



WORKING PAPER SERIES: WPS/0023

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Cite as:

Salisu A. A and Isah K. O (2017): Modeling the spillovers between stock market and money market in Nigeria - *Centre for Econometric and Allied Research, University of Ibadan Working Papers Series, CWPS 0023*

Modeling the spillovers between stock market and money market in Nigeria

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Abstract

This study examines the spillovers between stock market and money market in Nigeria over the period January 2000 to July 2015. Based on relevant pre-tests, the VARMA-CCC-GARCH is selected and consequently employed to model the spillovers. The study finds significant cross-market return and shock spillovers between the two markets. Thus, a shock to one market is more likely to spill over to the other market. It is also observed that shocks have persistent effects on stock market volatility but transitory effects on money market volatility. In other words, shocks to the money market die out over time while shocks to stock market tend to persist over time. In addition, including lagged own shocks and lagged own conditional variance when forecasting the future volatility of both return series may enhance their forecast performance.

Keywords: Return Spillover, Shock Spillover, Shock Persistence, VARMA-CCC-GARCH

JEL classification: C58, G10

MODELING SPILLOVERS BETWEEN STOCK MARKET AND MONEY MARKET IN NIGERIA

1. Introduction

Portfolio diversification has become a veritable investment strategy for mitigating the unpredictability of markets for investors. It helps to reduce portfolio loss and volatility particularly during periods of increased uncertainty. The Modern Portfolio Theory appears to be the bedrock for diversifying portfolios. It assumes that by combining assets that are not perfectly correlated, the risks embedded in a portfolio are lowered and higher risk-adjusted returns can be achieved. In essence, while one asset class is confronted with high uncertainty over a particular period, the other may not and therefore, a combination of these asset classes, for example, may reduce overall investment risk and prevent damaging a portfolio's performance by the underperforming asset. Thus, an effective combination of these asset classes will necessarily require rigorous analysis of any possible spillovers between the assets.

Perhaps due to its significance, studies dealing with spillover effect in financial markets are quite huge. Interestingly, the analyses appear to have covered the different layers of financial markets (i.e. developed, emerging and under-developed financial markets). Recent studies in the literature include, but not limited to, Hammoudeh et al. (2009), Jaiswal-Dale and Jithendranathan (2009), Koulakiotis et al. (2009), Beirne et al. (2010), Dean et al. (2010), Karmakar (2010), Corradia et al. (2012), Diebold and Yilmaz (2012), Raimony and El-Nader (2012), Abbas et al. (2013), Dua and Tuteja (2013), Gatfaoui (2013), Kanga et al. (2013), Louzis (2013), Wahyudi and Sani (2013), Weber (2013), and Nguyen and Nguyen (2014). Despite the impressive contributions rendered in the

literature on spillover analyses; very limited studies are available on African financial markets. The few notable studies on Africa are Duncan and Kabundi (2013), Giovannetti and Velucchi (2013) and Sugimoto et al. (2014). The only prominent reason often adduced is the fact that most financial markets in Africa are under-developed, less integrated and independent to each other and by implication; they are less vulnerable to external shocks. In the wake of the 21st century however and more noticeably after the global financial crisis, the reversal of this trend gradually began to emerge. Giovannetti and Velucchi (2013) comprehensively document these new trends about African financial markets. For instance, the Economist characterised Africa as the final frontier of globalisation for international investors (29/7/07), suggesting to “Buy Africa” (19/2/2008) to diversify their risk (see also Giovannetti and Velucchi, 2013). Many African markets have been found to offer very large returns to investors and every since 1995, there has been at least one African stock market in the top 10 best-performing markets in the world every year since 1995 (Giovannetti and Velucchi, 2013). In 2004, for example, six African countries (Ghana, Uganda, Kenya, Egypt, Mauritius and Nigeria) were among the world’s 10 best-performing stock markets, while in 2005, Egypt, Uganda and Zambia were in the top five (Giovannetti and Velucchi, 2013).

In addition to the scarce literature on Africa, one thing that is also conspicuously scanty in the literature is country specific analysis. Most of the studies in the literature essentially focus on inter-country financial market spillovers which account for spillovers across countries/international financial markets. Of course, the outcome of such analyses offers useful insights to foreign portfolio investors/managers on how to diversify their asset base in the international financial markets.¹ However, domestic investors within a country would also require information on how to diversify their

¹ In fact, most of these studies on international financial markets centre on stock/equity market spillovers; very limited papers are available on spillovers among different financial markets simultaneously such as equity, bond, currency and money markets. See table 1 for a cursory review of relevant studies.

assets within the domestic financial market. Such information can only be teased out from intra-country financial spillovers; that is, spillovers among financial assets within the same domestic economy. The only few recent studies dealing with intra-country spillovers are Dean et al. (2010) focusing on Australia; Karmakar (2010) on India; Raimony and El-Nader (2012) on Jordan; Diebold and Yilmaz (2012), Weber (2013), and Cronin (2014) focusing on US; Duncan and Kabundi (2013) on South Africa; Kanga et al. (2013) on Korea; and Wahyudi and Sani (2013) on Indonesia.

On the basis of these limitations in the literature, our paper focuses on intra-country spillovers drawing evidence from Nigeria. Some of the attractions to Nigeria are highlighted as follows. Nigeria has one of the largest pools of investment capital in Africa, with approximately five million registered capital market investors (KPMG report, 18/05/2015). In addition, the Nigerian financial markets service the largest economy in sub-Saharan Africa (KPMG report, 18/05/2015) and therefore, the database is more likely to provide very rich information about the dynamic behaviour of investors as well as the managers of the financial institutions.

Specifically, we analyse spillovers between two prominent financial markets in Nigeria namely the money market and stock market. Apparently, most studies on financial spillovers majorly involve the capital market (debt and equity) and currency market while the money market is rarely included in the asset classes studied. The few recent studies including money market in their spillover analyses are Browne and Cronin (2010, 2012), Wahyudi and Sani (2013), Cronin (2014) and Nguyen and Nguyen (2014). Two conflicting positions are rendered by Friedman (1988) regarding the nature of relationship between the money market and the stock market. These two positions are christened as the wealth effect and substitution effect. The wealth effect assumes a positive relationship between stock prices and money – that is, a fall in stock prices

reduces demand for money. However, the substitution effect assumes a negative relationship between the two variables in that a fall in the return in equities will lead to a substitution of stocks for money. Although Friedman's empirical evidence supports the wealth effect; he, however, submits that which factor dominates the other is an empirical issue (see Cronin, 2014).

In addition to the above considerations, we also conduct a survey of prominent studies on spillovers ranging from the choice of financial markets, methodological approaches, data utilized to their empirical findings (see Tables 1A and 1B). This we believe would facilitate the comprehension of the extant literature as well as areas of further research. Our paper is structured as follows: Section 2 presents the literature review; Section 3 describes the data and also provides some preliminary analyses; Section 4 presents the model with the underlying assumptions; Section 5 presents and discusses the results with diagnostics; while Section 6 concludes the paper.

2.0 Literature Review

In the finance literature, studies on volatility spillovers can be classified into two broad strands. The first strand relates to studies dealing with spillovers for a single market irrespective of the number of countries involved (i.e. whether within a country or across countries). We may classify this strand as single-market spillovers. The second strand covers studies that engage different financial markets and this may be named multiple-market spillovers.

Studies involving single-market spillovers are rapidly growing with the extant literature concentrating on volatility transmission in stock markets. The distinctions among these studies however lie in their choice of countries and methodological approaches. Majority of them cover international stock markets involving a

combination of two or more countries drawn from the US, UK, Europe, Gulf Cooperation Council (GCC) countries to Asia while a small number of them engage in individual country analyses. For example, Kim and Rogers (1994) focus on stock markets in Korea, Japan and the US and the symmetric GARCH (1,1) model is employed while Koutmos (1995) focus on the US, Japan and UK stock markets using the asymmetric GARCH (EGARCH) model. Using the same model as the latter, Booth et al. (1997) cover selected Scandinavian stock markets. Notwithstanding the depth of work on stock market spillovers, the stock markets in the US, Europe and Asia have dominated the literature. Although very few, there is also evidence of studies looking at single-market spillovers other than stock market. The few studies are Skintzi and Refenes (2006) using European and US Bond Markets, and Antonakakis and Vergos (2013), Claeys and Vařicek (2014) and Fernández-Rodríguez et al. (2015) using sovereign bond markets in Europe.

Similarly, there is a plethora of studies involving two or more financial markets such as the bond, currency, money, and stock markets regardless of whether the analysis is country specific or across countries. For example, Steeley (2006), Dean et al. (2010), Zhang et al. (2013) and Cenedese and Mallucci (2015) cover two markets namely bond and equity markets. Another prominent combination of two financial assets evident in the literature involves equity and money markets (see for example, Browne and Cronin, 2012; Wahyudi and Sani, 2013; and Cronin, 2014). Also studies like Flemming et al. (1998) and Nguyen and Nguyen (2014) have analysed spillovers among three financial markets relating to bond, equity and money markets while Kal et al. (2015) deal with bond, currency and equity markets. Analyses of four financial markets involving bond, commodity, currency, and equity markets have also been documented in the literature; the only notable study in this regard is Diebold and Yilmaz (2012) while Liow (2015) extends the work of the latter to include real estate. Also, in terms of modelling, the prominent

models used in the literature are the Diebold and Yilmaz (2009, 2012) models and the multivariate GARCH models such as the CCC, DCC, BEKK and the Ling and McAleer (2003) VAR-GARCH and VARMA-GARCH including their asymmetric versions.

As previously noted, studies dealing with spillovers in African financial markets are scarce and with the renewed interest by foreign portfolio managers to invest in Africa owing to the impressive performance of some financial markets after the global financial crisis; it, therefore, becomes imperative to begin to conduct research that will offer useful information to both local and international profit maximizing investors.

3.0 Data Description and Preliminary Analysis

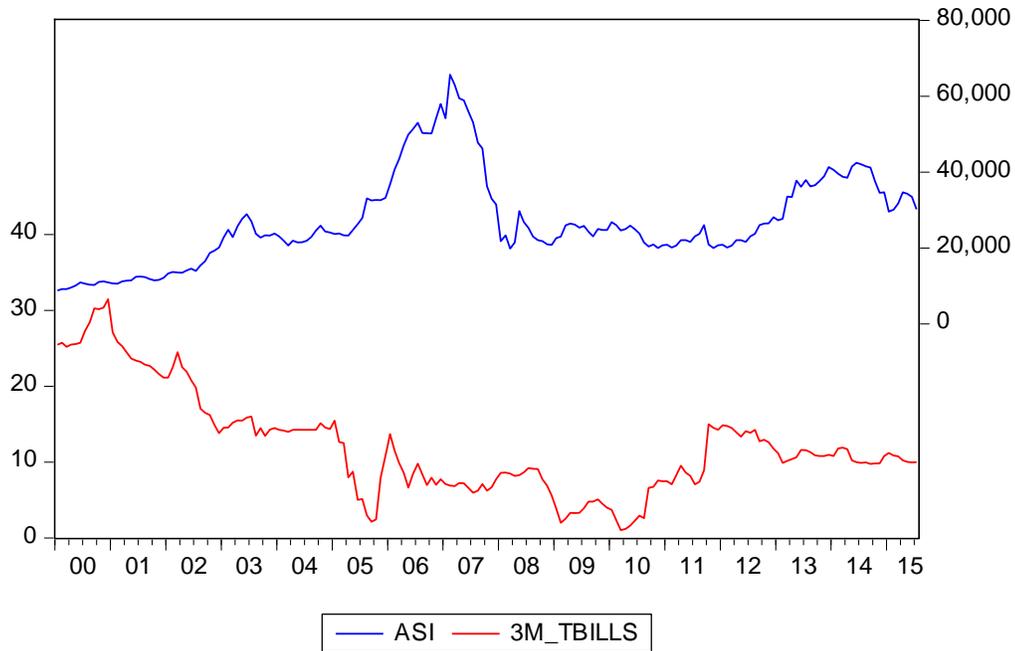
Essentially, this study covers two variables namely the stock market and the money market with the former proxied by All Share Index (ASI) of the Nigerian Stock Exchange while the latter is captured by the government bond yield (i.e. Treasury Bills). The ASI covers all the listed equities on the Exchange, including those listed on the Alternative Securities Market (ASeM), regardless of capitalization. The treasury bills (T-bills) used here is the short term (3-month) T-bills. The long term (6-month) T-bills is not considered due to data paucity; the publication of the data only commenced in 2008. The variables are sourced from the Central Bank of Nigeria's Statistical bulletin over the monthly period of January 2000 to September 2015. The graphical representation of the two series is shown in Figure 1 respectively.

The graph appears to suggest a negative correlation between stock price index and the treasury bills. Nonetheless, our interest however is to evaluate the dynamic spillover effects between the returns of the two series. This is not unconnected with the fact that profit maximizing investors consciously follow trends in returns rather than the level series when making investment decisions. Thus, we use the continuously compounded returns for both markets as computed below:

$$\text{Stock index return (stock)} = \ln(\text{asi}_{t+1}/\text{asi}_t) \quad (1)$$

$$\text{Money market return(money)} = \ln(1+\text{T-bills}) \quad (2)$$

Figure 1: Relationship between Stock Market and Money Market in Nigeria, 2000:M1-2015:M7



The descriptive statistics for the returns covering the mean, median, standard deviation as well as correlation are presented in Table 1. The mean of the summary statistics indicates that average returns in money market exceed that of stock market. The standard deviation on the other hand, reveals that volatility in the stock market exceeds that of the money market. More so, the median money market is extremely larger than the median for the money market returns. However, stock market and money are shown to be weakly correlated.

Furthermore, we explore some potential interdependencies in stock and money market returns conditioned on the signs of the returns in stock market. We find the volatility of money market returns to be higher than that of stock irrespective of the signs of the latter. However, the correlation suggests that both returns are negatively correlated when the stock is positive and positively correlated when the stock is negative.

Table 1: Descriptive Statistics for Stock and Money Market Returns for both Conditional & Unconditional Statistics

	Mean		Standard Deviation		Median		Correlation	N
	Stock	Money	Stock	Money	Stock	Money		
Unconditional	0.663	11.314	7.362	5.941	0.302	10.256	0.080	188
Stock>0	5.518	11.672	4.858	5.788	4.606	10.876	-0.107	100
Stock<0	-4.862	10.777	5.630	6.018	-3.487	9.421	0.173	88

Note: N is the number of observations. Unlike Dean et al (2010) with four possible conditional scenarios, we have two as shown in the table since the money market return is positive although the data period. Nonetheless, we are able to evaluate any possible variation in the relevant statistics given these scenarios.

In addition, we conduct formal tests to evaluate the statistical features of the series in order to justify the consideration of volatility models for the spillover analyses. The results of these tests are shown in table 2. As expected for financial series, the distributions for both return series are skewed and leptokurtic. In other words, the distributions of both money and stock (whether right- or left-tailed) are heavier than normal and therefore, the normal distribution assumption is inappropriate for the analysis of their spillover effects. Also, using the Ljung-Box test for serial correlation, we find evidence for the presence of significant higher order serial dependencies in both series. Similarly, the presence of ARCH effects is also evident in both series based on the Engle (1982) LM tests for ARCH. These results further strengthen our choice of volatility modelling framework for this study.

It has become increasingly important in the literature to account for asymmetry effect when modelling the behaviour of financial series (see for example, Dean et al, 2010 and Salisu and Oloko, 2015). This idea became popular after the seminal paper of Nelson (1991) arguing that positive and negative shocks of the same magnitude may not give identical impacts on the conditional variance. However, rather than modelling the asymmetry directly in the model; Engle and Ng (1993) propose three pre-tests: the sign

bias test, the negative size bias test and the positive size bias test to verify the presence of asymmetry effect. The logic of the tests is to see whether having estimated a particular GARCH model, an asymmetry dummy variable is significant in predicting the squared residuals (Harris and Sollis, 2003). The tests are of the null hypothesis that the null model is correctly specified suggesting that there is no remaining asymmetry (Harris and Sollis, 2003). These sign and size bias tests are individually computed using the following regressions:

$$\text{Sign bias test:} \quad v_t^2 = a + bS_{t-1}^- + e_t \quad (3)$$

$$\text{Negative size bias test:} \quad v_t^2 = a + bS_{t-1}^-u_{t-1} + e_t \quad (4)$$

$$\text{Positive size bias test:} \quad v_t^2 = a + bS_{t-1}^+u_{t-1} + e_t \quad (5)$$

Where u_t is the error term under the null, S_{t-1}^- is a dummy variable that takes the value of one when $u_{t-1} < 0$ and zero otherwise (vice versa for S_{t-1}^+). $v_t^2 = u_t^2/h_t^{1/2}$ where h_t is the conditional variance under the null. The sign bias test is the t -statistic for testing $H_0 : b = 0$ in (3); the negative size bias test is the t -statistic for testing $H_0 : b = 0$ in (4); and the positive size bias test is the t -statistic for testing $H_0 : b = 0$ in (5). These tests can also be carried out jointly using the following regression:

$$v_t^2 = a + b_1S_{t-1}^- + b_2S_{t-1}^-u_{t-1} + b_3S_{t-1}^+u_{t-1} + e_t \quad (6)$$

The LM test of the joint null hypothesis $H_0 : b_1 = b_2 = b_3 = 0$ has a χ_3^2 distribution.² The results obtained from applying these tests are also reported in Table 2. The results indicate that for both return series, there is evidence in favour of the null of symmetry for the individual as well as the joint tests. Therefore, our choice of multivariate volatility models has been narrowed down to the symmetric version. Prominent among these models include, but not limited to, the Conditional Constant Correlations (CCC) model of Bollerslev (1990), Baba, Engle, Kraft and Kroner (BEKK) (1990) multivariate

²Harris and Sollis (2003, pg 236) provide a more detailed expositions on the sign bias tests.

GARCH model which is fully described in Engle and Kroner (1995), the Dynamic Conditional Correlations (DCC) of Engle (2002), and the Vector Autoregressive Moving Average GARCH (VARMA-GARCH) model of Ling and McAleer (2003) and further described in Chang et al. (2013).³ The CCC and the VARMA-GARCH models assume constant conditional correlations; hence, the VARMA-GARCH models are considered a special case of the CCC model.⁴ We further test for the validity of the CCC assumption using the Engle and Sheppard (2001) test with the null hypothesis of constant correlation against the alternative of dynamic conditional correlation. Thus, the rejection of the null may imply adoption of DCC model while the non-rejection favours the CCC and its variants such as the VARMA-GARCH models. The result of the test as reported in table 2 does not seem to reject the null hypothesis of preference for the CCC model [p -value = 0.072].⁵ Therefore, it may be more appropriate to estimate with the CCC variants than the DCC. In addition, unlike the VECM and BEKK, the CCC models do not suffer from the curse of dimensionality (see McAleer, 2005; McAleer et al., 2008; Caporin and McAleer, 2009, 2010; and Chang et al., 2013). Dean et al. (2010) also highlight two main limitations of the BEKK model: (i) It lacks parameter parsimony and (ii) Interpretation of its parameters is complicated by its quadratic form. In the section that follows, we describe our choice of CCC variant for the spillover analysis.

Table 2: Some formal pre-tests for Stock and Money Market Returns

Statistics	Stock	Money
Skewness	-0.485	0.715
Kurtosis	8.116	3.019
Jarque-Bera normality test	210.125 ^a	15.916 ^a

³Also note that these multivariate models have their respective asymmetric versions that account for asymmetry effects. They are not discussed here because of the preliminary results indicating that the sign bias (which captures asymmetry effect) is not significant as to influence the outcome of the spillover analysis.

⁴ A review of all the multivariate volatility models is provided in Silvennoinen and Terasvirta (2008).

⁵Although it marginally rejects at 10%; however, the CCC variants offer more superior empirical attractions (see Caporin and McAleer, 2009, 2010 for a detailed critique of DCC and BEKK).

LB(5) returns	13.004 ^a	781.155 ^a
LB(10) returns	17.931 ^a	1331.703 ^a
LB(5) squared returns	30.718 ^a	799.019 ^a
LB(10) squared returns	34.141 ^a	1357.498 ^a
ARCH-LM(5) test	27.259 ^a	177.009 ^a
ARCH-LM(10) test	30.019 ^a	171.561 ^a
Sign bias test	0.608	1.280
Negative size bias test	0.331	0.562
Positive size bias test	0.928	0.311
Joint bias test	1.086	3.565
Engle-Sheppard CCC χ^2 test	5.268	

Note: ^a denotes Statistical significance at 5% level. The values in parentheses represent the lag orders for the relevant tests. The LB is the Ljung-Box test for autocorrelation while the ARCH-LM test is the Engle (1982) test for ARCH effects.

4.0 The Model

As noted, the CCC variants ranging from the traditional CCC to VARMA-GARCH variants seem more appropriate in relation to the two markets being studied. We however favour the use of the VARMA-GARCH model over the conventional CCC for the following reasons.⁶ First, it allows us to investigate the conditional volatility dynamics of the series as well as the conditional interdependence cross effects and volatility transmission between series (Arouri et al., 2011). Although, the conditional correlations can be estimated in practice, the CCC model does not permit any interdependencies of volatilities across different assets and/or markets, and does not accommodate asymmetric behaviour (Chang et al., 2013). Second, it also provides meaningful estimates of the parameters with less computational complication compared to several other multivariate specifications such as the full factor GARCH model (Hammoudeh et al., 2009; and Arouri et al., 2011a,b). This approach has increasingly gained prominence in the literature. For example, it has been applied by,

⁶ The computational advantages of the VARMA-GARCH model are well documented in Ling and McAleer (2003), McAleer et al. (2010) and Arouri et al. (2011).

among others, Chan et al. (2005), and Hammoudeh et al. (2009) to analyze tourism demand variations and stock markets, Agren (2006), Arouri et al. (2011) and Salisu and Oloko (2015) to oil price and stock markets, and Salisu and Mobolaji (2013) to oil price and exchange rate.

The generalized framework for the VARMA-GARCH model is described in the following specifications (see Chang et al., 2013: pg 121):

The Conditional Mean Equation (VARMA):

$$\Phi(L)(Y_t - \mu) = \Psi(L)\varepsilon_t \quad (7)$$

$$\varepsilon_t = D_t \eta_t \quad (8)$$

The Conditional Variance Equation:

$$H_t = W + \sum_{l=1}^r A_l \varepsilon_{t-l}^2 + \sum_{l=1}^s B_l H_{t-l} \quad (9)$$

where $Y_t = (y_{1t}, \dots, y_{mt})'$ denotes $m \times 1$ vector of return series; $\mu = (\mu_1, \dots, \mu_m)'$ is a vector of constants for the mean equations of the return series; $\Phi(L) = I_m - \Phi_1 L - \dots - \Phi_p L^p$ and $\Psi(L) = I_m - \Phi_1 L - \dots - \Phi_q L^q$ are polynomials in the lag operator (L); $D_t = \text{diag}(h_{i,t}^{1/2})$ for $i = 1, \dots, m$; $\eta_t = (\eta_{1t}, \dots, \eta_{mt})'$ is a sequence of independently and identically distributed random vectors; $H_t = (h_{1t}, \dots, h_{mt})'$, $\varepsilon^2 = (\varepsilon_{1t}^2, \dots, \varepsilon_{mt}^2)'$. Note also that $h_{i,t}^{1/2}$ and $h_{i,t}$ are conditional standard deviation and conditional variance for return i , m is the number of returns, W is a vector of constants for the variance equations of the return series and A_l for $l = 1, \dots, r$ and B_l for $l = 1, \dots, s$ are $m \times m$ matrices and represent the ARCH and GARCH effects, respectively. The conditional variance equation for each return in the portfolio captures the spillover effects between money and stock. As we are concerned

with two return series, a bivariate VARMA (1,1)-GARCH (1,1) model is estimated.⁷ The conditional mean and conditional variance equations for the latter model are given as:

A. The Conditional Mean [VARMA (1,1)]:

$$Y_t = \mu + \Phi_1 Y_{t-1} + \Psi_1 \varepsilon_{t-1} + \varepsilon_t, \quad (10)$$

where $Y_t = (y_{1t}, y_{2t})'$ denotes the return series for stock (with subscript 1) and money (with subscript 2) respectively; $\mu = (\mu_1, \mu_2)'$ is a vector of constants for stock and money respectively; $\Phi = \begin{pmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{pmatrix}$ is a (2×2) matrix of coefficients on the lagged terms of the return series and it captures return spillovers; $\Psi = \begin{pmatrix} \psi_{11} & \psi_{12} \\ \psi_{21} & \psi_{22} \end{pmatrix}$ is a (2×2) matrix of coefficients on the lagged terms of the residuals and $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ is a vector of disturbance terms for mean equations of stock and money. The return spillovers are better appreciated using the individual mean equations below:

$$y_{1t} = \mu_1 + \phi_{11} y_{1t-1} + \phi_{12} y_{2t-1} + \psi_{11} \varepsilon_{1t-1} + \psi_{12} \varepsilon_{2t-1} + \varepsilon_{1t} \quad (11)$$

$$y_{2t} = \mu_2 + \phi_{21} y_{1t-1} + \phi_{22} y_{2t-1} + \psi_{21} \varepsilon_{1t-1} + \psi_{22} \varepsilon_{2t-1} + \varepsilon_{2t} \quad (12)$$

Equations (11) and (12) are the respective mean equations for stock (y_{1t}) and money (y_{2t}) market returns. The return spillover from money to stock is measured by ϕ_{12} (see (11)) while from stock to money is ϕ_{21} (see (12)).

⁷ Of course, the usual way is to consider different lag combinations and then use the SIC or AIC to determine the optimal lag length. However, given that the model gets more complicated as the number of lags increases, a more plausible option is to start small and thereafter test for remaining serial correlation. Thus, higher orders are considered only if necessary.

B. The Conditional Variance Equation [GARCH (1,1)]:

$$H_t = W + A\varepsilon_{t-1}^2 + BH_{t-1} \quad (13)$$

where $H_t = (h_{1t} \ h_{2t})'$, $\varepsilon_t^2 = (\varepsilon_{1t}^2 \ \varepsilon_{2t}^2)'$, and W , A , and B are (2×2) matrices of constants, ARCH effects and GARCH effects respectively. Equation (13) can be further simplified into individual conditional variance equations for the two return series as described below (see Arouri et al., 2011):

$$h_{1t} = c_1 + \alpha_{11}\varepsilon_{1t-1}^2 + \alpha_{12}\varepsilon_{2t-1}^2 + \beta_{11}h_{1t-1} + \beta_{12}h_{2t-1} \quad (13)$$

$$h_{2t} = c_2 + \alpha_{21}\varepsilon_{1t-1}^2 + \alpha_{22}\varepsilon_{2t-1}^2 + \beta_{21}h_{1t-1} + \beta_{22}h_{2t-1} \quad (14)$$

The shock spillover effects seem more evident in equations (13) and (14). For example, the conditional variance of the stock returns (as in (13)) depends not only on its own past conditional variance and shocks, but also on those of the money market returns. The same explanation holds for the conditional variance of the money market returns. More specifically, the shock spillover effects from money to stock are captured by the parameters α_{12} (see (13)) while α_{21} measures the shock spillover effects from stock to money. Thus, the transmission of shocks from one market to another is easily quantified using the VARMA-GARCH model.

In terms of estimation technique, the quasi-maximum likelihood estimator (QMLE) is used to estimate the model parameters. The QMLE involves maximizing the likelihood function given as (see Ling and McAleer, 2003):

$$L_n(\lambda) = \frac{1}{n} \sum_{i=1}^n l_i(\lambda), \quad l_i(\lambda) = \frac{1}{2} \ln |D_i \Gamma D_i| - \frac{1}{2} \varepsilon_i' (D_i \Gamma D_i)^{-1} \varepsilon_i, \quad (15)$$

where $L_n(\lambda)$ takes the form of the Gaussian log-likelihood; λ denotes the vector of parameters to be estimated and $D_t \Gamma D_t' = \varepsilon_t \varepsilon_t' = D_t \eta_t \eta_t' D_t'$. One of the attractions to the QMLE is the fact that η_t is assumed to be non-normal which is a prominent feature of most financial series including those under consideration in this paper. Thus, when η_t does not follow a joint multivariate normal distribution, the appropriate estimator is the QMLE.⁸

C. Computation of Long Run and Short Run Persistence of Shocks to Returns:

Generally (using equation (9)), the short run persistence or ARCH effect of shocks to return i is denoted by $\sum_{l=1}^r \alpha_{il}$ while $\sum_{j=1}^r \alpha_{ij} + \sum_{j=1}^s \beta_{ij}$ represents the long run persistence of shocks to return i (see Chang et al., 2013: pg 120). Note that $\sum_{l=1}^s \beta_{il}$ denotes the GARCH effect. In relation to our specific model and using a simplified representation; the long run persistence to stock market is represented by $\alpha_{11} + \beta_{11}$. In a similar fashion, $\alpha_{22} + \beta_{22}$ denotes the long run persistence of shocks to money. These two sources of shocks persistence are also evaluated in this paper.

D. Diagnostics for VARMA-GARCH Models

Like other multivariate volatility models, the two prominent post-estimation diagnostic tests for the VARMA-GARCH models are the Ljung-Box test for serial correlation and McLeod-Li tests for ARCH effects. Both tests are performed on the standardized residuals which have been previously defined as $\hat{\varepsilon}_{i,t} = \hat{\eta}_{i,t} \hat{H}_t^{-1/2}$. The former test has the null hypothesis of no serial correlation while the latter tests the null of no ARCH effects.

⁸ The asymptotic properties of the VARMA-GARCH models are well detailed in Ling and McAleer (2003).

For the chosen VARMA-GARCH model to be valid, we are not expected to reject the null hypotheses for the two tests. A rejection of the null for the Ljung-Box test may imply inadequacy of the dynamics captured in the mean equation of the model. Thus, one way of resolving this is to increase the lags of the AR and MA terms in the mean equation and thereafter use the model selection criteria such as the Schwartz Bayesian Criterion (SBC) and Akaike Information Criterion (AIC) to determine the optimal lag length. However, a rejection of the null for the McLeod-Li tests is an indication that variance equation of the model is not properly specified. In other words, some ARCH effects are still present even after estimation. To resolve this problem, it may be necessary to consider other plausible types of the multivariate GARCH models such as the DCC and BEKK rather than increasing the ARCH and GARCH terms. In any case, it is rare to increase the ARCH and GARCH terms to fix the variance equation. In this study, we consider both tests to confirm the appropriateness of the estimated model for the analysis of the spillover effect between stock and money.

5.0 Results

The results of the VARMA(1,1)-CCC-GARCH are presented in table 3. We also estimate models with higher orders [VARMA(1,2)-CCC-GARCH, VARMA(2,1)-CCC-GARCH and VARMA(2,2)-CCC-GARCH] and thereafter compare their performance with our model using the standard model selection criteria (i.e. SIC, AIC and Hannan-Quin). The results are presented in table 4. As depicted in the table, the VARMA(1,1)-CCC-GARCH appears to give the best fit among the competing models based on the information criteria. Our interpretation of the VARMA(1,1)-CCC-GARCH results essentially focuses on three issues: return spillovers, shock spillovers and shock persistence (both short run and long run). Before we proceed, let us evaluate the post-estimation diagnostics in order to further check the desirability of the chosen model.

Table 3: VARMA-CCC-GARCH Results

Variables	Stock	Variables	Money
Mean Equation			
μ_1	-0.0374 (0.0000) ^a	μ_2	-0.0098 (0.0000) ^a
ϕ_{11}	0.0530 (0.0000) ^a	ϕ_{22}	0.9860 (0.0000) ^a
ϕ_{12}	0.0927 (0.0000) ^a	ϕ_{21}	-0.0043 (0.0003) ^a
ψ_{11}	0.0243 (0.0005) ^a	ψ_{22}	-0.0207 (0.0000) ^a
ψ_{12}	0.0541 (0.0005) ^a	ψ_{21}	0.2772 (0.0000) ^a
Variance Equation			
c_1	9.3295 (0.0020) ^a	c_2	0.5296 (0.0000) ^a
α_{11}	0.2331 (0.0000) ^a	α_{22}	0.2082 (0.0000) ^a
α_{12}	0.0135 (0.0049) ^a	α_{21}	0.0302 (0.0005) ^a
β_{11}	0.6101 (0.0000) ^a	β_{22}	0.2771 (0.0000) ^a
β_{12}	0.0632 (0.0014) ^a	β_{21}	-0.0227 (0.0005) ^a
Long run shock Persistence	0.8432	Long run shock Persistence	0.4853
CCC between stock & money	-0.1092 (0.0000) ^a		

Note: ^a denotes Statistical significance at 5% level.

Table 4: Model Selection Criteria

Information Criteria	VARMA(1,1)-CCC-GARCH	VARMA(1,2)-CCC-GARCH	VARMA(2,1)-CCC-GARCH	VARMA(2,2)-CCC-GARCH
AIC	9.718	9.798	9.813	10.045
SBC	10.082	10.233	10.248	10.550
Hannan-Quin	9.866	9.975	9.989	10.250

Table 5: Diagnostics (Post-Estimation)

Statistics	Stock	Money
LB (5)	6.2489	14.5015 ^a
LB (10)	9.2184	22.4869 ^a
McLeod-Li (5)	7.4221	0.9056
McLeod-Li (10)	8.3547	12.5095

Multivariate ARCH-LM (9)	8.750
Multivariate LB (4)	9.0299

Note: ^a denotes Statistical significance at 5% level.

5.1 Diagnostics

The results of the diagnostic tests are presented in table 5. We observe from the diagnostics that there are no remaining ARCH effects after the estimation judging by the McLeod-Li tests both at 5 and 10 lags. In this case of Ljung-Box tests, there is no evidence of serial correlation at different lags for stock while the null of serial independence is rejected for the money market returns. However, the Multivariate (joint) Ljung-Box indicates evidence of serial independence in the estimated multivariate model. Overall, the results seem plausible and therefore form the basis for the estimation of spillover effects between the stock and money market returns.

5.2 Return Spillovers

The parameters of interest here are ϕ_{12} and ϕ_{21} . As noted earlier, the former measures return spillover from money to stock while the latter captures return spillover from stock to money. Nonetheless, we include own lagged returns in the conditional mean equations to ensure that spillover effects are not confounded with serial dependence (see Dean et al., 2010). As observed in table 4, ϕ_{12} is estimated as 0.0927 and it is statistically significant and positively signed. This indicates that a 1% increase in money market returns will increase stock returns the following month by approximately 0.09% on average, *ceteris paribus*. Expectedly, at some level, it may make sense to assume that an increase in the rate of growth of money supply occasioned by an increase in the demand for money may strengthen the rate of increase in stock prices. In other words, the rate of change in stock prices is expected to increase if it is preceded by an increase in the rate of change of money supply. Conversely however, we find ϕ_{21} to be negative

and statistically significant. The coefficient is given as 0.0043 implying that the money market returns will reduce by 0.0043% the following month should the stock returns increase by 1%. This finding supports the substitution effect where an increase in stock returns creates an incentive for increased investments in stocks as a substitute for money. Intuitively, the spillover effect from money to stock is stronger than from stock to money in absolute value. Digging further, we find that returns to both markets are significantly affected by their past realizations and therefore accounting for them when forecasting the returns may enhance their forecast performance.

5.3 Shock Spillovers and Persistence of Shocks

In the case of shock spillovers and persistence of shocks, the parameters of interest are the ARCH (α_{ij}) and GARCH (β_{ij}) terms [$i, j = 1, 2$] and all of them are statistically significant. Specifically, lagged own shocks (α_{ii}) and lagged own conditional variance (β_{ii}) [$\forall i = 1, 2$] significantly and positively influence the volatilities of the two markets. In essence, the volatilities of stock returns and money market returns are sensitive to both past own shocks as well as past own conditional variance. In clear terms, volatilities in these two markets may be accentuated by their own shocks. These findings have far reaching implications. First, unanticipated events in the stock market in the current period, for example, are capable of fuelling a high volatility in the market in the immediate succeeding period. Secondly, volatility of the market in one period has the potentiality of driving a higher volatility in the immediate later period. Thirdly, technically speaking, the past own innovation and past own conditional variance of the two returns can be employed to forecast their future volatility.

Similarly, we find evidence for significant shock spillovers between the two markets. Considering the shock spillovers and looking at the stock market returns, the result shows that a 1% increase in the shocks to money market returns in the current month will increase the volatility of stock market returns by 0.01% in the following month. However, the shock spillover from stock returns to money market returns seems higher (although marginally) as a 1% increase in the shock to stock returns in the current period is likely to increase the volatility of money market returns by 0.03% in the following month. Nonetheless, the cross-market shock spillovers are both positive and statistically significant. In other words, there is possibility of contagion effect between the two markets.

In terms of persistence of shocks, we find that stock returns appear to experience higher long run shock persistence than the money market returns. The magnitude of the long run persistence of shocks to stock returns is very close to 1 (0.8432) implying that shocks have persistent effects on stock returns in different ways. In other words, volatility in the stock market exhibits weak mean reversion. However, the long run persistence of shocks to money market returns is fairly small (0.4853); therefore, the shocks are likely to die out overtime and thus are not permanent.

In the case of short run persistence of shocks, the magnitudes for both stock and money market returns (0.2466 and 0.2384 respectively) are quite small. Thus, a more distinct shock which is anticipated in the short run does not have persistent effects on the returns of the two markets in the short run. Lastly, the constant conditional correlation coefficient is constant and statistically significant; thus, validating the assumption of constant correlations between the two markets.

In sum, the following features are discernible from the analyses:

- (1) Overall, the Nigerian stock market is more sensitive to shocks than its money market judging by both the long run and short run persistence of shocks. This further reinforces the descriptive statistics (standard deviation to be precise) showing that stock market is more volatile than money market. This is understandable given the increasing magnitude of foreign investment portfolio investments in the Nigerian stock exchange.
- (2) Also, there is a significant contagion effect between the stock market and money market in Nigeria. In other words, a shock to one market (say stock market) is more likely to spill over to the other market (i.e. money market); thus, fuelling a higher volatility in the latter market.
- (3) We also find evidence of both wealth and substitution effects in the Nigerian financial markets. However, further analyses of the transmission mechanism for these effects by future research would uncover the supposed complex interactions between the stock and money markets.

6.0 Conclusion

The goal of this paper was to examine the extent of return and shock spillovers between stock market and money market using monthly data for the period January 2000 to July 2015. To model the spillovers, we used the VARMA-CCC-GARCH model after careful considerations of relevant tests and model selection criteria. Our main findings are as follows.

First, stock market is more volatile than money market in Nigeria. Second, shocks to stock returns tend to persist when they occur while shocks to money market returns tend to die out over time. There are two implications of these findings: (i) these findings imply that the behaviour of stock market returns tends to change over time while that of the money market appears fairly stable; and (ii) it then follows that

investors need to consider this nature of stock market behaviour when making investment decisions.

Thirdly, we find significant cross-market return and shock spillovers between the two markets although the stock market volatility seems more sensitive to money market volatility than it is from the former to the latter. In addition, the stock market is more susceptible to external shocks than the money market. Finally, it may be necessary to include the past realizations of both returns and volatilities when forecasting their future values in order to enhance forecast performance.

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