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A STUDY ON THE VOLATILITY SPILLOVER BETWEEN NIGERIAN AND BRICS ECONOMIES USING MULTIVARIATE GARCH MODELS

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ABSTRACT

BRIC-African relation has been of interest to key stakeholders especially given the inclusion of South Africa. In the existing literature some researchers hypothesized inclusion of Nigeria will accelerate BRICS objective of enhancing market access to ensure rapid economic growth among other objectives. This study utilized daily exchange rates of Naira/Dollar together with BRICS Dollar exchange rate for a period of 18 years. The study aimed to determine the volatility spillover between Nigerian and BRICS nations via Multivariate GARCH family: VECH, DBEKK and CCC Models. The result of VECH and DBEKK Models showed that all parameters were significant at 5% level, indicating clearly that there is positive impact of Exchange Rate shocks of Nigeria on the Exchange Rate Volatility of the BRICS economies, while for the CCC model only one parameter was significant at 5% level. This clearly indicated the existence of positive impacts of Exchange rates shocks of Nigeria on the Exchange Rate Volatility of the BRICS economies. On the other hand, only VECH model was able to capture the volatility spillover (own and cross) both on negative direction, suggesting a causal relationship between past volatility shocks in Nigeria and current volatility in the BRICS economies. Conclusively based on the information above VECH model was found to be appropriate to capture the volatility spillover between Nigerian exchange rate and that of the BRICS nations.

Keywords: Multivariate GARCH Models, Volatility Spillover, Volatility clustering, BRICS, Bilateral Relations

INTRODUCTION

The acronym BRICS is referring to the top emerging economies (EE) of Brazil, Russia, India, China and South Africa were initially introduced by O'Neill and Gold- man (2001) after which South Africa was formally incorporated in 2011. BRICS are famously the upcoming piloting powers for world supply and demand of goods. BRICS nations have appeared to be a symbol of progress in global economic power with distinction to the G7 (UK, US, France, Germany, Canada, Italy and Japan) nations relative to the developing countries. Assessments by O'Neill and Goldman (2001) reveal that the BRICS economies will have out-shined the G7economies in the next 30 years, noting that India and China are likely to be the first and third biggest economies, with Brazil, Russia and South Africa just behind. BRICS economy growth and demographic are projected to introduce an economic base whose consumption would provide economic development. The BRICS nation's together account for 30% world capital development, 40% of global population and 25% of the world's land mass, their collaborated GDP is predicted at $27.6 trillion in 2023 representing 26.3% of the global total (Marcus, 2023). BRICS nations' consumption is growing faster than the first economic nations (G3: United States, Japan, EU) as final demand has been impacted by the current crisis of the economy (Yamakawa *et al.*, 2009). The BRICS are also becoming dominant in international trade. In 2011, exports were growing at 38% (Brazil), 28% (India), 25% (China) and 18% (Russia) (Vardi, 2011). In 2012, $3.2 trillion was reported to be their estimated combined total exports. The BRICS nations contributed up to 60% of the trade between low-income countries. However, the 2023 summit was centered on the expansion of membership, with six new members proposed to join in 2024. Thus, BRICS nations have attracted investors who are seeking for opportunities to diversify their economies (Sule, 2011). BRICS as a club aims to strengthen bilateral and multilateral relations among member states. Moreover, it has adopted the strategy of contributing to the increase in economic competitiveness and the growth of the economies of the BRICS nations on the global stage. It is believed that the BRICS nations will have the potential to reshape the global economy soon since their recognition as a center of global growth has an impact on global political and economic affairs. As a result, the club's emergence is projected to limit or lessen the Western countries' dominance in global affairs. Additionally, the combined GDP of BRICS countries is projected to exceed 128 USD trillion in 2050 as compared to a projected 66 USD trillion for the G7 countries (Hammoudeh et al., 2013).

In Africa, Nigeria is among the most important partners of the BRICS nations. Nigeria is an upcoming market, mixed economy and middle-income, whose financial, technology, communications, services and entertainment sectors are expanding. It ranks 25th globally in aspect of GDP in 2020 and sits at the top of African economy (International Monetary Fund, 2021). Its manufacturing sector is the third largest in Africa responsible for a high proportion of goods and services in Africa. Due to mismanagement in the past years, the economic policies of the past ten years have placed the country on a path to achieve its maximum economic potentials. In 2022, Nigeria's GDP on a Purchasing Power Parity (PPP) basis was $1,044.21 billion. Nigeria's GDP based on PPP increased from $285.64 billion in 2001 to $1,044.21 billion in 2020 averaging growth rate of 7.8% per annum (Folarin *et al.*, 2016). Nigeria is expected to be the fastest growing economy in Africa with an average growth rate of 4.2% annually. The Nigerian economy, as every other, has been affected by constant fluctuation in exchange rates (ER), unstable macroeconomic variables and weak capital development in general.

Musyoki *et al.,* (2012) reported that ERV is an integral factor in determining capital development. This result from the fact that a high level of ERV causes uncertainty that can hinder the easy operation of trade and related commercial engagements. Additionally, uncertainties caused by fluctuating ER can reduce international trade; low investment and uneven competition that could benefit foreign companies in the aspect of product pricing. Despite its impact on capital development and the usefulness of earlier research on the subject, the weight of ERV and its visible impacts on capital development is still open to studies, especially in growing nations such as Nigeria. ERV in commercial engagements can happen at any stage hence, there should be regular monitoring, due to the wide-ranging impacts on commercial engagements, which are of interest to researchers, government and other economic agencies. The ER is one of the most fundamental macroeconomic factors affecting the financial state of any nation (Benjamin, 2019). It is the conversion rate of one currency into the other, and evaluates the global competition. International financial research on ERV has been intensified following the adoption of the flexible ER system. Since then, ERV has been increasing, and it has been difficult to predict empirically the future ER values. Volatility is yet again an important aspect especially in the fields of finance and economics, as it is used in decision-making, financial risk management and portfolio selection among others (Tsay, 2010).

Exchange rate volatility can occur in economic activities any time and this requires constant investigation, given the widespread effects on economic activities, which is of concern to the Nigerian government, investors, researchers and other agents of the economy. From the literature reviewed so far, it was noted that most authors have focused their studies on the BRICS economy on one or two developed/EE, and there is little or no literature examining ERV in the BRICS economy with the Nigerian economy. A study of the Nigerian economy with BRICS as in Hashiru and Tufekci (2018) suggested that the inclusion of Nigeria or the replacement of South Africa with Nigeria would accelerate the BRICS objective of enhancing market access among other objectives to ensure rapid growth as well as competition with the G7. He argues that both Nigeria and South Africa can facilitate progress towards the goal and objectives of the club if they come together. This study will adopt the MGARCH Models to examine the Volatility Spillover between Nigerian and BRICS economies which will enable us to empirically fail to reject or reject the claim of Hashiru and Tufekci 2018.

Nigeria and BRICS Economies Bilateral Relation

Nigeria is an important African country, with an estimated population of over 217,862 million in 2022, it is by far the most populous country on the continent with an area of 923,765 km^2 (Sasu, 2022). However, what gives Nigeria the most appreciation is its vast riches in natural resources, especially in oil and natural gas. It is among the 10 largest oil producers in the world and the largest oil producer in Africa. It has the largest reserves of natural gas in the continent and was the world's fifth largest exporter of liquefied natural gas (LNG) in 2018. In fact, oil provides more than 95% of Nigeria's profits (Ademuyiwa et al., 2014).

Nigeria and Brazil Bilateral Relation

Bilateral relations between Nigeria and Brazil began with the initiation of diplomatic relations in 1960. During this time, the relationship between the two nations was primarily aimed at promoting culture and history as opposing to commerce. Their association remained without progress until the introduction of Professional African Foreign Trade Policy 2003-2010 by Luiz de Silva the Brazilian President. This improved further trade union between the pair of nations. Bilateral trade between Brazil and Nigeria recorded an overall peak in 2013, hitting $10.52 billion in commercial value. Brazil's export to Nigeria includes aircraft, automobiles, equipment and chemicals among others. On the other hand, Brazil imports crude oil from Nigeria (Garrick, 2013). A Bilateral Commission was created in effort to promote relationship between the two nations in 2013 (Mthuli *et al.,* 2011).

Nigeria and Russian Bilateral Relation

Relations between Nigeria and Russia started in 1961 with the establishment of Russian embassy in Nigeria. The latter replied the gesture by establishing its embassy in Russia, a year later, this marked an era of mutual association between the two nations. Since then, both countries have always maintained friendly political, economic and humanitarian relations (Abimbola, 2016). Nigeria went on to become the second biggest commercial ally of Russia in sub-Saharan Africa, trailing South Africa (Alao, 2011). It is a fact that Russia landed the first man in space, Yuri Gagarin in 1962 and in 2007 the Nigerian Sat-1 was launched from a Russian space platform and that marked the beginning of the Nigerian presence in space, a cause for learning. To tackle insecurity, Russia has provided tremendous assistance in Nigeria's battle against insurgents.

Nigeria and India Bilateral Relation

Nigeria and India have enjoyed warm, friendly and deeply rooted bilateral relations before 1960. India is Nigeria's biggest commercial ally with bilateral patronage peaking US$13.89 billion in two years as of 2019 (Opusunji *et al.,* 2020). Total joint trade of the two nations between 2019-2020 stood at $13.82 billion, compared to US $13.89 billion realized in year 2018-19. Indian exports to Nigeria during 2019-2020 amounted to $3.61 billion, compared to $3.0 billion (20% increase) in 2018-2019. India's imports during 1919-2020 recorded $10.21 billion, compared to $10.88 billion in 2018-19. Of the total imports of $10.88 billion, crude oil accounts for $9.43 billion. Nigeria exports most of its crude oil to India.

Nigeria and China Bilateral Relation

Nigeria serves as a market for a variety of Chinese goods and is China's largest trading partner in African. In 1971, the two nations formally established diplomatic ties. They further agreed to collaborate on technology and scientific projects. Aiming to take the lead and quickly surpass the 20 greatest economies in the world, Nigeria and China were two enormous economic nations. In terms of population, being the most populous country in Africa (Nigeria), and the most populous in the world (China), both countries stand a better chance of profiting from trade with each other. Scientific cooperation between the two countries is also flourishing. Relationship in this field saw the launch of NIGER-COMSTAT 1, Nigeria's first communications satellite in early 2007. Being the most populous nations in their respective continents, both nations have a greater opportunity of making money from their mutual trade. The Federal Government's initiatives to strengthen, diversify, and increase Nigeria's export base by ensuring that non-oil exports account for a sizable portion of the GDP should be encouraged or supported in accordance with the bilateral agreements already in place between the two nations that will ensure sustainable trade balance and economic growth (Aja,

2012).

Nigeria and South Africa Bilateral Relation

Since the inception of democratic rule in Nigeria in 1960, Positive bilateral economic links have existed between South Africa and Nigeria. South Africa has emerged among the top investors in many sectors of the Nigerian economy. South African investments presence in the Nigerian economy are in areas such as telecommunication, engineering, banking, retail, hospitality, property development, construction and tourism, to mention a few. In terms of technology and infrastructure, South Africa has a better advantage over Nigeria while Nigeria has an edge of large market potentials for investments over South Africa. This is why there are a lot of South African companies with huge investments in Nigeria. (Joseph, 2013)

The existence of economic bilateral relations between countries and the effect of globalization, really opened a door to conducting empirical studies to assess and examine the own and cross volatility spillover between two or more economies. For instance, a research by Joshi (2014) examined the volatility spillover among BRIC markets using a four variable symmetric GARCH-BEKK model. The results revealed evidence of bi-directional shock spillover among Brazil and Russia, Brazil and China, Russia and India and bidirectional volatility spillover among stock markets of Brazil and Russia, between Brazil and India, and among Brazil and China. The magnitude of volatility linkages is low indicating weak integration of BRIC stock markets. The study also revealed that own volatility spillover is higher than cross-market spillover. The overall persistence of stock market volatility is highest for China and lowest for Russia.

Bala and Takimoto (2017) investigated stock returns volatility spillovers in emerging markets (EMs) and developed markets (DMs) using multivariate GARCH models and their variants. Their findings revealed that correlations among emerging markets are lower compared with correlations among developed markets. Furthermore, they detected evidence of volatility spillovers and observed that own-volatility spillovers are higher than cross-volatility spillovers for emerging markets suggesting that shocks have not been substantially transmitted among EMs compared to DMs. Trivedi *et al.*, (2021) examined volatility spillovers, cross-market correlation and co-movements between selected developed (Spain, UK, Germany and France) and emerging stock markets (Poland, Hungary, Croatia and Romania) in the European Union. They used family of GARCH models to explore volatility movement, presence of leverage effect/asymmetry in selected financial markets, from January 2000 to July 2018. Results revealed significance presence of volatility clustering in all selected financial markets except in Poland and Croatia, the results 5also indicates that both recent and past news generate a considerable impact on present volatility.

Das and Debnath (2022) assessed the impact of COVID-19 on stock market volatility spillover in India using equity (NSE exchange) and bond (Foreign Exchange) indices. They utilized the TGARCH model (1,1) to evaluate the volatility of the NSE stock exchange and sectoral indices, they compared stock price returns in pre and post COVID-19 scenarios to global indices, such as NASDAQ, Nikkei 225, and FTSE100. It also utilised stock exchange and bond indices to explore the volatility spillover influence using Vector autoregressive-Baba, Engle, Kraft, and Kroner with multivariate GARCH (VAR-BEKKGARCH model). The findings revealed a negative and statistically significant correlation that suggests that the COVID-19 outbreak lowered stock market volatility in India. In terms of historical errors, the coefficients represent the persistence of volatility for each nation. NIFTY and NASDAQ have the largest and longest-term spillover effect.

Mohammed *et al.*, (2023) investigated stock return and volatility spillovers between Nigeria and five global markets (China, Hong Kong, Japan, UK, and the US) from January 2000 to August 2021. The study adopts the Diebold-Yilmaz interconnectedness index and concludes that most of the returns generated in Nigeria are due to domestic shocks, implying that the country is less integrated. Also, larger proportions of risks in Nigeria are attributable to global shocks suggesting that the Nigerian stock market is vulnerable to international shocks. The study also showed that the global financial crisis (GFC) is associated with higher and intensified return and volatility spillovers among global markets. The study recommends that investors should consider assets in the Nigerian stock market in their portfolios to benefit from diversification. The study also advocates for policies to stabilize the domestic economy and build buffers to make the market resilient to global uncertainties

MATERIALS AND METHODS

The study employed the Nigerian Naira daily ER along with the BRICS currencies, and the data used the US dollar as the main currency for all the nations under consideration (Brazil Real, Russian Ruble, Indian Rupee, Chinese Yuan and South African Rand) The data covers the period 18 years from January 2002 to December 2020 which consists of 4958 observations obtained from the Federal Reserve Bank of Saint Louis, U.S.A. and the Central Bank of Nigeria (CBN). The return on exchange rate is defined as:

$$r_t = log\left(\frac{e_t}{e_{t-1}}\right) \quad (1)$$

where e_t is the exchange rate at time t and e_{t-1} represent exchange rate at time t-1. Equation (1) will be used in observing the volatility of the exchange rate between the selected currencies over the period under study.

Multivariate GARCH (MGARCH) Models

Generally, the MGARCH models are regarded as direct extension of the popular GARCH (p,q) model. Detailed discussion of the GARCH (p,q) can be found in Musa *et. al.*, (2014). However, this research utilizes three Multivariate GARCH models. These are VECH, DBEKK and CCC.

VECH Model

Vectorized Heteroskedastic (VECH) Model, in the VECH model, every conditional variance and covariance is a function of all lagged conditional variances and covariances, as well as lagged squared returns and cross products of returns. Applying the VECH operator to a symmetric matrix stacks the lower triangular elements into a column, Bunnag (2015)

Consider the following specification:

$vech(H_t) = vech(\boldsymbol{\Omega}) + \sum_{i=1}^{q} A_i vech(\varepsilon_{t-i}\varepsilon'_{t-1}) + \sum_{i=1}^{p} B_i\, vech(H_{t-i})$ (2)

Where $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, ..., \varepsilon_{Nt})'$ are the error terms associated with the conditional mean equations for y_{1t} to y_{Nt}, Ω is an *N* x *N* positive definite matrix and A_i and B_i are [N(N+1)/2 x N(N+1)/2] matrices, p and q are non-negative integers. In the case six variables and *p* = *q* = 1, equation (2) can be written as.

$$\begin{pmatrix} h_{11,t} \\ h_{21,t} \\ h_{31,t} \\ \vdots \\ h_{66,t} \end{pmatrix} = \begin{pmatrix} a_{11}^0 \\ a_{21}^0 \\ a_{31}^0 \\ \vdots \\ a_{66}^0 \end{pmatrix} + \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{121} \\ a_{21} & a_{22} & \cdots & a_{221} \\ a_{31} & a_{32} & \cdots & a_{321} \\ \vdots & \vdots & \vdots & \vdots \\ a_{211} & a_{212} & \cdots & a_{2121} \end{pmatrix} \begin{pmatrix} \varepsilon_{1,t-1}\varepsilon_{1,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} \\ \varepsilon_{3,t-1}\varepsilon_{1,t-1} \\ \vdots \\ \varepsilon_{6,t-1}\varepsilon_{6,t-1} \end{pmatrix} + \begin{pmatrix} b_{11} & b_{12} & \cdots & b_{121} \\ b_{21} & b_{22} & \cdots & b_{221} \\ a_{31} & a_{32} & \cdots & a_{321} \\ \vdots & \vdots & \vdots & \vdots \\ b_{211} & b_{212} & \cdots & b_{2121} \end{pmatrix} \begin{pmatrix} h_{11,t-1} \\ h_{21,t-1} \\ h_{31,t-1} \\ \vdots \\ h_{66,t-1} \end{pmatrix} \quad (3)$$

$$h_{11,t} = a_{11}^o + a_{11}\varepsilon_{1,t-1}^2 + a_{12}\varepsilon_{2,t-1}\varepsilon_{1,t-1} ... + a_{121}\varepsilon_{6,t-1}^2 + b_{11}h_{11,t-1} + b_{12}h_{21,t-1} + ... + \mathrm{b}_{121}\, h_{66,t-1} \quad (4)$$

$$h_{21,t} = a_{21}^o + a_{21}\varepsilon_{1,t-1}^2 + a_{22}\varepsilon_{2,t-1}\varepsilon_{1,t-1} ... + a_{221}\varepsilon_{6,t-1}^2 + b_{21}h_{11,t-1} + b_{22}h_{21,t-1} + ... + \mathrm{b}_{221}\, h_{66,t-1} \quad (5)$$

. . .
. . .
. . .

$$h_{66,t} = a_{66}^o + a_{211}\varepsilon_{1,t-1}^2 + a_{212}\varepsilon_{2,t-1}\varepsilon_{1,t-1} ... + a_{2121}\varepsilon_{6,t-1}^2 + b_{211}h_{11,t-1} + b_{212}h_{21,t-1} + ... + \mathrm{b}_{2121}\, h_{66,t-1} \quad (6)$$

where each element of H_t depends only on its own past value and the corresponding product term in $\varepsilon_{t-1}\varepsilon'_{t-1}$. That is each element of the VECH model follows a GARCH (1,1) type model. Where $h_{11.t}$ is the conditional variance of the error relative y_{1t}, $h_{22.t}$ to is the conditional variance of the error relative to y_{2t} and $h_{12.t}$ is the conditional covariance between the errors relative to $y_{12.t}$.

BEKK Model

BEKK was proposed by Engle and Kroner (1995). The BEKK model is given below.

$$H_t = \Omega\Omega' + \sum_{k=1}^{K}\sum_{i=1}^{q} A_{ki}\varepsilon_{t-1}\varepsilon'_{t-1}A'_{ki} + \sum_{k=1}^{K}\sum_{i=1}^{q} B_{ki}H_{t-1}B'_{ki} \quad (7)$$

where Ω is a upper triangular matrix, A_{ki} and B_{ki} are *N* x *N* parameter matrices. Based on the symmetric parameterization of the model, H_t is almost surely positive definite provided that ΩΩ is positive definite (Tsay, 2005). In the case of six variables, the BEKK representation model can be written in full as;

$$\begin{pmatrix} b_{11} & \cdots & b_{16} \\ b_{21} & \cdots & b_{26} \\ b_{31} & \cdots & b_{36} \\ b_{41} & \cdots & b_{46} \\ b_{51} & \cdots & b_{56} \\ b_{61} & \cdots & b_{66} \end{pmatrix} \begin{pmatrix} b_{11} & \cdots & \omega_{61} \\ b_{12} & \cdots & \omega_{62} \\ \omega_{13} & \cdots & \omega_{63} \\ \omega_{14} & \cdots & \omega_{64} \\ \omega_{15} & \cdots & \omega_{65} \\ \omega_{16} & \cdots & \omega_{66} \end{pmatrix} + \begin{pmatrix} a_{11} & \cdots & a_{16} \\ a_{21} & \cdots & a_{26} \\ a_{31} & \cdots & a_{36} \\ a_{41} & \cdots & a_{46} \\ a_{51} & \cdots & a_{56} \\ a_{61} & \cdots & a_{66} \end{pmatrix} \begin{pmatrix} \varepsilon_{1,t-1}^2 & \cdots & \varepsilon_{1,t-1}\varepsilon_{6,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \cdots & \varepsilon_{2,t-1}\varepsilon_{6,t-1} \\ \varepsilon_{3,t-1}\varepsilon_{1,t-1} & \cdots & \varepsilon_{3,t-1}\varepsilon_{6,t-1} \\ \varepsilon_{4,t-1}\varepsilon_{1,t-1} & \cdots & \varepsilon_{4,t-1}\varepsilon_{6,t-1} \\ \varepsilon_{5,t-1}\varepsilon_{1,t-1} & \cdots & \varepsilon_{5,t-1}\varepsilon_{6,t-1} \\ \varepsilon_{6,t-1}\varepsilon_{1,t-1} & \cdots & \varepsilon_{6,t-1}^2 \end{pmatrix} \begin{pmatrix} a_{11} & \cdots & a_{61} \\ a_{12} & \cdots & a_{62} \\ a_{13} & \cdots & a_{63} \\ a_{14} & \cdots & a_{64} \\ a_{15} & \cdots & a_{65} \\ a_{16} & \cdots & a_{66} \end{pmatrix} + \begin{pmatrix} b_{11} & \cdots & b_{16} \\ b_{21} & \cdots & b_{26} \\ b_{31} & \cdots & b_{36} \\ b_{41} & \cdots & b_{46} \\ b_{51} & \cdots & b_{56} \\ b_{61} & \cdots & b_{66} \end{pmatrix} \begin{pmatrix} h_{11,t-1} & \cdots & h_{16,t-1} \\ h_{21,t-1} & \cdots & h_{26,t-1} \\ h_{31,t-1} & \cdots & h_{36,t-1} \\ h_{41,t-1} & \cdots & h_{46,t-1} \\ h_{51,t-1} & \cdots & h_{56,t-1} \\ h_{61,t-1} & \cdots & h_{66,t-1} \end{pmatrix} \begin{pmatrix} b_{11} & \cdots & b_{61} \\ b_{12} & \cdots & b_{62} \\ b_{13} & \cdots & b_{63} \\ b_{14} & \cdots & b_{64} \\ b_{15} & \cdots & b_{65} \\ b_{16} & \cdots & b_{66} \end{pmatrix} \quad (8)$$

Constant Conditional Correlation

The constant conditional correlation (CCC) model was proposed by Bollerslev (1990). This model focuses on the parameterization of the conditional correlation matrix and has the flexibility of univariate GARCH models with respect to the conditional variances. They need simple conditions to ensure the positive definite of H_t and the estimation is much easier than the usual GARCH models. The general CCC model is given as:

$$H_t = D_t\rho_t D'_t \quad (9)$$

where ρ_t is the *N* x *N* conditional correlation matrix of ε_t and D_t is *N* x *N* diagonal matrix consisting of the conditional standard deviations of elements ε_t.

where $D_t = diag\left(\sqrt{h_{11,t}}, ..., \sqrt{h_{NN,t}}\right)$

Now we define the structure of the constant conditional correlation matrix ρ and the variance covariance matrix H_t as follows:

$$\rho = \begin{pmatrix} 1 & r_{12} & \cdots & r_{1N} \\ r_{21} & 1 & \cdots & r_{2N} \\ \vdots & \vdots & \cdots & \vdots \\ r_{N1} & r_{N2} & \cdots & 1 \end{pmatrix} \quad (10)$$

where r_{ij} is the conditional correlation coefficient measuring the correlation of variable *i* with variable *j*.

$$H_t = \begin{pmatrix} h_{1,t}^2 & h_{12,t} & \cdots & h_{1N,t} \\ h_{21,t} & h_{2,t}^2 & \cdots & h_{2N,t} \\ \vdots & \vdots & \cdots & \vdots \\ h_{N1,t} & h_{N2,t} & \cdots & h_{\mathrm{N},t}^2 \end{pmatrix} \quad (11)$$

ARCH-LM Test - Breusch (1978) introduced the Multivariate ARCH-LM test, the test is for testing the presence of heteroskedasticity in the fitted residuals. The Multivariate ARCH-LM test is based on the following equation:

$$\hat{u} = C + A_1 y_t + ... + A_p y_{t-p} + ... + B_1 \hat{u}_{t-1} + ... + B_h \hat{u}_{t-h} + \varepsilon_t \quad (12)$$

where *Ai* and *Bi* are coefficients matrices and ε_t is the regression error term. Below are the hypothesis tested for Multivariate ARCH-LM.

Ho: $B_1 = B_2 = ... = B_h = 0$ (absence of ARCH errors)
H_1: $Bi \neq 0$ (presence of ARCH errors)

$$LM_h = T\hat{C}_h' \hat{\Sigma}_c^{-1} \hat{C}_h \quad (13)$$

Where $C_h = (C_1, ..., C_h)'$ such that $C_h = \frac{1}{T}\Sigma_{t=h+1}^{T} u_t u_{t-h}'$, $\hat{\Sigma}_c$ is the covariance matrix of the residuals

Portmanteau Test - investigates the presence of autocorrelation in residuals of any fitted model.

H_0: the residuals are not serially correlated versus
H_1: the residuals are serially correlated

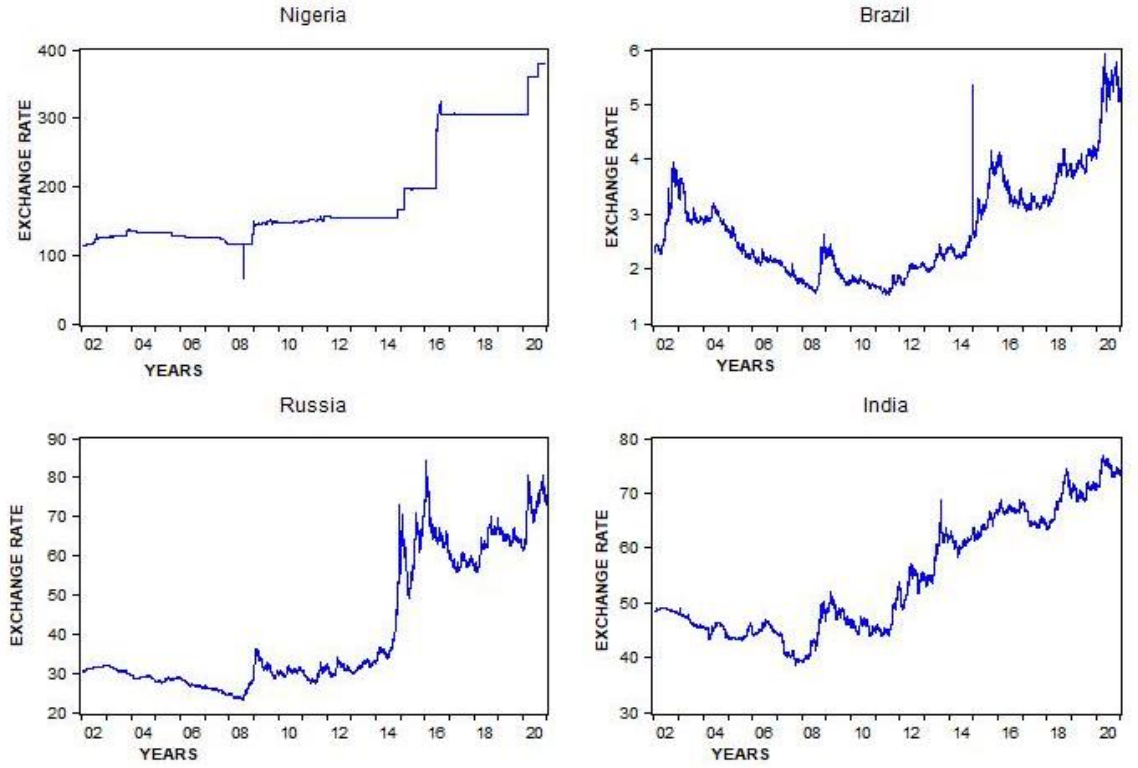
The test statistic, a modified Q statistic originally developed by Box and Pierce in (1970) is given by

$$Q_1 = n(n+2)\sum_{j=1}^{k}\left(\frac{\rho_k^2}{n-k}\right) \quad (14)$$

where n is the number of observation, the Q_1 statistic approximately follows a Chi-square distribution with k-p-q degree of freedom depending only on the number of parameters in the model.

RESULTS AND DISCUSSION

In this section the data analysis is presented and the result is discussed. The aim here is to simultaneously investigate the volatility spillover in the local currencies of the sampled nations in comparison with the US dollar using MGARCH models, the data analysis was carried out using E-views 9.0 (Economics-views). Log difference transformation is applied to transform the data into continuously compound returns, given that the returns (log values) for both countries are not stationary (see Figure 1) and are stationary when their first difference is considered (see Figure 2).



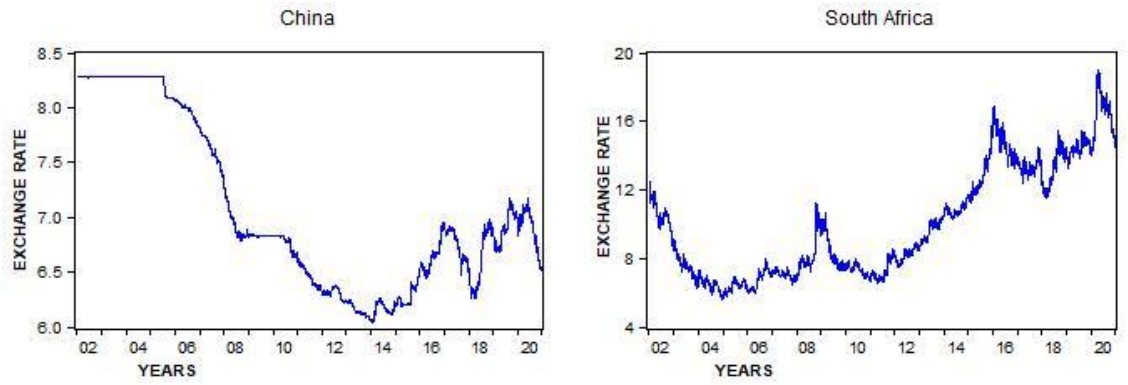
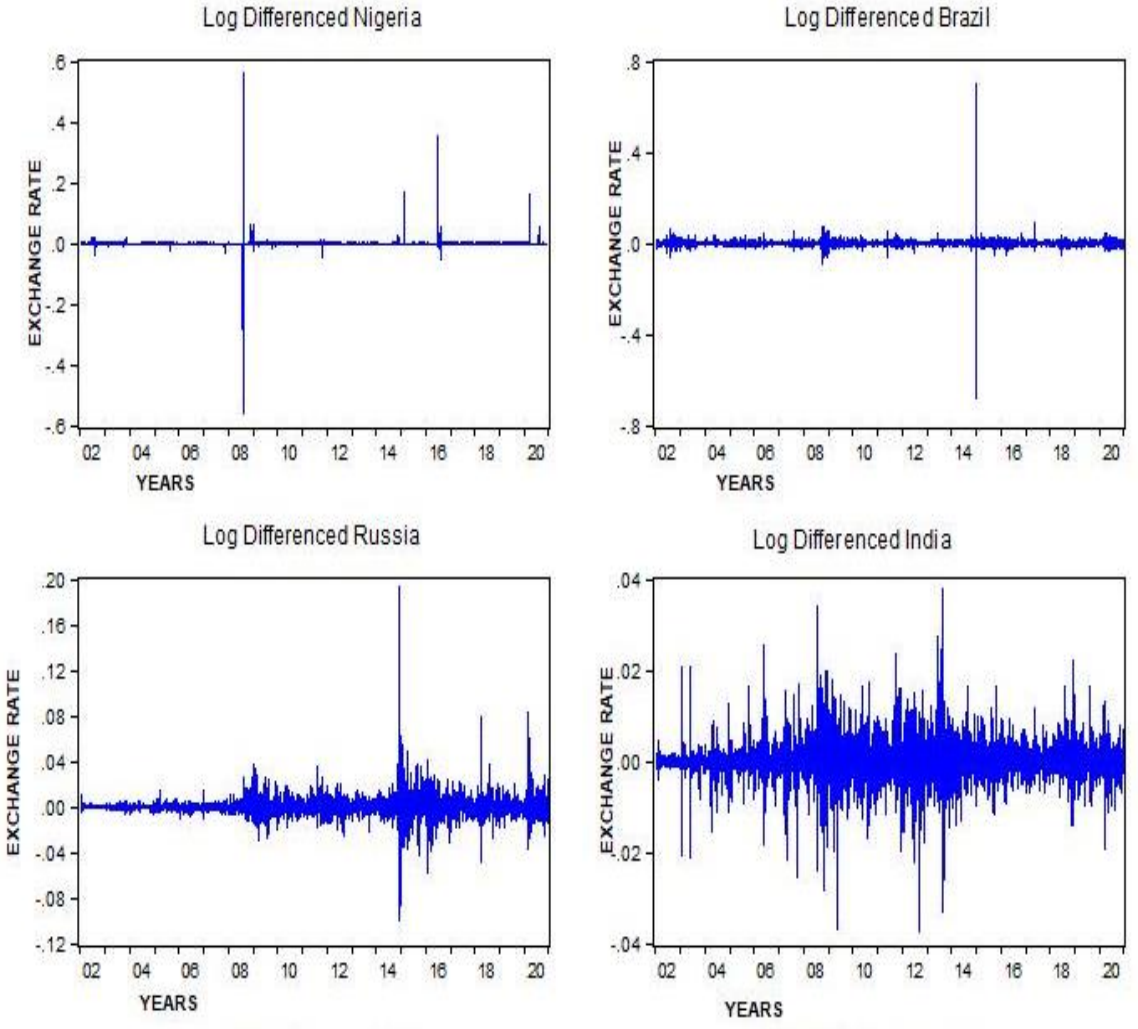


Figure 1: Exchange Rates of the N-BRICS

Figure 1 above shows that all the sequences are not stationary as there is upward and downward movement throughout the period under study. This irregular movement should be remove before modeling, these trend components have been taken care of see Figure 2.



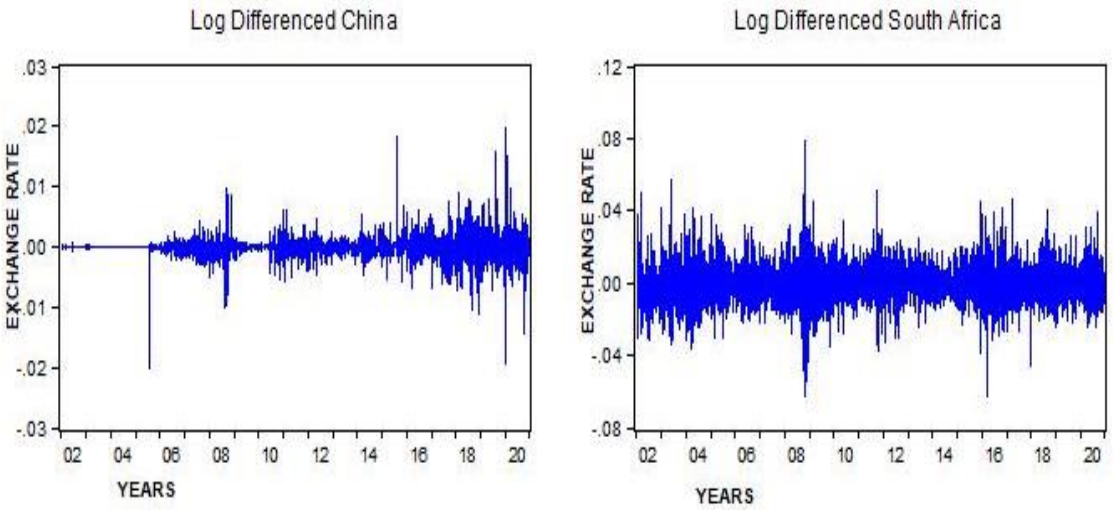


Figure 2: Exchange Rates of the N-BRICS

Figure 2 above shows that all series have evidence of volatility clustering, i.e. periods with high volatility and periods with low volatility which clearly indicates that a GARCH models can be used to fit the series. Large changes tend to be followed by large changes and small changes (of either sign) tend to be followed by small changes.

Table1: Descriptive Statistics Measures

	Naira	Real	Ruble	Rupee	Yuan	Rand
Std. Dev.	77.05553	0.926358	16.69003	10.71985	0.758277	3.228192
Skewness	-20.39895	21.64471	-0.148518	-3.038629	-5.564535	-0.831599
Kurtosis	1782.361	1016.807	67.74758	103.1380	259.9290	23.52862
Jarque-Bera	6.54E+08	2.13E+08	865892.3	2078751.0	13659920	87612.99
Probability	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Observations	4958	4958	4958	4958	4958	4958

Table 1 shows the descriptive measures of the six countries under consideration, the result obtained shows that the skewness is less than zero (for the normal distribution), this clearly display that the distribution is negatively skewed which is a sign of a non-symmetric series, meaning that there is an asymmetric effects in these models except for Brazilian Real. The kurtosis is also greater than 3 (normal distribution kurtosis). Note that; large kurtosis suggests indicates that the ER return series distribution is leptokurtic (i.e. showing a fat tail). Implying another features of Financial Time Series.

Autocorrelation Function (ACF)

We can clearly see that the ER can be studied using MGARCH model. The auto- correlation function was examined to identify the extent of correlation in the data. Those with a higher level of correlation would be suitable for modeling. We utilize the Portmanteau's test to verify the existence of autocorrelation in the ER series.

Portmanteau Tests

The Portmanteau test investigates the presence of autocorrelation in residuals of any fitted model.

Table2: Residual Portmanteau Tests for Autocorrelations

Lags	Q-Statistics	Probability	Adj. Q-Statistics	Probability	df
1	1508.429	0.000	1508.734	0.000	36
2	1589.525	0.000	1589.862	0.000	72
3	1637.581	0.000	1637.947	0.000	108
4	1742.292	0.000	1742.743	0.000	144
5	1886.415	0.000	1887.011	0.000	180
6	1941.398	0.000	1942.061	0.000	216

df is degrees of freedom for chi-square distribution (approximated)

Table 2 above shows that in all cases, the null hypothesis of no autocorrelation can be rejected. Therefore, the existence of strong autocorrelations in the residuals of the returns can be concluded.

Interpretation of Model Parameters

M_{ij} - means the impact of i stock in j market,

A_{ij} - means the volatility clustering between i stock in j market,

B_{ij} - means the volatility spillover from i stock in j market.

$\forall_{i,j}$ = 1, 2, ..., 6, where;

1 = Nigeria, 2 = Brazil, 3 = Russia, 4 = India, 5 = China and 6 = South Africa For simplicity we present and interpret the $M_{i,j}$, $A_{i,j}$ *and* $B_{i,j}$ individually in table below:

Modeling of VECH, DBEKK and CCC Models in Bivariate Version

Tables 1, 2, 3 and 4 contain the coefficients, log-likelihood and information criteria for Multivariate VECH, DBEKK and CCC models.

Table 3: Impact of ER shocks of NIGERIA on the ERV of BRICS

ERV	VECH	DBEKK	CCC
M_{12}	7.70E-07	-2.36E-06	-0.010108
	(0.0055)	(0.000)	(0.4228)
M_{13}	1.54E-06	4.46E-07	-0.008326
	(0.000)	(0.000)	(0.6048)
M_{14}	5.77E-06	5.95E-06	0.036388
	(0.000)	(0.000)	(0.0103)
M_{15}	9.34E-07	1.90E-07	-0.000757
	(0.000)	(0.000)	(0.9664)
M_{16}	1.67E-06	5.00E-06	-0.010094
	(0.0022)	(0.000)	(0.3152)

From Table 3 above, the result of VECH and DBEKK models shows that all parameters are significant at 5% level ($p < 0.05$) while for CCC model only one parameter $M_{1,4}$ is significant, and this clearly indicated the presence of positive effects of ER shocks of Nigeria on the ERV of BRICS markets. For example, in the VECH model, the Naira/Dollar ER shocks significantly impacted about 0.000007%, 0.00001%, 0.00005%, 0.000009% and 0.00001% on the ERV market of the BRICS, respectively. In the BEKK model, the Naira/Dollar ER shocks significantly affected around -0.00002%, 0.000004%, 0.00005%, 0.000001% and 0.00005% on the stock ERV markets of the BRICS, respectively, whereas in the CCC model, Naira/Dollar ER shocks significantly affected only 0.036388% on ERV in the Indian market.

Table 4: Volatility spillover between NIGERIAN and BRICS markets

Volatility Spillover	VECH	DBEKK	CCC
B_{11}	-0.002417	-	-
	(0.7939)		
B_{12}	-0.081922	-	-
	(0.9673)		
B_{13}	-0.943382	-	-
	(0.000)		
B_{14}	-0.937258	-	-
	(0.000)		
B_{15}	-1.000127	-	-
	(0.000)		
B_{16}	-0.349757	-	-
	(0.9068)		

From Table 4 above, it is indicated that only VECH model was able to captured the volatility spillover between Nigeria and BRICS markets (own and cross) both on negative directions. For instance $B_{11} = -0.002417\%$, $B_{12} = -0.081922\%$, $B_{13} = -0.943382\%$, $B_{14} = -0.937258\%$, $B_{15} = -1.000127\%$, *and* $B_{16} = -0.349757\%$. imply that there is causal relationship among Nigeria's past volatility shocks and recent volatility in BRICS.

CONCLUSION

This study focuses mainly on examining the volatility spillover between the economies of Nigeria and the BRICS nations, using MGARCH time series models; VECH, DBEKK and CCC. Thus, to study some features of good volatility modeling on FTS. It is shown that not all series are stationary since trend components exist which must be transformed prior to modeling. These trend components have been appropriately handled, having noted that some periods pose more threats than the others. In addition, risky periods are spread out at random and a certain degree of autocorrelation exists in the series, implying that big changes are likely to follow big changes and small to follow small, which is called volatility clustering. The result of the VECH model shows that all parameters are significant at 5% level ($p < 0.05$) and this clearly indicates that there are positive effects of ER shocks in Nigeria on the ERV of BRICS markets. In addition, the VECH model was able to capture volatility spillover (own and across) with both parameters are on negative directions for Nigerian market, suggesting a causal relationship between past volatility shocks of Nigeria and current volatility in the BRICS markets (which clearly revealed that Nigeria has better advantage in being with the BRICS nation). The result of the DBEKK model shows that all parameters are significant at 5% level ($p < 0.05$) for Nigeria, but it clearly indicates that there is positive impact on the ER shocks in Nigeria on the ERV of the BRICS market, except for Nigeria and Brazil which indicate negative impact. The result for the CCC model show that only one parameter $M_{1,4}$ is significant for Nigeria and this clearly indicates that there are negative impact of ER shocks of Nigeria on the ERV of BRICS markets, except for Nigeria and India which indicate positive impact. Conclusively, the VECH model is seen to be superior in the sense that it is able to capture the impact of ER shocks of Nigeria on the ERV of BRICS markets and also volatility spillover, followed by DBEKK model.

RECOMMENDATIONS

This research has clearly shown the existence of positive impacts of ER volatility and volatility spillover between

Nigerian and BRICS markets, though having analyzed the data critically and drawn reasonable conclusions, it is important to give some recommendations. It first reveals that Nigerian exports are monocultural and that there is very low complementarity with BRICS imports. This suggests that the results of existing commerce with the BRICS are not what they should be. Therefore, the research emphasized the necessity of diversifying Nigeria's economy, specifically its exports. Given the growing economies and populations of the various BRICS republics, which could create enormous prospects for Nigerian exports, such expansion might result in better output. Second, importation dominates Nigeria's economy, sometimes even importing the most basic manufactured goods. Policymakers should take advantage of current trade relations with BRICS nations to emphasize transfer through the imitation effect in order to create numerous chances in other sectors of the economy in order to benefit from this import and gain bigger advantages from trade. Third, it is important for the Nigerian government to tackle tariff and non-tariff barriers to the importation of products relevant to the transformation of the Nigerian economy, especially machinery and equipment. This will guarantee that these products enter Nigeria at the lowest possible prices. Finally, best of all the indicators, Nigeria's level of trade with Russia is the lowest among all BRICS Countries. It is an opportunity with Nigerian government to seek more ways of promoting trade and sharing knowledge with Russia, specifically in the area of energy.

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