests that VARMA-AGARCH is superior to VARMA-GARCH and CCC
6	2013	Alter and Beyer	The Dynamics of Spillover Effects during the European Sovereign Debt Turmoil	Eleven euro-area countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain	VECTOR AUTOREGRESSIVE MODEL WITH EXOGENOUS VARIABLES (VARX)	Daily data from October 2009 to July 3, 2012.	Results show clear growing interdependencies between banks and sovereigns, that represents a potential source of systemic risk.
7	2014	Vasco and Agudelo	Liquidity spillover effects of equity offerings over dual-class shares	Stock markets of five Latin American countries: Brazil, Chile, Colombia, Mexico and Peru	Panel Regression	Daily data from January 1995 to December 2012	Stock liquidity reduction of dual-class shares upon the offering; consistent with trading migration effects, according with the theory of inventory costs.
8	2014	Andrikopoulos et al.	Illiquidity, return and risk in G7 stock markets: Interdependencies and spillovers	G7 stock markets	Vector Autoregression (VAR)	Daily data from June 28, 1991 to September 30, 2013, in the G7 markets	International stock markets are characterized by persistent illiquidity and also that illiquidity shocks are significantly correlated across markets.
9	2014	Wang and Ma	Excess volatility and the cross-section of stock returns	NYSE/AMEX/ NASDAQ common stocks	Fama–MacBeth regression analysis	January 1963 to December 2010	Reliable positive relation between excess volatilityand the cross-section of stock returns

S/N	Year	Author(s)	Title	Region /Market	Methodology	Data / Scope	Findings and Conclusion
10	2015	Alotaibi and Mishra	Global and regional volatility spillovers to GCC stock markets	Five GCC markets (Bahrain, Kuwait, Oman, Qatar, UAE), regional market (Saudi Arabia) and global market (US)	Bivariate GARCH models	Weekly data from from June 2005 till May 2013	Significant return spillover effects from Saudi Arabia and US to GCC markets. Trade, turnover and institutional quality have significant impacts on regional volatility spillovers from Saudi Arabia to GCC markets
11	2015	Du and He	Extreme risk spillovers between crude oil and stock markets	S&P500 composite	Granger causality in risk, Value at Risk (VaR) and a class of kernel-based tests	Daily data from September 1, 2004 to September 11, 2012	There are significant risk spillovers between the two markets. Extreme movements, past or current, in one market may have a significant predictive power for those in the other market
12	2016	Fauzi and Wahyudi	The Effect of Firm and Stock Characteristics on Stock Returns: Stock market crash analysis	Indonesia	Multivariate Regression	Daily or monthly stock prices	This study finds that there are short-term and long-term momentum effects on stock returns during most of stock market crashes
13	2016	Bekiros et al.	On economic uncertainty, stock market predictability and nonlinear spillover effects	US	Nonparametric Granger causality test	Monthly data from 1900:1–2014:2	No predictability can be observed for the various measures of uncertainty i.e., firm-level,macroeconomic and economic policy uncertainty, vis-à-vis realstock returns
14	2016	Diaz and Garcia	Oil price shocks and stock returns of oil and gas corporations	four oil and gas corporations listed on NYSE	VAR	Monthly data from January 1974 to December 2015	Evidence supports significant positive impact of oil price shocks on stock returns in the short-run
15	2016	Gamba-Santamaria et al.	Stock Market Volatility Spillovers: Evidence for Latin America	Stock market indexes of the United States and four Latin American countries: Brazil, Chile, Colombia and Mexico	DCC-GARCH framework	Daily data from January 2nd, 2003 to January 27th, 2016	Results show that Brazil is a net volatility transmitter for most of the sample period, while Chile, Colombia and Mexico are net receivers

S/N	Year	Author(s)	Title	Region /Market	Methodology	Data / Scope	Findings and Conclusion
16	2016	Huo and Ahmed	Return and volatility spillovers effects: Evaluating the impact of Shanghai-Hong Kong Stock Connect	Granger Causality, VAR , univariate and multivariate GARCH models including GJR GARCH and BEKK GARCH models	Shanghai Stock Exchange Composite Index (SSEC) and the Hong Kong Hang Seng Index (HSI)	Per minute data from 2 July 2014 to 8 April 2015	New Stock Connect does contribute to the increasing importance of the Chinese mainland stock market and economic activity
17	2016	Liu et al.	The evolution of spillover effects between oil and stock markets across multi-scales using a wavelet-based GARCH–BEKK model	S&P 500 (USA) index and the MICEX index (Russia)	Wavelet-based GARCH–BEKK method	Daily data from Jan 2003 – Dec 2014	Result implies that the linkage between oil and US stock market is weakening in the long-term, and the linkage between oil and Russia stock market is getting close in all time scales
18	2016	Majdoub and Sassi	Volatility spillover and hedging effectiveness among China and emerging Asian Islamic equity indexes	Six Islamic MSCI index from the Asian region, namely China, India, Malaysia,Indonesia, Korea and Thailand	Bivariate VARMA-BEKK-AGARCH model	Daily data from February 7, 2011 to February 5, 2016	Results show a significant positive and negative return spillover from China to selected Asian Islamic stock market and bidirectional volatility spillovers between China, Korea and Thailand Islamic market showing evidence of short-term predictability on Islamic Chinese stock market movements
19	2017	Kinnunen	Dynamic cross-autocorrelation in stock returns	US small-and large-firms	Exponential Vector Auto-regressive model with Volatility	Daily and Weekly data from 1965 to 2015	Constant cross-autocorrelation pattern is rejected. Returns on a Large-firm portfolio are found to lead returns on a small-firm portfolio
20	2017	Jebran et al.	Does volatility spillover among stock markets varies from normal to turbulent periods? Evidence from emerging markets of Asia	Emerging Markets in Asia (China, Pakistan, Hong Kong, Sri Lanka, and India)	Extended EGARCH model	Daily data from 2nd January, 2001 to 31st December, 2013	Bidirectional volatility spillover between stock markets of India and Sri Lanka in both sub-periods. However the volatility spillover is bidirectional between stock markets of Hong Kong and India; Pakistan and India in pre-crisis period, while in stock markets of Sri Lanka and Pakistan in post-crisis period.

S/N	Year	Author(s)	Title	Region /Market	Methodology	Data / Scope	Findings and Conclusion
21	2017	Kpughur et al.	Volatility of stock market returns and the naira exchange rate	Nigeria	Multivariate GARCH model (VARMA-AGARCH model)	2007 to 2016	Presence of a transmission mechanism between markets. Shock spillovers showed a stronger unidirectional transmission of shocks from the stock market to the foreign exchange market without breakpoints. When breakpoints were considered, a bi-directional spillover pattern was observed across both markets.
22	2017	Oh	Absorptive Capacity, Technology Spillovers, and the Cross-Section of Stock Returns	Common stocks on NYSE, AMEX and NASDAQ		Monthly data from from 1976 to 2006	Firm's absorptive capacity (AC) is crucial to benefit from spillovers. Higher AC firms, when exposed to large potential spillovers, exhibit stronger future real outcomes (cite-weighted patents and operating performance) and market value.
23	2017	Boako and Alagidede	Currency price risk and stock market returns in Africa: Dependence and downside spillover effects with stochastic copulas	Six (6) African stock markets (namely, Kenya, South Africa, Morocco, Nigeria, Botswana, and Egypt)	VaR and conditional CoVaR measures based on copulas	Weekly data from 7th Jan 2003 to 21st Feb 2016 covering six (6) African stock markets	Evidence of non-homogenous weak negative dependence between stocks and exchange rates
24	2017	Ghouse and Khan	Tracing dynamic linkages and spillover effect between Pakistani and leading foreign stock markets	Nine worldly equity markets (KSE 100, NIKKEI 225, HIS, S&P 500, NASDAQ 100, DOW JONES, GADXI, FTSE 350 and DFMGI)	Univariate GARCH type models	Daily data between 2005 and 2014	Mixed co-movements between leading foreign stock markets and Pakistani stock market. Evidence of unidirectional mean and volatility spillover effect from S&P 500, NASDAQ 100, DJI and DFMGI to KSE 100. Also, presence of bidirectional spillover effect between DFMGI and KSE 100.
25	2017	Sharma	Oil Price Shocks and American Depositary Receipt Stock Returns	Twelve countries: Brazil, China, France, Germany, India, Italy, Japan, Mexico, Norway, Russia, South Korea, and United Kingdom. France, Germany, Italy, Japan, and United Kingdom	Vector Autoregression (VAR)	Monthly data from from 1991:01 to 2014:12	Oil price shocks have a positive and significant impact on ADR returns in all twelve countries.

S/N	Year	Author(s)	Title	Region /Market	Methodology	Data / Scope	Findings and Conclusion
26	2017	Naresh et al.	Spillover effect of US dollar on the stock indices of BRICS	BRICS	Panel Generalized Methods of Moments	Daily data from Jan 1, 2006 to July 23, 2015	Results indicate that appreciation in the value of BRICS currencies against dollars has increased the value of the respective nation's stock indices.
27	2017	Apergis and Gupta	Can (unusual) weather conditions in New York predict South African stock returns?	South Africa and U.S	GARCH models	Daily data from January 2, 1973 to December, 31, 2015	Unusual deviations of weather variables have a statistically significant negative effect on the stock returns in South Africa, indicating that unusual weather conditions in New York can be used to predict South African stock returns, which otherwise seems to be highly unpredictable
28	2017	Blau	The volatility of exchange rates and the non-normality of stock returns	Europe	Panel Regression	Daily data over a 12-year period	Evidence suggests that the adoption of the Eurodecreased the level of kurtosis and increased the skewness of stock returns.
29	2017	Boubaker and Raza	A wavelet analysis of mean and volatility spillovers between oil and BRICS stock markets	BRICS	Multivariate ARMA-GARCH model and Wavelet multiresolution analysis	Daily data over the period January 4, 2000 until March 25, 2015	Strong evidence of time-varying volatility in all markets under study. Also,evidence shows that oil price and stock market prices are directly affected by their own news and volatilities and indirectly affected by the volatilities of other prices and wavelet scale.
30	2017	Christon et al.	Economic Policy Uncertainty and Stock Market Returns in Pacific-Rim Countries: Evidence based on a Bayesian Panel VAR Model	Australia, Canada, China, Japan, Korea and the US	Bayesian Panel VAR Model	Monthly data is used over 1998:01 to 2014:12	Effect of own country EPU negatively affects stock returns. Effect of US EPU negatively affects stock returns of all countries except Australia

Econometric Methodology

This study applies the Diebold and Yilmaz (2012) spillover indices to explore the return and volatility spillover sectoral effects in the Nigerian stock market. Practically, the Diebold and Yilmaz (2012) spillover approach is a volatility spillover measure grounded on the forecast error variance decompositions from vector autoregressions (VARs), and it can be used to measure the spillovers in any return characteristic of interest across the individual assets, asset portfolios, asset markets, etc., both within and across countries, revealing spillover trends, cycles, bursts (Diebold and Yilmaz 2012). The underlying framework for the spillover analysis is the generalized vector autoregressive (VAR) model of KPSS which is invariant to variable ordering. Essentially, four different spillover types can be generated using the DY (2012) and they are the Total Spillovers, Directional Spillovers, Net Spillovers and Net Pairwise Spillovers. In setting up the spillover indexes, a covariance stationary VAR (***p***) is considered (see DY, 2009 and DY, 2012).

$$r_t = \Phi r_{t-1} + \varepsilon_t ; \quad \varepsilon_t \sim (0, \Sigma) \tag{1}$$

Where $r_t = (r_{1t}, r_{2t},...,r_{Nt})'$ is an $N \times 1$ vector of return or volatility series, Φ is an $N \times N$ matrix of parameters, ε_t is a vector of independently and identically distributed disturbances and Σ is the variance matrix for the error vector ε. The moving average representation can be written as:

$$r_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-1} \tag{2}$$

Where A_i is estimated by the recursion $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + ... + \Phi_p A_{i-p}$. A_0 is an identity matrix with an $N \times N$ dimension and $A_0 = 0$ for $i < 0$. Equation (2) forms the basis for the derivation of variance decompositions required to determine the spillover indexes. Before providing the representations for the various indexes, the following preliminary considerations are important:

Firstly, the own variance shares are defined as the fractions of the H-step-ahead error variances in forecasting r_i that are due to shocks to r_i, for $i = 1, 2....N$.

Secondly, the cross variance shares or spillovers are defined as the fractions of the H-step ahead error variances in forecasting r_i that are due to shocks to r_j, for $i, j = 1,2, ..., N$ such that $\boldsymbol{i \neq j}$.

Thirdly, based on the generalized VAR framework of KPPS, H -step-ahead forecast error variance decompositions denoted by θ_{ij}^g is written as:

$$\theta_{ij}^g(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)} \tag{3}$$

Where σ_{jj} is the standard deviation of ε for the jth equation and ε_i is the selection vector, with one as the ith element and zeros otherwise.

Lastly, since the sum of the contributions to the variance of the forecast error is not equal to one – that is $\sum_{j=i}^{N} \theta_{ij}^{g}(H) \neq 1$; DY (2012) normalized each entry of the-variance decomposition matrix by the row sum in order to use the full information of the matrix. The normalized KPPS H -step-ahead forecast error variance decompositions represented by $\tilde{\theta}_{ij}^{g}(H)$ is expressed as:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(N)} \tag{4}$$

where $\sum_{j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{1,j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = N$ by construction.

Given these preliminaries, the total spillover index is written as:

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{1,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \times 100 = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \times 100 \tag{5}$$

All the parameters in equation (5) have been previously defined. Essentially, equation (5) measures the contribution of spillovers of return or volatility shocks across the assets under consideration. In our case, the total spillover index captures the contribution of spillovers of return/volatility shocks across the nine (9) sectoral stocks to the total forecast error variance.

It is also possible to assess quantitatively the direction of spillovers across the nine sector stocks using the DY (2012) approach. These directional spillovers are classified into two namely 'Directional *Spillover To' and 'Directional Spillover From'*. The former measures the directional spillovers whether return or volatility transmitted by market *i*to all other markets *j* while the latter relates to return or volatility received by market *i*from all other markets *j*. The index for the computation of '*Directional Spillover To*' denoted by $S_{.i}^{g}$ is given as:

$$S_{.i}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ji}^{g}(H)} \times 100 = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ji}^{g}(H)}{N} \times 100 \tag{6}$$

The *'Directional Spillover From'* denoted as $S_{i.}^{g}$ is measured using the index given below:

$$S_{i.}^{g}(H)=\frac{\sum_{\substack{j=1\\ j\neq i}}^{N}\theta_{ij}^{g}(H)}{\sum_{i,j=1}^{N}\theta_{ij}^{g}}\times 100=\frac{\sum_{\substack{j=1\\ j\neq i}}^{N}\theta_{ij}^{g}(H)}{N}\times 100 \tag{7}$$

Equally, the Net Spillovers can be obtained using the index expressed below:

$$S_{i}^{g}(H)=S_{.i}^{g}(H)-S_{i.}^{g}(H). \tag{8}$$

Equation (8) gives the difference between the gross return or volatility shocks transmitted to and received from all other markers. In other words, information about each market's contribution to the return/volatility of other markers can be obtained through the net spillovers. This analysis considers a second order 9-variable VARs with 10-step-ahead forecasts. Relevant diagnostics are also rendered to validate the robustness of our results.

Data and Preliminary Analyses

This paper covers nine (9) different sectoral stock prices These sectors include, Consumer goods (CGD); Conglomerate (CGL); Construction (CON); Financial Services (FIN); Health (HTH); Industrial (IND); Natural Resources (NTR); Oil and Gas (OGS); Service (SVS). The sample period runs from January 2007 to December 2016. The scope and frequency of our study is based on data availability. Data on the monthly sectoral stock prices are obtained from the Nigerian Stock Exchange (NSE). It is expedient to note that the returns of the series (r_t) are computed as the first difference of the natural logarithm of the level series (P_t); this is expressed in equation (9) below:

$$r_t=\left(\Delta\log\left(p_t\right)\right)\times 100 \tag{9}$$

Where (r_t) represents the calculated returns of any of the sectoral stocks under study. (P_t) represents the price level of the sector stocks. However, the volatility series is obtained from the estimation of GARCH (1,1) model, which is expressed below:

$$\hat{\sigma}_t^2=\hat{\varpi}+\hat{\alpha}v_{t-1}^2+\beta\hat{\sigma}_{t-1}^2 \tag{10}$$

Table 2: Summary statistics for return series of sector stocks

	Mean	Maximum	Minimum	Std. Dev.	No. of Obs.
CGD	-0.3030	15.4165	-15.1095	5.9458	119
CGL	-1.0971	26.4235	-19.7812	8.0417	119
CON	-1.6589	32.0354	-36.3697	9.9046	119
FIN	-2.0048	63.2580	-72.6032	12.0205	119
HTH	-1.4616	24.2418	-33.3213	8.2877	119
IND	-0.9635	14.1952	-26.8755	6.5125	119
NTR	-0.1260	48.9642	-24.4182	7.9651	119
OGS	-0.7674	36.1529	-31.3394	7.3177	119
SVS	-1.8535	32.1586	-30.6675	7.4366	119

Source: Eviews Software Output (Compiled by the authors)

Table 2 highlights the relevant descriptive properties of the series. Over the period, all the sectors observe negative returns in their average values. This is a clear indication that all the sectors appear to be more running on a loss with the financial sector ranking high in the relative loss of stock prices experienced by the sectors. Losses in the remaining sectors hover between 0.126%and 1.659%. However, a large difference is observed between the maximum and minimum values of all the sectoral stock returns. An implication of this is that the sectoral stock markets are subject to high level of fluctuations without certainty of stability over time. This fact is further substantiated by the standard deviation. The large values of the standard deviation depict a large deviation of the data points of each variable from their mean values. A more robust explanation to this is that all the sectors observe significant outliers in their returns.

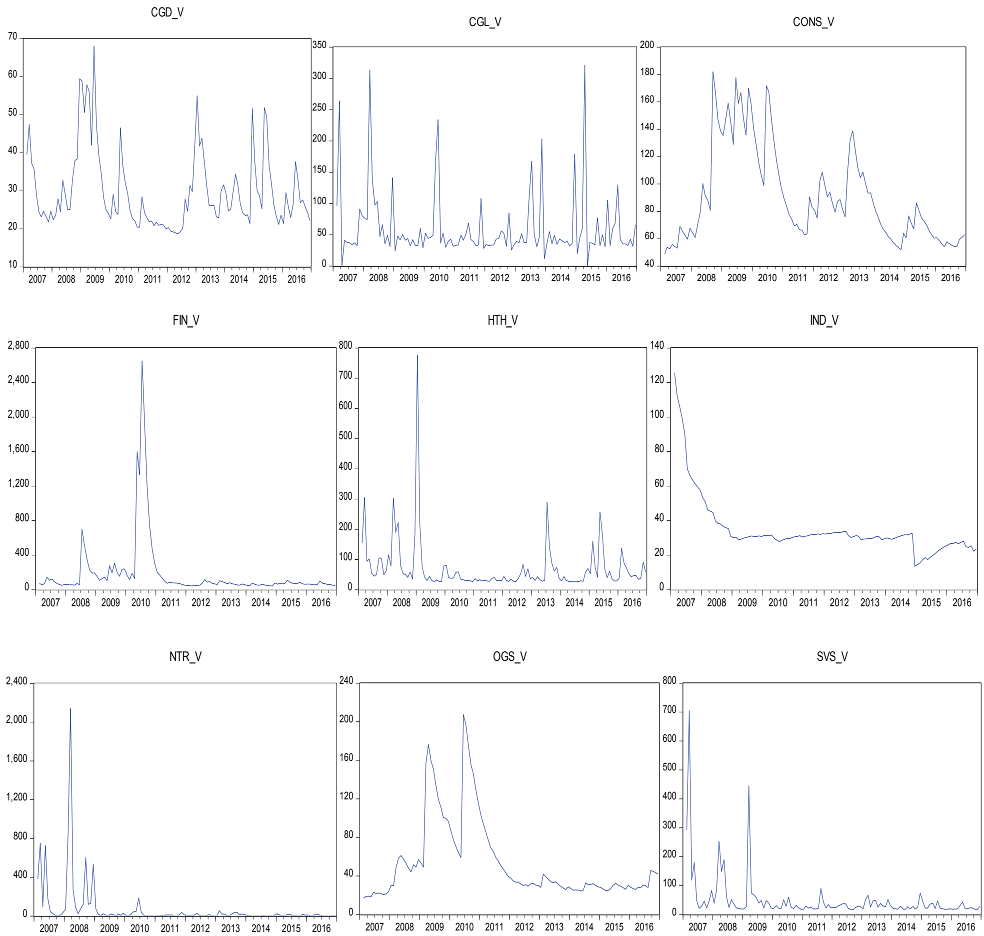
Table 3: Summary statistics for volatility series of sector stocks

	Mean	Maximum	Minimum	Std. Dev.	No. of Obs.
CGD	30.1165	67.9429	18.6728	10.3114	119
CGL	60.2554	320.8137	0.0004	54.2147	119
CON	90.9314	181.9230	48.6694	35.1628	119
FIN	182.9512	2651.974	43.6223	362.1005	119
HTH	71.0254	776.1542	26.0867	87.5590	119
IND	34.9565	125.6464	13.5468	17.9333	119
NTR	72.7789	2140.019	4.0174	239.9179	119
OGS	53.3841	207.3233	16.9867	42.0257	119
SVS	49.6596	704.5618	17.6580	82.2782	119

Source: Eviews Software Output (Compiled by the authors)

Table 3 shows the descriptive statistics for the volatility series of all the sectoral stocks under the whole sample period. The average unpredictability nature of each sector stock is captured by the mean in table 3. Thus, the consumer goods stock is more volatile than others judging by the standard deviation. In addition, all the volatility series are positively skewed and have fat tails.

Figure 1: Volatility graph for sectoral stocks



Drawing from figure 1, all the nine sector stocks are volatile (though some are more volatile than others) with evidence of volatility clustering, i.e., periods of high volatility are followed by periods of relatively low volatility except for industrial stocks which show no sign of being volatile. Also, virtually all the volatile sectoral stocks exhibit notable spikes that coincide with the post-global financial crisis effect expect for the conglomerates stocks volatility (with notable spike around 2008 as a result of global financial crisis and introduction of safe haven for fixed securities) and the construction sector with mixed behaviour.

Analysis of Spillover Results

The DY approach is usually partitioned into two namely the Spillover Tables and the Rolling Window Analyses. The former produces a single-fixed (scalar) value for each of the indices over the period of interest. This may be useful where the interest is to estimate the aggregate spillovers over a particular period of time. However, a deeper and intuitive result can be obtained where unprecedented events characterizing the behaviour of the spillovers are reflected in the analysis. This is the essence of the rolling window analyses. Thus, the latter complements the former as it unveils the cyclical and secular movements explaining the behaviour of the spillovers from one period to another.

Table 4: Return Spillovers of Sectoral Stock Markets

	FROM										
TO	**CGD**	**CGL**	**CON**	**FIN**	**HTH**	**IND**	**NTR**	**OGS**	**SVS**	Contribution from others	Net Spillovers
CGD	**42.1**	3.7	11.3	9.8	6.8	6.6	8.6	2.3	8.7	58	25
CGL	6.3	**33.0**	16.7	7.9	6.0	8.7	1.9	9.6	9.9	67	-21
CON	12.1	8.4	**35.2**	10.7	6.2	10.1	3.4	4.2	9.6	65	33
FIN	15.4	5.2	13.5	**39.2**	4.7	5.6	0.9	2.2	13.3	61	1
HTH	13.1	2.7	11.0	3.6	**42.1**	9.1	10.1	0.3	8.0	58	-12
IND	9.6	4.7	14.7	7.4	8.8	**35.9**	6.4	1.3	11.3	64	-9
NTR	7.4	2.5	4.4	0.8	3.7	6.1	**60.0**	7.0	8.0	40	4
OGS	9.9	10.4	13.0	11.2	2.0	2.4	7.3	**36.3**	7.5	64	-31
SVS	9.0	8.6	12.9	10.4	8.1	6.8	5.2	5.9	**33.0**	67	9
Contribution to others	83	46	98	62	46	55	44	33	76	543	
Contribution including own	125	79	133	101	88	91	104	69	109	Spillover Index **60.4%**	

Source: RATS software output (Compiled by the authors)

Here, the analysis for the spillover tables for both returns and volatilities of sector stocks are done (see Tables 4 and 5 respectively). Table 4 presents the return spillovers computed for the whole sample based on a second order 9-variable VARs with 10-stepahead forecasts. The off-diagonal column sums give the "contribution to others" while the off-diagonal row sums provide the "contribution from others".

Both are directional spillovers where "Directional spillovers to" is represented by "contribution to others" while "Directional spillovers from" is denoted by "contribution from others" in both tables. Thus, each element in each column, other than the main diagonal elements, captures individual market's contribution to the forecast error variance of other markets. In the same vein, each element in each row, excluding the main diagonal elements, measures the amount of contributions of other markets to the forecast error variance of a particular market under consideration. Technically, "contribution to others" measures the total contribution of shocks to a particular market to the forecast error variance of other markets while "contribution from others" measures the total contribution of shocks to other markets to the forecast error variance of a particular market. In essence, the spillover table is analogous to the input-output table as it shows how shocks are absorbed and transmitted within the system under consideration.

Table 5: Volatility Spillovers of Sectoral Stock Markets

	FROM										
TO	**CGD**	**CGL**	**CON**	**FIN**	**HTH**	**IND**	**NTR**	**OGS**	**SVS**	Contribution from others	Net Spillovers
CGD	**42.6**	5.0	10.5	12.1	5.5	6.4	6.0	2.1	9.8	57	17
CGL	5.6	**38.3**	14.1	8.1	5.5	6.5	0.9	10.4	10.4	62	-9
CON	11.7	9.9	**34.3**	10.7	5.7	9.5	2.5	3.9	11.9	66	22
FIN	14.2	6.3	13.2	**39.3**	4.2	6.2	0.7	2.2	13.7	61	7
HTH	11.4	3.5	10.5	4.0	**45.3**	8.2	9.6	0.4	7.3	55	-17
IND	9.3	5.0	13.6	8.6	6.8	**40.7**	5.5	1.1	9.4	59	-8
NTR	4.6	2.1	4.1	1.5	0.9	6.9	**69.8**	7.0	3.2	32	3
OGS	7.3	10.8	10.5	10.9	2.3	2.2	6.6	**42.4**	7.1	58	-24
SVS	10.1	10.0	12.0	11.8	6.7	5.3	2.9	6.4	**34.8**	65	8
Contribution to others	74	53	88	68	38	51	35	34	73	513	
Contribution including own	117	91	123	107	83	92	105	76	107	**Spillover Index 56.9%**	

Source: RATS software output (Compiled by the authors)

The net spillovers are obtained by subtracting the "contribution from others" from "contributions to others" or vice versa. In other words, the net spillovers reflect the difference between the contribution a market gives to and receives from others. Using the former definition, a positive magnitude is an indication that the market under consideration has a greater influence in other markets than the influence it receives from them. This makes the market under consideration less vulnerable to external shocks. Conversely, a negative magnitude implies that the market under examination is more vulnerable to shocks to other markets. Furthermore, the total spillover index is represented in the lower right corner of the spillover table and it is computed by expressing the sum of "contributions to others" (or the sum of "contributions from others") as a percentage of sum of "contributions including own". This renders the various directional spillovers into a single index; therefore, it effectively captures the total spillovers transmitted among the markets under consideration.

Discussion of Results

Proceeding to the analysis of the spillover table for the return series as shown in Table 4, starting with each sector directional spillovers from others, the *construction stocks* records the highest contribution to the forecast error variance of the *consumer goods* returns with about 11.3% followed by the *financial services stocks* with about 9.8%. Thus, shocks to the *construction sector stocks* are more likely to affect the behaviour of the stock return of *consumer goods* than shocks to other sectoral markets in the Nigeria.

Expectedly too, shocks to the *consumer goods stocks* have greater impact on the forecast error variance of the *construction* returns than shocks to other sector stock markets considered. The *consumer goods stocks* explains about 12.1% of the forecast error variance of the *construction stock* returns and similarly followed by the *financial stocks* with 10.7%. Also, although relatively smaller compared to the *consumer goods* and the *Construction* stock markets, the forecast error variance of the *financial services* returns is more influenced by shocks to the *consumer goods* with about 15.4% and closely followed by the *construction stocks* and the *services stocks* with about 13.5% and 13.3% respectively.

In the case of the *conglomerates market* however, the contribution from other markets to its forecast error variance is dominated by the *construction stocks* with 16.7% and distantly followed by the *services* with 9.9% and closely with *oil and gas stocks* with 9.6%. The *natural resource* market however receives the lowest contribution from other markets with the *services sector* having the highest with about 8.0% and followed by the *consumer goods* with about 7.4%. Thus, bidirectional spillovers seem more evident between the *construction* and the *conglomerates markets* as well as between the *consumer goods sector* and the *financial services sector* than any other sectoral stock market pairs. On the whole however, the *conglomerates and services markets* receive the highest contribution from others with about 67% and they are followed closely by the *construction*, *industrial* and *oil and gas sector* returns with contributions of about 65%, and 64% for both industrial and oil and gas sector respectively while the *consumer goods and health services* receive about 58%, the *natural resource* records the lowest contributions from others of 40%. In other words, shocks to other markets account for greater percentage of the forecast error variances of the *construction*, *consumer goods*, *services, financial* and *industrial* markets than their own shocks while the forecast error variances of the *conglomerates, health* and *oil and gas* are substantially explained by their own shocks. Intuitively, the *consumer goods*, *construction*, *services* and *natural resource* are more vulnerable to return shocks of the stock markets than other sectoral stocks in the Nigeria.

In a similar fashion to the gross directional spillovers from others, shocks to the *construction market* have greater impact on other sectoral stock markets than any other stock market. Following the *construction stock* in terms of influence in the stock markets are the *consumer goods*, *services, natural resource and financial services* in that order while the impact of the *oil and gas* seems minimal. In essence, the Nigeria stock markets are also vulnerable to the return shocks of the *construction*, *consumer goods* and *services*. In relation to the net spillovers, positive values are recorded for five sector stocks- the *construction, consumer goods, services, natural resource* and *financial services stocks* although the construction market is the highest (about 33%) down to the financial service sector (about 1%) while other sectoral stocks considered have negative net spillovers. This suggests that the *construction, consumer goods, services, natural resource* and *financial services stocks* give more than they receive in the Nigerian stock market while others *such as* the *conglomerates, health, industrial* and *oil and gas* give less than they receive. This finding further strengthens the significance of the *construction, consumer goods, services, natural resource* and *financial services stock* returns in the Nigerian stock markets.

Looking at the total spillover index, the computed value is 60.4% which is an indication that more than half of the total variance of the forecast errors during the sample is explained by shocks across the sectoral stocks, whereas the remaining 39.6% is explained by idiosyncratic shocks.

Table 5 presents the volatility spillovers over the full sample period. The distribution of the spillovers slightly differs from the return spillovers reported in table 4. Like returns, the directional volatility spillovers from and to other markets are quite robust and above the average for all the sectoral stocks except in the case of *health services*, *natural resource and oil and gas* markets. Therefore, a large amount of return spillovers may not necessarily imply a large amount of volatility spillovers. Nonetheless, on the basis of the reported volatility spillovers, the *construction market* seems to be most vulnerable to volatility shocks of other markets followed by the *services*, *conglomerates*, *financial services, industrial, oil and gas* and *consumer goods* while the *natural resource market* has the least vulnerability and less risky relative to others. The spillover index of about 56.9 percent for the volatility is also smaller than the returns. This suggests that the return volatility for the individual sector stocks is driven by exogenous factors which are not captured in the VAR system used. However, without any comparism with return spillovers, the volatility spillover index quite explain more than half of the total variance of the forecast errors during the sample which is explained by shocks across the sectoral stocks. Notwithstanding, the spillover indexes of 60.4 percent and 56.9 percent for return and volatility spillovers respectively suggest high level of interdependence among the major sectoral stocks in Nigeria.

Rolling-Window Analysis

Even though, from the above the spillover tables, the spillover index and other relevant discussions above have given an overview of the average spillover performance in the Nigerian stock market. It is however inadequate in capturing the important secular and cyclical movements in spillovers (Diebold and Yilmaz, 2012). In view of this, a rolling window framework using 100-month sub-sample rolling windows is proposed in a bid to address these insufficiencies and correctly reveal events or crises episodes that may have occurred during the period considered.

The resultant plots for total spillover indexes for both returns and volatilities are presented in figures 2 and 3 respectively. Both total spillovers start at a value above 65 percent with return spillover slightly higher than volatility spillover in the first window. The total return spillover plot reveals that spillover effects across the major sectoral stocks were quite high fluctuating between 65 percent and 75 percent with an exception in 2013 and mid-2015 where it exceeded the 75 percent mark. However, the total volatility spillover mostly varied between 68 percent and 75percent with an important exception in mid-2015 which was prominently characterized by period where many investors were seeking for a haven in the fixed income securities, while some patronised Ponzi schemes in their desire for higher returns. The 2016 investment year will remain indelible in the minds of investors on the Nigerian Stock Exchange, NSE, just like the 2008 global financial meltdown. This stems from the fact that the nation's stock market in the review period experienced a major setback which eroded investors' confidence with over N1trillion drop in market capitalisation.

Consequently, 2016, according to analysts, turned out to be a year of wailing and lamentations not only in the capital market but in every sector of the economy occasioned by the prevalent economic recession. The nation's Gross Domestic Product (GDP) recorded a negative growth of -2.1 per cent, with the Naira exchanging for N304 per dollar at the official market in the latter part of the year at the Foreign Exchange Market. As it was the case in 2015, investors returned to another locust era with many of them seeking for a haven in the fixed income securities, while some patronized Ponzi schemes in their desire for higher returns. However, most stakeholders attributed the prolonged lull in the equities market and economy in general to tight macroeconomic policies, falling crude oil prices which thwarted stakeholders expectations which led to the exit of foreign investors.

Also, the market capitalisation lost N737 billion or 7.48 per cent to close trading in the same period under review at N9.113 trillion against N9.850 trillion posted on Dec. 31, 2015. However, an analysis of the price movement from January to November showed that Forte Oil emerged the worst performing stock in percentage terms having dropped by 83.72 per cent to close at N52.71 against N330 it opened for the year. Skye Bank followed with a loss of 68.35 per cent to close at 50k against the year opening price of N1.58, while Caverton dipped 61.94 per cent to close at 94k compared with N2.47 it opened for the year. Conversely, Dangote Flour topped the gainers' table between January and November in percentage terms, appreciating by 214.16 per cent to close at N3.55 per share against the year's opening price of N1.13. It was trailed by UBA Capital having appreciated by 87.02 per cent to close at N2.45 against N1.31 and Total grew by 76.11 per cent to close at N258.90 compared with N147.01 it opened for the year.

Other factors that affected market growth in spite of enhanced regulatory framework embarked upon by regulators were hike in inflation, increase in Cash Reserve Requirement by the Central Bank of Nigeria as well as increase in Monetary Policy Rate. The market was also negatively impacted by the instability in the Naira exchange rate against other international currencies, crash in global oil price, Niger Delta unrest, delay in the presentation and passage of the 2016 budget as well as insecurity issues.

Figure 2: Total Spillovers Plot for Return Series

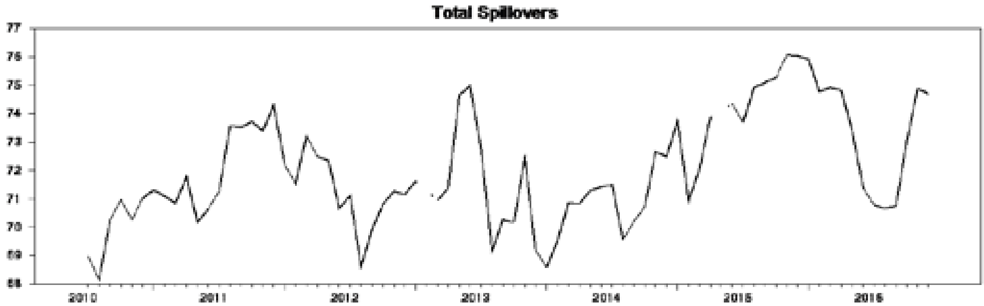
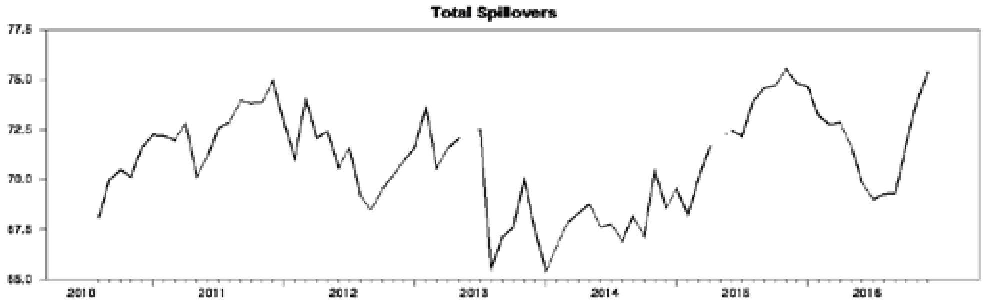


Figure 3: Total Spillovers Plot for Volatility Series



Concluding Remarks

This study measures the degree of interdependence among sector stocks in Nigeria using monthly data from January 2007 to December 2016. We employ the Diebold and Yilmaz (2012) spillover approach and consequently, we compute the Total Spillover, Directional Spillover and Net Spillover indices. In a bid to capture the inherent secular and cyclical movements in the Nigerian stock market, we carry out the rolling sample analysis which complements the spillover results. We find evidence of interdependence among major sector stocks in Nigeria given the spillover indices. Interestingly, return and volatility spillovers exhibit both trends and bursts respectively. In addition, we recognize crisis periods that seem to have motivated the documented fluctuations in returns and volatilities of the Nigerian stock exchange market at sector level.

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