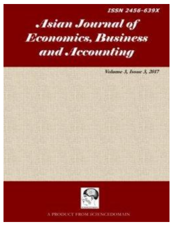

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Modeling Exchange Rate and Nigerian Deposit Money Market Dynamics Using Trivariate form of Multivariate GARCH Model

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Authors' contributions

This work was carried out in collaboration between the two authors. Author DZD wrote the first draft of the manuscript, performed the statistical analysis and results interpretation and author TGL designed the study, managed the literature searches and the protocol. Both authors read and approved the final manuscript.

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ABSTRACT

The risks associated with exchange rate and money market indicators have drawn the attentions of econometricians, researchers, statisticians, and even investors in deposit money banks in Nigeria. The study targeted at modeling exchange rate and Nigerian deposit banks money market dynamics using trivariate form of multivariate GARCH model. Data for the period spanning from 1991 to 2017 on exchange rate (Naira/Dollar) and money market indicators (Maximum and prime lending rate) were sourced for from the central bank of Nigeria (CBN) online statistical database. The study specifically investigated; the dynamics of the variance and covariance of volatility returns between exchange rate and money market indicators in Nigeria were examine whether there exist a linkage in terms of returns and volatility transmission between exchange rate and money market indicators in Nigeria and compared the difference in Multivariate BEKK GARCH considering restrictive

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indefinite under the assumption of normality and that of student's –t error distribution. Preliminary time series checks were done on the data and the results revealed the present of volatility clustering. Results reveal the estimate of the maximum lag for exchange rate and money market indicators were 4 respectively. Also, the results confirmed that there were two co-integrating equations in the relationship between the returns on exchange rate and money market indicators. The results of the diagonal MGARCH –BEKK estimation confirmed that diagonal MGARCH –BEKK in students'-t was the best fitted and an appropriate model for modeling exchange rate and Nigerian deposit money market dynamics using trivariate form of multivariate GARCH model. Also, the study confirmed presence of two directional volatility spillovers between the two sets of variables.

Keywords: Exchange rate; money; market; dynamics; trivariate; GARCH; model.

1. INTRODUCTION

In Nigeria and the world at large Exchange rate is consider as one of the strongest indicator and instrument used in evaluating economic performance of a nation. Once refers to exchange rate as the amount at which a country's currency exchange for another [1]. In another separate view, it was also referred to as the price of one country's currency with respect to another country's currency [2]. They further opined that a very strong exchange rate is an indication of a viable and strong economy. On the contrary, a very weak currency is an evidence of a very weak economy. Although, it depreciates in measure when the amount of money required to purchase a foreign currency increases, on the other hand, it will appreciate if the amount of local currency required to purchase a foreign currency reduces.

Also, when we talk about money market it appears to our mind that we are referring to shops, outlets, stalls, hawkers and other newly developed markets refers to as malls. Although, all these are crucial parts of what constitutes market but when we talk about Money Market, we are referring to financial markets (deposit money banks) that provide quick liquidity for short term financial need that is helpful in meeting the urgent and immediate obligations in the economy. It is a type of markets that aids all form of business transactions such as purchase and sales of funds on short term bases and it is controlled by central banks. Some of the examples of financial institutions that deal in money markets and their respective indicators include; commercial Banks, central banks, discount houses, insurance companies, acceptance and financial houses and some of the indicators used in this markets are treasury bills, call money funds, Bill of exchange interest rate, Saving rate, maximum lending and prime lending rate etc.

The greatest advantage of this markets is that it enables investors to meet up with their short-term financial need and funds invested in the markets can be recalled at short notice for purposes. According to Lyndon and peter, the money market plays an important role in the mobilization of financial resources for long term investment through financial intermediation [3]. Meanwhile , it was observed that the existence of money markets facilitate trading in short-term debt instruments to meet short-term needs of large users of funds such as government, banks and similar institutions [4].

Also, it was revealed that the money market is mainly for the easy distribution of liquidity in the financial system, allocation of capital as well as the hedging of short-term risks [5]. It is essentially an intermediary, where short-term financial assets that are near substitute for money are usually traded [3]. According to Lyndon and peter, the money market in Nigeria is not yet vibrant and developed [3]. They further opined that the reason why the market is not yet vibrant and developed could be attributed to liquidity problems currently facing the institution. In another development, they observed that the market is largely dominated by government instruments such as treasury bills and bonds that has created wide gap for deposit and lending rates that leads to very high cost of borrowing when observed.

The risk associated with exchange rate market is one of the major challenges facing developing countries in the world. One central aspect of it is its volatility and its associated effects on other micro and macroeconomic indicators. According to Deebom and Essi, the difficulties encountered in major international markets are shocks caused by the interplay of demand and supply while the external demand shocks arise from the economic difficulties encountered by the marketers and major trading partners [6].

In order to measure this behavior and other volatility conditions, the GARCH family models were introduced [6]. However, there are still existing problems and one of the major weaknesses was the inability of the Univariate GARCH to capture the dynamic process for time-varying variance-covariance matrix of times series data as well as jointly modeling of the first and second order conditional moment of time series data. This led to the introduction and use of the multivariate GARCH Model in modeling such conditions. One of the advantages of this is that it helps in measuring covariance and correlation between two markets directly, yet, it has its own weaknesses like in the case of VEC-GARCH model, there is no guarantee of a positive semi-definite covariance matrix [7]. It is against this background that this study used Multivariate BEKK GARCH with restrictive indefinite under the assumption of normality and student's –t error distribution. This will in a way provide for positive definiteness and measure dynamic dependence existing among the volatility series.

However, the exchange rate and money market are two different markets both in terms of liquidity and transactional stability among others. Although, both markets are critical to the development of the economy, there is need to examine the relationship that exists between them. Also, there is need to examine the interdependencies of these markets, the shocks spillover, co-movement and their cross-market linkages. Although, several studies have attempted to examine the relationship between these markets, for example Lyndon and peter examined the relationship between money market and economic growth in Nigeria [3]. Ogunbiyi, Samuel, Ihejirika, and Peters, examine interest rates and deposit money banks' profitability nexus: the Nigerian experience with the target of knowing how interest rates affect the profitability of deposit money banks in Nigeria [8]. Similarly, Agbada and Odejimi investigated the developments in money market operations and economic viability in Nigeria for the period 1981 – 2011, using multiple regression techniques for data analysis [9]. Also, Tasi'u, Yakubu, and Gulumbe, studied exchange rate volatility of Nigerian naira against some major currencies in the world and applied multivariate GARCH models [10]. In another development, Afees, Salisu and Kazeem, developed spillovers model between stock market and money market in Nigeria using VARMA-AMGARCH1 models [11]. A wealth of literature existing in this area focus on the relationship between the two markets , while the only one that considered shocks spillover did not account for the underlying Multivariate GARCH error distribution assumptions. Also, basically most of the literature existing in this area deals with bivarate Multivariate GARCH modeling. For example, Shamiri and Isa examine the multivariate GARCH model with BEKK representation to test the transfer of volatility in the financial crisis of 2007 to the stock markets of Southeast Asia [12]. They found a spillover effect of the volatility from US to Asian countries.

Similarly, Bensafta and Semodo introduced breaks in variance in a multivariate GARCH to analyze contagion during crises [13]. The authors emphasized that the bias correction of heteroscedasticity conditional correlation allows saying that crises are not always contagious confirming results found by Forbes and Rigobon [14].

Serpil and Mesut, examined BEKK-MGARCH model approach to generate the conditional variances of monthly stock exchange prices, exchange rates and interest rates for Turkey [15]. The study used a sample period 2002:M1-2009:M1, for the effects of global economic crisis in Turkey and the results obtained indicate a significant transmission of shocks and volatility among the three financial sectors.

Therefore, the research study seeks to fill this gap in literature by adopting trivariate BEKK form of multivariate GARCH with specific error distribution assumption. This study serves as yardstick for market control, determination and establishes an idea ~~s~~ in terms of Value at risks determination.

Sequel to the above facts, the aim of this study was to model the exchange rate and Nigerian deposit money market indicators dynamics using trivariate form of multivariate GARCH model, while the specific objectives were to : Investigate the dynamics of the variance and covariance of volatility returns between exchange rate and money market indicators in Nigeria, examine whether there is a linkage in terms of returns and volatility transmission between exchange rate and money market indicators in Nigeria and to compare the difference in Multivariate BEKK GARCH considering restrictive indefinite under the assumption of normality and that of student's –t error distribution.

2. MATERIALS AND METHODS

Data used in this study was sourced and extracted from the official website of the Central Bank of Nigeria [16]. It spans from the period January, 1997 – December, 2017 consequently comprises 240 observations. It includes; Nigerian/American exchange rate (naira/dollar) and maximum lending rate (MLR) series. Having sourced for and extracted the data on the series [17] and Christoffersen suggested that there is need to transform the data [18]. They further opined that using an unstable series such as Nigerian/American exchange rate (naira/dollar), maximum and prime lending rate series may lead to non-stationarity which cannot be used for further statistical inferences. The reason for this can be attributed to bias and spurious implication. These are some of the reasons why the series need to be transformed. However, the data were analysed with the aid of a statistical Software; Eviews version 10.

2.1 Transformation

Nigerian/American exchange rate (naira/dollar) and maximum lending rate (MLR) series used in the study were transformed to returns. In the transformation of the series, this study uses the estimate of the residuals obtained from an ARMA process for the estimation of the return on each of the series. The reason for the use of estimation of the return has both theoretical and empirical implication. Similarly, Reuben, Hussaini and Shehu opined that estimating return on series has both theoretical and empirical implication for preferring logarithmic returns [19]. Meanwhile, it is well noted that, theoretically, logarithmic returns are analytically more expanse when linking together sub-period returns to form continuous returns. However, empirically and logarithmic returns have much better statistical inferential properties. According to Christoffersen, logarithmic returns on series are more likely to be normally distributed [19]. Therefore, monthly returns on the series are defined thus:

$$\text{Re}xchrate = \log\left(\frac{Excharate}{Excharate_{t-1}}\right)x100. \quad (3.1)$$

$$\text{Rmaxilrate} = \log\left(\frac{\text{maxilrate}_t}{\text{maxilrate}_{t-1}}\right)x100 \quad (3.2)$$

$$\text{RPrlrate} = \log\left(\frac{\text{Plrate}_t}{\text{Plrate}_{t-1}}\right)x100 \quad (3.3)$$

For t = 1, 2, ….t-j where Rexcharatet is exchange rate return at time t, Rmaxilrate_t is Return on Maximum lending rate at time t and Rplrate is return on Prime lending rate at "t" . Similarly, Excharatet-1 represents exchange rate at time "t-1" , Maxilrate_{t-1} represents maximum lending rate at time "t-1" and Rplrate$_{t-1}$ represents return on Prime lending rate at time "t-1". The transformation of above is the monthly returns on the variables used in the study, It helps us to ensure that all the variables are well differenced (D) to get rid of outlier and it is also useful in obtaining stationarity of the data.

2.2 Model Specification

Multivariate BEKK-GARCH(1,1) model specification, the BEKK – GARCH Model is simply an acronym BEKK representing Baba, Engle, Kraft and Kroner, which was a preliminary version of Engle and Kroner [20] and was stated that for a single series, the volatility pattern follow univariate specification of GARCH model of the form:

$$h_t = c_0 + a_1\varepsilon_{t-1}^2 + \ldots\ldots + a_p\varepsilon_{t-p}^2 + b_1h_{t-1} + \ldots. + b_qh_{t-q} \quad (3.4)$$

Where ρ and q are order of the GARCH Model. The multivariate model can be generalized in the form

$$\text{H}_\text{t} = C_o^1C_0 + \sum_{k=1}^{k}\ \sum_{i=1}^{q}\beta_{\text{ik}}H_{t-c}\,\beta^1{}_{ik} \quad (3.5)$$

Where C, A$_{\text{ik}}$ and βik are (NxN) matrix, $C_o^1C_0$ is the intercept of the matrix in a dew posed form, where C is a lower triangular matrix and it is positive semi definite.

For BEKK (1, 1), it is represented as thus:

$$H_t = C_o^1C_0 + A_{11}\varepsilon_{t-1}\varepsilon_{t-1}^1A_{11} + B_{11}^1H_{t-1}B_{11} \quad (3.6)$$

Where, A$_\text{i}$ and B$_1$ are nxn parameter matrix and C$_\text{o}$ is nxn upper triangular matrix. Then, the Bivariate BEKK (1,1) model can be written as;

$$H_t = C_o^1 C_0 + \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} \varepsilon_{it-1}^2 \, \varepsilon_{1t-1} & \varepsilon_{2t-1} \\ \varepsilon_{2t-1} \, \varepsilon_{1t-1} & \varepsilon_{2t-1}^2 \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}^1$$

$$+ \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} \begin{pmatrix} h_{11} & h_{12t-1} \\ h_{21t-1} & h_{22} \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}^1 \qquad (3.7)$$

The off diagonal parameter in matrix B, B_{12} and B_{21} respectively estimated as the independence of conditional volatility of the returns on exchange rate and money market rate series. The b_{11} and b_{22} represents persistence in one set of variable of the returns on exchange rate and money market rate series. Similarly, the parameter a_{12} or a_{21} represents the cross variable effects. Conversely, a_{11} and a_{22} represents the returns own effects. This specification is applied in several bivariate GARCH empirical studies. It ensures that the variance-covariance matrix is positive. However, the number of parameters to estimate for the variance-covariance matrix is very high. It is of the order of $\frac{N(N+1)}{2} + 2N^2$: 24 parameters to be estimated for 3variables.

Most studies using a multivariate GARCH specification to limit the number of studied assets and / or impose restrictions on the process generating Ht. Bollerslev [21] and [22] assume that correlations are constant. Bollerslev et al. [23] require diagonality condition matrices A and B. This implies that the variances of Ht depend only on the square past residuals and an autoregressive term. Covariances depend on the cross product past residuals and an autoregressive term. This specification also seems very restrictive because does not take into account the dependence of conditional volatilities between markets evidenced particularly by Hamao et al. [24] on data with high frequencies. Many researchers [25], [26] and [27] found that, in most cases, the effect of a negative shock to the conditional variance is greater than that of a positive shock. This adopted an extension to MGARCH BEKK model specification in order to capture the asymmetric responses of conditional variances and covariance of the return series as it is recommended in Samar and Khoufi [28] stated as thus:

$$H_t = C^1 C + A^1 \varepsilon_{t-1} \varepsilon_{t-1}^1 A + B^1 H_{t-1} B + X^1 \xi_{t-1} \xi_{t-1}^1 S + T^1 \eta_{t-1} \eta_{t-1}^1 T \qquad (3.8)$$

Where S and T are two size matrices (N×N) such as:

$\xi_{it} = \varepsilon_{it} I_{\xi it}$ where $I_{\xi it}$ = 1 if $\varepsilon_{it} < 0$ and 0 otherwise

$\eta_{it} = \varepsilon_{it} I_{\xi it}$ where $I_{\xi it}$ = 1 if $|\varepsilon_{it}| > \sqrt{h_{iit}}$ and 0 otherwise

For the reasons already mentioned, we impose the condition of diagonality for S and T matrices. However, the the transformed trivariate Diagonal BEKK–GARCH Specification (Eviews) Estimation Command for restrictive indefinite in specific error distributional assumption could stated as thus: ARCH(TDIST) @DIAGVECH C(INDEF) ARCH(1,INDEF) GARCH(1,INDEF)

Estimated equations

REXCHRATE = C(1) (3.9)

RMLRATE = C(2) (3.10)

RPLRATE = C(3) (3.11)

The transformed variance-covariance representation

GARCH = M + A1.*RESID(-1)*RESID(-1)' + B1.*GARCH(-1) (3.12)

Variance and covariance equations

GARCH1 = M(1,1) + A1(1,1)*RESID1(-1)^2 + B1(1,1)*GARCH1(-1) (3.13)

GARCH2 = M(2,2) + A1(2,2)*RESID2(-1)^2 + B1(2,2)*GARCH2(-1) (3.14)

GARCH3 = M(3,3) + A1(3,3)*RESID3(-1)^2 + B1(3,3)*GARCH3(-1) (3.15)

COV1_2 = M(1,2) + A1(1,2)*RESID1(-1)*RESID2(-1) + B1(1,2)*COV1_2(-1) (3.16)

COV1_3 = M(1,3) + A1(1,3)*RESID1(-1)*RESID3(-1) + B1(1,3)*COV1_3(-1) (3.17)

COV2_3 = M(2,3) + A1(2,3)*RESID2(-1)*RESID3(-1) + B1(2,3)*COV2_3(-1) (3.18)

Similarly, for simple analysis, understanding and representation the restricted indefinite trivariate GARCH BEKK model in specific error distribution assumption above can be represented in generic form as thus:

Mean component,

REXCHRATE = C(1) (3.19)

RMLRATE = C(2) (3.20)

RPLRATE = C(3) (3.21)

The transformed variance-covariance representation

$$\begin{bmatrix} \hat{\sigma}_{11,t} = M(1,1) + A1(1,1)^2 \varepsilon_{1,t-1}^2 + B1(1,1)^2 \sigma_{11,t-1} \\ \hat{\sigma}_{22,t} = M(2,2) + A1(2,2)^2 \varepsilon_{2,t-1}^2 + B1(2,2)^2 \sigma_{22,t-1} \\ \hat{\sigma}_{33,t} = M(3,3) + A1(3,3)^2 \varepsilon_{2,t-1}^2 + B1(3,3)^2 \sigma_{22,t-1} \\ \hat{\rho}_{12,t} = M(1,2) + A1(1,1) \ * A1(2,2) \varepsilon_{1,t-1}^2 * \varepsilon_{2,t-1}^2 + B1(1,1) * B1(2,2) \hat{\rho}_{2,t-1} \\ \hat{\rho}_{13,t} = M(1,3) + A1(1,1) \ * A1(3,3) \varepsilon_{1,t-1}^2 * \varepsilon_{3,t-1}^2 + B1(1,1) * B1(3,3) \hat{\rho}_{3,t-1} \\ \hat{\rho}_{23,t} = M(2,3) + A1(2,2) \ * A1(3,3) \varepsilon_{2,t-1}^2 * \varepsilon_{3,t-1}^2 + B1(2,2) * B1(3,3) \hat{\rho}_{3,t-1} \\ \end{bmatrix} \quad (3.22)$$

2.3 Model Estimation Procedure

i. Time plot for the raw data
ii. Time plot on the transformation of the return series
iii. Descriptive Test Statistic for Normality Test on the estimated return series.

The normality test was carried out using the Jarque-Bera test statistics. According to Chinyere et al. [29] Jargue-Bera is defined as joint test of skewness and kurtosis that examine whether data series exhibit normal distribution or not; and this test statistic was developed by Jargue and Bera [30]. It is defined as;

$$X^2_{\simeq} \ \frac{N}{6}\left[S^2 + \frac{(K-3)^2}{4}\right] \qquad (3.23)$$

Where S represents Skewness, K represents Kurtosis and N represents the size of the macroeconomic variables used. The test statistic under the Null hypothesis of a normal distribution has a degree of freedom 2. When a distribution does not obey the normality test, [31] suggested that the alternative inferential statistic should use GARCH with its error distribution assumptions with fixed degree of freedom.

Test for Co-integration

There is need to identify the co-integrating relationship between the two series and the two likelihood ratio tests to be used are the λ_{Trace} and λ_{Max} respectively.

$$\lambda_{\text{Trace}} = -\text{T} \sum_{\text{t}=\text{r}+1}^{\text{n}} In\left(1 - \lambda_{\text{i}}\right) \qquad (3.24)$$

For i = 0, 1………………n -1

$$\lambda_{Max} = -T\ln(1 - \lambda\text{r} + 1) \qquad (3.25)$$

Where n is the number of usable observations and λ_i are the estimated eigenvalues otherwise refers to as characteristics roots, the trace test statistic (λ_{Trace}) test the null hypothesis of r co-integrating relationship Vs the alternative hypothesis of less than or equal to r co-integrating relationship. Similarly, λ_{Max} test statistic examines the null hypothesis of r co-integrating relation against r +1 co-integrating relations. However, the rank of π estimate can be determined using λ_{Trace} or λ_{Max} test statistic. This is done on the condition that if rank of π = 1, then there is single co-integrating vector and the estimator π can be factorized as π = aβ, where α and β are α x 1, vectors representing error correction co-efficient examining the speed of convergence and integrating parameters respectively.

Vector error correction model

The vector Error correction model (VECM) is used to investigate the causal relationship between the return on exchange rates and crude oil prices after identifying the appropriate order of integration of each variable. This is done by first identifying the significant lag length of the VAR model using suitable information criteria. If the returns on Nigerian/American exchange rate and money market indicator are co-integrated we can estimate the VAR model including a variable representing the deviations from the long- run equilibrium. The VECM model for variables including; constant, the error correction term and lagged form;

$$\text{D(REXCHRATE)} = \text{A}(1,1)*(\text{B}(1,1)*\text{REXCHRATE}_{\text{t-1}} + \text{B}(1,2)*\text{RMLRATE}_{\text{t-1}} + \text{B}(1,3)*\text{RPLRATE}_{\text{t-1}} + \text{B}(1,4)) + \text{A}(1,2)*(\text{B}(2,1)*\text{REXCHRATE}_{\text{t-1}} + \text{B}(2,2)*\text{RMLRATE}_{\text{t-1}} + \text{B}(2,3)*\text{RPLRATE}_{\text{t-1}} + \text{B}(2,4)) + \text{C}(1,1)*\text{D}(\text{REXCHRATE}_{\text{t-1}}) + \text{C}(1,2)*\text{D}(\text{RMLRATE}_{\text{t-1}}) + \text{C}(1,3)*\text{D}(\text{RPLRATE}_{\text{t-1}})) + \text{C}(1,4) \qquad (3.26)$$

$$\text{D(RMLRATE)} = \text{A}(2,1)*(\text{B}(1,1)*\text{REXCHRATE}_{\text{t-1}} + \text{B}(1,2)*\text{RMLRATE}_{\text{t-1}} + \text{B}(1,3)*\text{RPLRATE}_{\text{t-1}} + \text{B}(1,4)) + \text{A}(2,2)*(\text{B}(2,1)*\text{REXCHRATE}_{\text{t-1}} + \text{B}(2,2)*\text{RMLRATE}_{\text{t-1}} + \text{B}(2,3)*\text{RPLRATE}_{\text{t-1}} + \text{B}(2,4)) + \text{C}(2,1)*\text{D}(\text{REXCHRATE}_{\text{t-1}}) + \text{C}(2,2)*\text{D}(\text{RMLRATE}_{\text{t-1}}) + \text{C}(2,3)*\text{D}(\text{RPLRATE}_{\text{t-1}}) + \text{C}(2,4) \qquad (3.27)$$

$$D(RPLRATE) = A(3,1)*(B(1,1)*REXCHRATE_{t-1} + B(1,2)*RMLRATE_{t-1} + B(1,3)*RPLRATE_{t-1} + B(1,4)) + A(3,2)*(B(2,1)*REXCHRATE_{t-1} + B(2,2)*RMLRATE_{t-1} + B(2,3)*RPLRATE_{t-1} + B(2,4)) + C(3,1)*D(REXCHRATE_{t-1}) + C(3,2)*D(RMLRATE_{t-1}) + C(3,3)*D(RPLRATE_{t-1}) + C(3,4) \quad (3.28)$$

REXCHRATE represents returns on exchange rate, RMLRATE represent the returns on Maximum lending rate series and RPLRATE represent the returns on prime lending Rate. The VECM estimation as a preliminary stage to model estimation is particularly necessary and interesting as it allows for estimation of how the variables adjust deviations towards the long- run equilibrium. The error correction co-efficient (a_i) reflects the speed of Adjustment.

2.4 Estimation of Multivariate GARCH Models

The estimation of the BEKK-model could be liken to the univariate case where the parameters of the multivariate GARCH model are estimated by maximum likelihood (ml) optimizing arithmetically the Gaussian log-likelihood function. We say let f should denote the multivariate normal density, the contribution of a single observation; l_t to the log-likelihood of a sample is given as:

$$l_t = In\{f(\varepsilon_t / F_{t-1})\} = -\frac{N}{2}In(2\pi) - \frac{1}{2}In(|\varepsilon_t|) - \frac{1}{2}\varepsilon_t^T \sum\nolimits_t^{-1} \varepsilon_t \quad (3.29)$$

According to Berndt et al. [32] maximizing the log-likelihood $L = \sum_t^T l_t$ may likely requires nonlinear maximization methods and this can be done easily by the use of first order derivatives the algorithm developed by Berndt et al. [32]. This is easily implemented and particularly useful for the estimation of multivariate GARCH processes.

Student's –t Distribution Assumption

The conditional student's-t distribution could be stated as thus:

$$l(\theta,\upsilon) = In\frac{\Gamma\left(\frac{n+\upsilon}{2}\right)^{\nu^{\frac{n}{2}}}}{(\upsilon\pi)^{\frac{n}{2}}\Gamma\left(\frac{\upsilon}{2}\right)(\nu-2)^{\frac{n}{2}}} - \frac{1}{2}In\det(\Omega_t(\theta)) - \frac{1}{2}(\nu+n)In\left[1+\frac{Z_t'\Omega_t^{-1}(\theta)Z_t}{\nu-2}\right] \quad (3.30)$$

In the case of the student's-t distribution, V > 2 is the number of degrees of freedom.

2.5 Normal Error Distribution Assumption

Also, the conditional normality distribution assumption could be stated as thus:

$$l(\theta) = -\frac{1}{2}nIn(2\pi) - \frac{1}{2}In\det(\Omega_t(\theta)) - \frac{1}{2}Z_t^1\Omega_t^{-1}(\theta)Z_t \quad (3.3)$$

3. RESULTS

The summary of the results of statistical data analysis using the Eviews 10 are presented below in tables and equations. The discussions are also presented thereafter.

Table 4.1. Descriptive statistics on returns of the study variables

Variables	Mean	Median	Maximum	Minimum	Std. Dev	Skewness	Kurtosis	Jarque-Bera
Rexcharate	1.086	0.201	20.537	-15.007	4.148	0.943	8.976	528.543
Rmaxilrate	0.1204	0.091	31.135	-58.778	4.750	-5.049	80.584	82384.12
Rplrate	-0.037	0.000	25.472	-54.654	4.562	-4.921	69.106	60117.18

Source: Researcher's computations, 2019 using E view software version10

Estimated VEC Model

$$D(REXCHRATE) = 0.0044*REXCHRATE_{t-1} - 5.1073*RPLRATE_{t-1} - 1.2590 + 0.1017*RMLRATE_{t-1} - 0.6200*RPLRATE_{t-1} - 0.1497 - 0.2703*D(REXCHRATE_{t-1}) - 0.0342*D(RMLRATE_{t-1}) - 0.0088*D(RPLRATE_{t-1}) - 0.0116 \quad (4.1)$$

$$D(RMLRATE) = 0.1377*(REXCHRATE_{t-1} - 5.1073*RPLRATE_{t-1}) - 1.2590) - 0.8328*(RMLRATE_{t-1} - 0.6199*RPLRATE_{t-1} - 0.1497) - 0.0623*D(REXCHRATE_{t-1}) - 0.2112*D(RMLRATE_{t-1}) + 0.1663*D(RPLRATE_{t-1}) + 0.00154 \quad (4.2)$$

D(RPLRATE) = 0.2331*(REXCHRATE $_{t-1}$ - 5.1073*RPLRATE $_{t-1}$) - 1.2590) +
0.3360*(RMLRATE $_{t-1}$) - 0.6200*RPLRATE $_{t-1}$ - 0.1497) - 0.0564*D(REXCHRATE $_{t-1}$) -
0.2767*D(RMLRATE $_{t-1}$) + 0.2196*D(RPLRATE $_{t-1}$) + 0.0005 (4.3)

The trivariate Diagonal BEKK–GARCH for restrictive indefinite in normal error distributional assumption estimate could be stated as thus

Mean Component

REXCHRATE = 0.1974 (4.4)
(0.2691)

RMLRATE = 0.0650 (4.5)
(0.6567)

RPLRATE= -0.1410 (4.6)
(0.3861)

The estimated transformed variance-covariance representation

$$\hat{\sigma}_{11,t} = 1.5090 + 0.3967\varepsilon^2_{1,t-1} + 0.5659\sigma_{11,t-1} \tag{4.7}$$
(0.0000) (0.0000) (0.0000)

$$\hat{\sigma}_{22,t} = 1.1819 + 0.3638\varepsilon^2_{2,t-1} + 0.6456\sigma_{22,t-1} \tag{4.8}$$
(0.0000) (0.0000) (0.0000)

$$\hat{\sigma}_{33,t} = 1.1099 + 0.3317\varepsilon^2_{2,t-1} + 0.6844\sigma_{22,t-1} \tag{4.9}$$
(0.0000) (0.0000) (0.0000)

$$\hat{\rho}_{12,t} = 0.0352 + 0.3799\varepsilon^2_{1,t-1} * \varepsilon^2_{2,t-1} + 0.6044\hat{\rho}_{2,t-1} \tag{4.10}$$
(0.8633) (0.0000) (0.0000)

$$\hat{\rho}_{13,t} = 0.0426 + 0.3627\varepsilon^2_{1,t-1} * \varepsilon^2_{3,t-1} + 0.6223\hat{\rho}_{3,t-1} \tag{4.11}$$
(0.7378) (0.0000) (0.0000)

$$\hat{\rho}_{23,t} = 0.5611 + 0.3474\varepsilon^2_{2,t-1} * \varepsilon^2_{3,t-1} + 0.6647\hat{\rho}_{3,t-1} \tag{4.12}$$
(0.0000) (0.0000) (0.0000)

The trivariate Diagonal BEKK–GARCH for restrictive indefinite in student's-t error distributional assumption estimate could be stated as thus

Mean Component

REXCHRATE = 0.1208 (4.13)
(0.1570)

RMLRATE= 0.1339 (4.14)
(0.0646)

RPLRATE = -0.0518 (4.15)
(0.4837)

The Estimated Transformed Variance-Covariance Representation

$$\hat{\sigma}_{11,t} = 1.4029 + 1.1659\varepsilon^2_{1,t-1} + 0.4783\sigma_{11,t-1} \tag{4.16}$$
(0.0323) (0.0421) (0.0000)

$$\hat{\sigma}_{22,t} = 1.4426 + 0.6619\varepsilon^2_{2,t-1} + 0.4934\sigma_{22,t-1} \tag{4.17}$$

(0.0179) (0.0282) (0.0000)

$$\hat{\sigma}_{33,t} = 0.864 + 0.7329\varepsilon^2_{2,t-1} + 0.5801 * \sigma_{22,t-1} \tag{4.18}$$

(0.0420) (0.0293) (0.000)

$$\hat{\rho}_{12,t} = \text{-}0.2689 + 0.2246\varepsilon^2_{1,t-1} * \varepsilon^2_{2,t-1} + 0.0145\hat{\rho}_{2,t-1} \tag{4.19}$$

(0.6478) (0.04067) (0.9875)

$$\hat{\rho}_{13,t} = 0.0683 + 0.0415\varepsilon^2_{1,t-1} * \varepsilon^2_{3,t-1} + 0.0897\hat{\rho}_{3,t-1} \tag{4.20}$$

(0.9037) (0.8644) (0.9828)

$$\hat{\rho}_{23,t} = 0.5289 + 0.5833\varepsilon^2_{2,t-1} * \varepsilon^2_{3,t-1} + 0.5545\hat{\rho}_{3,t-1} \tag{4.21}$$

(0.0535) (0.0225) (0.9875)

Table 4.2. Correlation between return on exchange rate and money market indicators

Prices Series	Exchrate	Rmaxilrate	Rplrate
REXCHARATE	1	0.0301	0.1004
RMAXILRATE	0.0301	1	0.7996
RPLRATE	0.1004	0.7996	1

Source: Researcher's computations, 2019 using Eview software version10

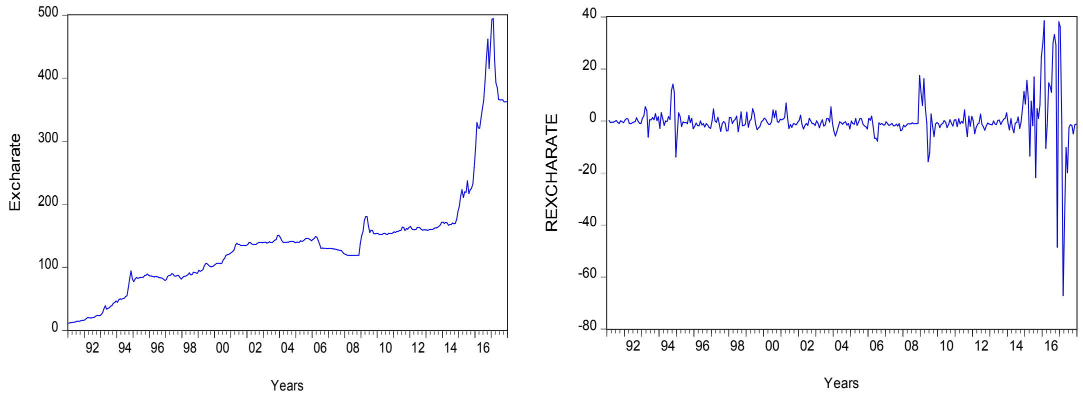

Fig. 4.1. Time plot of the raw data and return of exchange rate

Table 4.3. VAR lag order selection criteria

Lag	AIC	SC	HQ
0	16.50697	16.54238	16.52111
1	16.38635	16.52799*	16.44292*
2	16.40395	16.65182	16.50294
3	16.42359	16.77768	16.56500
4	16.36802*	16.82835	16.55186

** indicates lag order selected by the criterion*
Source: Researcher's computations, 2019 using E view software version10

Table 4.4. Test for cointegration using the Johansen co-integration test

Hypothesized	**Unrestricted cointegration rank test (Trace)**				**Unrestricted cointegration rank test (Maximum Eigen value)**				
	Eigen value	**Trace statistic**	**0.05 Critical value**	**Prob**	**Hypothesized**	**Eigen value**	**Max-eigen statistic**	**0.05 Critical value**	**Prob**
None *	0.255386	197.1144	29.79707	0.0001	0.255	93.77459	21.13162	0.000	0.255
At most 1 *	0.169764	103.3398	15.49471	0.0001	0.169	59.16235	14.26460	0.000	0.169
At most 2 *	0.129705	44.17747	3.841466	0.0000	0.129	44.17747	3.841466	0.000	0.129

Source: Researcher's computations, 2019 using E view software version10

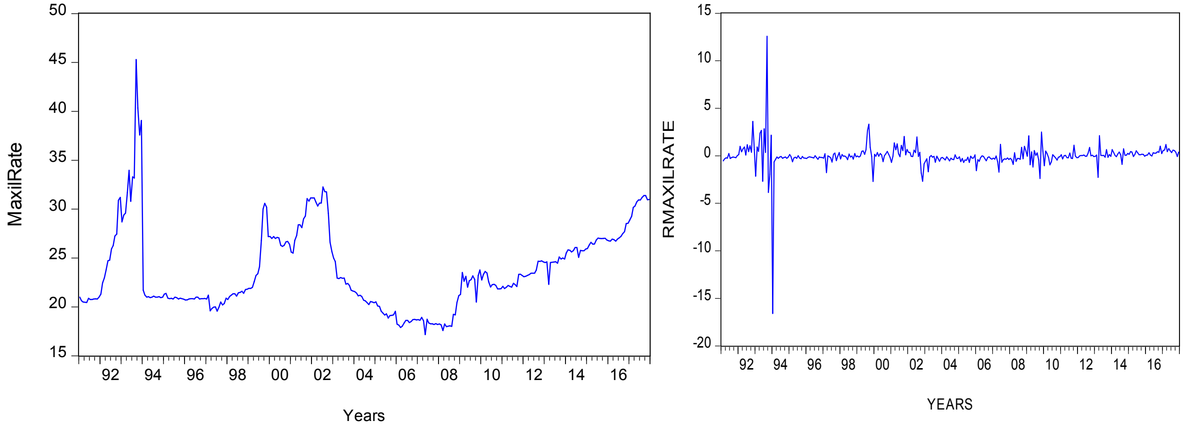

Fig. 4.2. Time plot of the raw data and returns on Nigerian money market indicator

Table 4.5. VEC residual heteroskedasticity tests (levels and squares)

Dependent	R-squared	F(10,310)	Prob.	Chi-sq(10)	Prob.
res1*res1	0.040836	1.319799	0.2187	13.10824	0.2177
res2*res2	0.051008	1.666226	0.0878	16.37345	0.0894
res3*res3	0.049175	1.603254	0.1045	15.78507	0.1060
res2*res1	0.103963	3.596774	0.0002	33.37203	0.0002
res3*res1	0.094600	3.238999	0.0005	30.36650	0.0007
res3*res2	0.049842	1.626160	0.0981	15.99935	0.0997

Table 4.6. Information criteria selection technique

Information criteria selection technique	Diagonal MGARCH - BEKK in normal error distribution	Diagonal MGARCH-BEKK In students'-T error distribution	Least Akaike information criteria(AIC)
Schwarz criterion	15.00652	13.51352	
Hannan-Quinn criter.	14.90112	13.35893	
Akaike info criterion	14.83109	13.25622	13.25622

Source: Researcher's computations, 2019using Eview software version 10

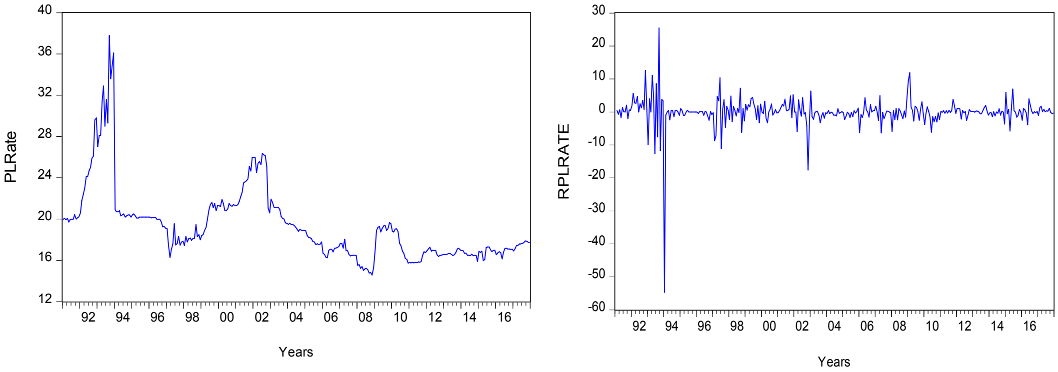

Fig. 4.3. Time plot of the raw data and returns on prime lending rate

4. DISCUSSION OF RESULTS

Figs. 4.1, 4.2 and 4.3 show the time plot of the raw data variables used in the study. It reveals that all the variables showed fluctuations within the period of the study. No variables followed a particular steady trend.

Table 4.1 present the summary descriptive statistics of the set of returns (returns on exchange rate and money markets indicators). The sample mean of all the returns with an exception of returns on prime lending rate (RPlrate) are positive and small compare to their standard deviations. The simply mean that returns on exchange rate and maximum lending rate exhibit the characteristic of mean reverting. Also, the higher the standard deviation leads to an increasing volatility as acclaimed in De and Marquering [7] and this means that the interaction between these indicators is risky. The return distributions of maximum and prime lending rate are negatively skewed to the left. According to Bala and Takimoto [33], this simply implies that negative returns are more common than positive returns in the two indicators. The kurtosis are all greater than three (3) and since this measures the magnitude of extremes, and it is higher than it mean. This simply means all the variables exhibit leptokurtic behavior. Also, the Jarque –Bera (JB) statistics indicate that the returns are not normally distributed.

Similarly, Table 4.3 shows the corresponding correlation between exchange rates and indicators of money market. The result shows positive strong relationship between these variables. This simply means there is significant relationship revealing higher co-movement and greater integration between these variables.

In another development, Johansen test of co-integration for lag of endogenous variables were considered for selection using three information criteria and lag two (2) was choose as it is represented in Table 4.4.

Table 4.4 presents the results for the test for co-integration using the Johansen co-integration test. In this case, the trace test statistic, result indicates evidence of long run relationship among the returns on exchange rate and money markets indicators used in the study. The evidence of this claim is clearly shown as the trace and maximum eigenvalue statistics with their corresponding probabilities values (P-values) as estimated in the test are less than 5%. This indicates that long run relationship exist among exchange rate and variables money markets. This results corroborates the findings of Ogunbiyi and Ihejirika [8].

Ogunbiyi and Ihejirika [8] investigated how interest rates affects deposit money Bank's profitability in Nigeria and it was found that long run equilibrium relationship exist among variables used in their study.

Table 4.5 VEC residual heteroskedasticity tests (Levels and Squares) shows no presence of ARCH effect in the model as their probability values are not all greater than the standard probability of 0.05.

Also, the results of the Diagonal MGARCH–BEKK model estimated in students'-t and normal error distribution as shown in equation 4.7-4.21 reveals that there exists strong GARCH (1, 1) process influencing the conditional variances of the variables under investigation. The results obtain here corroborates Malik and Ewing's [34] assertion. In Malik and Ewing's [34] study, it was asserted that in parameterized multivariate GARCH model when the diagonal quadratic function are positively significant this means there exist a very strong GARCH(1,1) and this is evident as the values of the sum of the ARCH and GARCH coefficients are 0.9826,1.0094 and 1.0161 respectively for Diagonal MGARCH – BEKK in Normal error distribution while in student's-t error, we have 0.64442,1.1553 and 1.313 respectively. This also proves that the covariance matrix are positive semi-definite. This is synonymous to the assertion of Tasi'u et al. [10]. Tasi'u et al. [10] examined exchange rate volatility of Nigerian naira against some major currencies in the world and applied multivariate GARCH models. It was found that the covariance matrixes were positive semi-definite.

In another development, the results also confirmed that there is linkage in terms of returns and volatility transmission between returns of exchange rate and money market rate. In both model all the estimates of all the diagonal parameters are significant at 5% level of significance. This indicates that own shocks have effect on the current volatility of the Nigerian money market indicator. Similarly, all the off-diagonal estimates were all statistically significant at 1% and 5% level of significance, revealing that own volatility does affect the current volatility of exchange rate and money market rate in Nigeria.

In the same vein, the two models in equation 4.7-4.21 also revealed evidence of bi-direction shock transmission between these variables. This confirmed [11] findings. Afees and Kazeem [11] examined the modeling of return and shock spillovers between stock market and money market in Nigeria and found that shocks to stock returns tend to persist when they occur while shocks to money market returns tend to die out over time.

Finally, the result shows that these models allow for dynamic dependence between the two set of volatility series. However, selection of the two models were also considered and the result revealed that the model with the least Akaike Information Criteria(AIC) should be choose since its' maximizes the lost of degree of freedom [6]. Therefore, the Diagonal MGARCH BEKK in student's-t was considered the best fitted and appropriate model for modeling exchange rate and Nigerian deposit money market dynamics in trivariate form.

5. CONCLUSION

This shows that there is a serious interdependence of measure of deposit Bank s money market rate on the exchange rate (dollar/Naira) and the dynamics of the variance and covariance of volatility returns between exchange rate and money market indicators in Nigeria was also confirmed. Evidence shows there is a linkage in terms of returns and volatility transmission between exchange rate and money market indicators in Nigeria. Also , on the bases of Comparison the difference between Multivariate BEKK GARCH with restrictive indefinite under the assumption of normality and that of student's –t error distribution, the Multivariate BEKK GARCH with restrictive indefinite in students'-t error distribution was considered best fitted and appropriate in modeling exchange rate and Nigerian deposit money market dynamics using trivariate form of multivariate GARCH model.

6. RECOMMENDATION

The result of the analysis reveal that diagonal BEKK model in student's-t error distribution assumption was recommended to be the best model. This is because most of their variances/covariance are statistically significant and they have maximum likelihood, lower Akaike information criteria (AIC) and lower Schwarz information criteria (SIC). There are some implications of these findings include;

(i) The findings of this study imply that exchange rate returns exhibit a behavior that tends to change over time while that of the money market indicator appears to be fairly stable.
(ii) This follows that investors need to consider risks involved in exchange rate markets before making investment decisions in terms of deposit money market transaction.
(iii) Thirdly, we find significant cross-variables returns and shock spillovers between exchange rate and money market indicators.
(iv) In addition, the exchange rate and money market rate are more susceptible to external shocks as there exist the present of strong GARCH (1,1).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2629.861	NA	2961.162	16.50697	16.54238	16.52111
1	-2601.623	55.76880	2624.704	16.38635	16.52799*	16.44292*
2	-2595.431	12.11255	2671.364	16.40395	16.65182	16.50294
3	-2589.562	11.36888	2724.442	16.42359	16.77768	16.56500
4	-2571.700	34.26900*	2577.381*	16.36802*	16.82835	16.55186

Multivariate Diagonal BEKK –GARCH with Normal error Distribution

```
System: UNTITLED
Estimation Method: ARCH Maximum Likelihood (BFGS / Marquardt steps)
Covariance specification: Diagonal BEKK
Date: 02/14/19   Time: 02:07
Sample: 1991M02 2017M12
Included observations: 323
Total system (balanced) observations 969
Presample covariance: backcast (parameter =0.7)
Convergence achieved after 48 iterations
Coefficient covariance computed using outer product of gradients
                              Coefficient   Std. Error   z-Statistic   Prob.
C(1)                          0.197353      0.178564     1.105226      0.2691
C(2)                          0.065018      0.146291     0.444438      0.6567
C(3)                          -0.141009     0.162682     -0.866780     0.3861
                              Variance equation coefficients
C(4)                          1.508953      0.228832     6.594155      0.0000
C(5)                          0.035180      0.204263     0.172226      0.8633
C(6)                          0.042607      0.127279     0.334752      0.7378
C(7)                          1.181901      0.141258     8.366969      0.0000
C(8)                          0.561101      0.087547     6.409138      0.0000
C(9)                          1.109899      0.197285     5.625878      0.0000
C(10)                         0.629765      0.064869     9.708257      0.0000
C(11)                         0.603192      0.036497     16.52727      0.0000
C(12)                         0.575942      0.046810     12.30388      0.0000
C(13)                         0.752293      0.037937     19.83013      0.0000
C(14)                         0.803493      0.018094     44.40560      0.0000
C(15)                         0.827289      0.018935     43.69189      0.0000
Log likelihood                -2380.221     Schwarz criterion          15.00652
Avg. log likelihood           -2.456369     Hannan-Quinn criter.       14.90112
Akaike info criterion         14.83109
Equation: REXCHRATE = C(1)
R-squared                     -0.046031       Mean dependent var       1.086046
Adjusted R-squared            -0.046031       S.D. dependent var       4.148597
S.E. of regression            4.243004        Sum squared resid        5796.994
Durbin-Watson stat            1.249847
Equation: RMLRATE = C(2)
R-squared                     -0.000137       Mean dependent var       0.120477
Adjusted R-squared            -0.000137       S.D. dependent var       4.750449
S.E. of regression            4.750774        Sum squared resid        7267.493
Durbin-Watson stat            2.127896
Equation: RPLRATE = C(3)
R-squared                     -0.000518       Mean dependent var       -0.037338
Adjusted R-squared            -0.000518       S.D. dependent var       4.562551
S.E. of regression            4.563733        Sum squared resid        6706.506
Durbin-Watson stat            2.222938
```

Covariance specification: Diagonal BEKK
GARCH = M + A1*RESID(-1)*RESID(-1)'*A1 + B1*GARCH(-1)*B1
M is an indefinite matrix
A1 is a diagonal matrix
B1 is a diagonal matrix

	Transformed variance coefficients			
	Coefficient	**Std. Error**	**z-Statistic**	**Prob.**
M(1,1)	1.508953	0.228832	6.594155	0.0000
M(1,2)	0.035180	0.204263	0.172226	0.8633
M(1,3)	0.042607	0.127279	0.334752	0.7378
M(2,2)	1.181901	0.141258	8.366969	0.0000
M(2,3)	0.561101	0.087547	6.409138	0.0000
M(3,3)	1.109899	0.197285	5.625878	0.0000
A1(1,1)	0.629765	0.064869	9.708257	0.0000
A1(2,2)	0.603192	0.036497	16.52727	0.0000
A1(3,3)	0.575942	0.046810	12.30388	0.0000
B1(1,1)	0.752293	0.037937	19.83013	0.0000
B1(2,2)	0.803493	0.018094	44.40560	0.0000
B1(3,3)	0.827289	0.018935	43.69189	0.0000

Multivariate diagonal BEKK –GARCH with student's-t error distribution

System: UNTITLED
Estimation Method: ARCH Maximum Likelihood (BFGS / Marquardt steps)
Covariance specification: Diagonal VECH
Date: 02/14/19   Time: 02:10
Sample: 1991M02 2017M12
Included observations: 323
Total system (balanced) observations 969
Disturbance assumption: Student's t distribution
Presample covariance: backcast (parameter =0.7)
Failure to improve likelihood (non-zero gradients) after 68 iterations
Coefficient covariance computed using outer product of gradients

	Coefficient	**Std. Error**	**z-Statistic**	**Prob.**
C(1)	0.120778	0.085341	1.415241	0.1570
C(2)	0.133885	0.072444	1.848123	0.0646
C(3)	-0.051773	0.073925	-0.700339	0.4837
	Variance equation coefficients			
C(4)	1.402945	0.655267	2.141029	0.0323
C(5)	-0.268061	0.586815	-0.456806	0.6478
C(6)	0.068292	0.564171	0.121049	0.9037
C(7)	1.442653	0.609104	2.368484	0.0179
C(8)	0.528961	0.273939	1.930942	0.0535
C(9)	0.864398	0.425089	2.033450	0.0420
C(10)	1.165930	0.573647	2.032487	0.0421
C(11)	0.224585	0.270667	0.829749	0.4067
C(12)	0.041464	0.242881	0.170719	0.8644
C(13)	0.661891	0.301644	2.194279	0.0282
C(14)	0.583276	0.255598	2.282003	0.0225
C(15)	0.732855	0.336332	2.178963	0.0293
C(16)	0.478384	0.056306	8.496131	0.0000
C(17)	0.014523	0.923752	0.015722	0.9875
C(18)	0.089714	4.162533	0.021553	0.9828
C(19)	0.493361	0.040417	12.20666	0.0000
C(20)	0.554548	0.023259	23.84220	0.0000
C(21)	0.580139	0.042820	13.54840	0.0000

```
                            t-Distribution (Degree of Freedom)
C(22)                       2.513800      0.281295      8.936533      0.0000
Log likelihood              -2118.880     Schwarz criterion           13.51352
Avg. log likelihood         -2.186666     Hannan-Quinn criter.        13.35893
Akaike info criterion       13.25622
Equation: REXCHRATE = C(1)
R-squared                   -0.054305     Mean dependent var          1.086046
Adjusted R-squared          -0.054305     S.D. dependent var          4.148597
S.E. of regression          4.259753      Sum squared resid           5842.850
Durbin-Watson stat          1.240038
Equation: RMLRATE = C(2)
R-squared                   -0.000008     Mean dependent var          0.120477
Adjusted R-squared          -0.000008     S.D. dependent var          4.750449
S.E. of regression          4.750468      Sum squared resid           7266.557
Durbin-Watson stat          2.128170
Equation: RPLRATE = C(3)
R-squared                   -0.000010      Mean dependent var         -0.037338
Adjusted R-squared          -0.000010      S.D. dependent var         4.562551
S.E. of regression          4.562574       Sum squared resid          6703.102
Durbin-Watson stat          2.224067
Covariance specification: Diagonal VECH
GARCH = M + A1.*RESID(-1)*RESID(-1)' + B1.*GARCH(-1)
M is an indefinite matrix
A1 is an indefinite matrix
B1 is an indefinite matrix*
                            Transformed variance coefficients
                            Coefficient   Std. Error    z-Statistic   Prob.
M(1,1)                      1.402945      0.655267      2.141029      0.0323
M(1,2)                      -0.268061     0.586815      -0.456806     0.6478
M(1,3)                      0.068292      0.564171      0.121049      0.9037
M(2,2)                      1.442653      0.609104      2.368484      0.0179
M(2,3)                      0.528961      0.273939      1.930942      0.0535
M(3,3)                      0.864398      0.425089      2.033450      0.0420
A1(1,1)                     1.165930      0.573647      2.032487      0.0421
A1(1,2)                     0.224585      0.270667      0.829749      0.4067
A1(1,3)                     0.041464      0.242881      0.170719      0.8644
A1(2,2)                     0.661891      0.301644      2.194279      0.0282
A1(2,3)                     0.583276      0.255598      2.282003      0.0225
A1(3,3)                     0.732855      0.336332      2.178963      0.0293
B1(1,1)                     0.478384      0.056306      8.496131      0.0000
B1(1,2)                     0.014523      0.923752      0.015722      0.9875
B1(1,3)                     0.089714      4.162533      0.021553      0.9828
B1(2,2)                     0.493361      0.040417      12.20666      0.0000
B1(2,3)                     0.554548      0.023259      23.84220      0.0000
B1(3,3)                     0.580139      0.042820      13.54840      0.0000
                                * Coefficient matrix is not PSD

System Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Date: 02/16/19   Time: 10:26
Sample: 1991M02 2017M12
Included observations: 323
```

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	Df
1	52.55832	0.0000	52.72155	0.0000	9
2	63.48067	0.0000	63.71195	0.0000	18
3	72.02376	0.0000	72.33513	0.0000	27
4	99.64742	0.0000	100.3052	0.0000	36
5	120.8047	0.0000	121.7951	0.0000	45
6	134.9654	0.0000	136.2238	0.0000	54
7	152.7274	0.0000	154.3793	0.0000	63
8	190.3441	0.0000	192.9514	0.0000	72
9	208.1538	0.0000	211.2715	0.0000	81
10	223.7651	0.0000	227.3816	0.0000	90
11	248.0447	0.0000	252.5171	0.0000	99
12	269.9683	0.0000	275.2867	0.0000	108

**The test is valid only for lags larger than the System lag order*
df is degrees of freedom for (approximate) chi-square distribution

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Peer-review history:
The peer review history for this paper can be accessed here:
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