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Monetary Policy and Economic Growth in Nigeria: An Ardl-Bound Testing and ECM Approach

Aderemi Timothy Ayomitunde
Olabisi Onabanjo University, Nigeria
Ogundare Oladiran Olaniyi
Sejoro Mauton Zannu
Yaba College of Technology, Nigeria
Balogun Abayomi Stephen
Property Tax Directorate, Kwara State Internal Revenue Service, Nigeria

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Abstract

The aim of this study is to examine the relationship between monetary policy and economic growth in which the past studies have shown conflicting results in Nigeria. Data was collected from the Central Bank of Nigeria Statistical Bulletin from 1990 to 2017 and Autoregressive Distributed Lag (ARDL) model and Error Correction Model (ECM) were utilized to address the objective of the study. Consequently, the result of ECM term indicates that about 16% of the total disequilibrium in the previous year due to shock was corrected in the current year. There is a significant negative relationship between exchange rate and economic growth in the short run. Also, there is a significant positive relationship between monetary policy rate and economic growth in the short run. In addition, economic growth and credit reserve ratio have a negative relationship in both short run and long run. Economic growth and inflation rate have a significant positive relationship in both short run and long run. Therefore, this study makes the following recommendations for the policy makers and future researchers in Nigeria: the policy makers in Nigeria should increase the level of broad money supply in the country since both the broad money supply and inflation lead to economic growth in the short run and the long run. Also, the apex bank in Nigeria should embark on the use of appropriate monetary policy variables that will address non-performance of credit requirement ratio, monetary policy rate and exchange rate in contributing to the nation`s economic growth.

Keywords: Monetary Policy; Economic Growth: ARDL; ECM.

Introduction

Monetary policy is one of the macroeconomic policies that cannot be overemphasized in any economy. Generally, monetary policy is normally used deliberately by the monetary authority to regulate the supply of money and the credit level with a view to achieving some broad economic objectives which might be conflicting in most of times. Primarily, some of objectives of monetary policy in most countries are stability of price, employment generation, maintenance of balance of payments equilibrium, economic growth, and sustainable development. In Nigeria, formulation of monetary policy is centered on the stability of price level and exchange rate in order to ensure a sustainable economic growth and competitive external sector (Sanusi 2012).

It is worth of note that fluctuations in some critical macroeconomic variables such as price level, interest rate, unemployment rate and exchange rate could adversely retard economic growth, this could spell doom for the welfare of people in the country. Over time, attempts to ensure efficient coordination of macroeconomic variables in Nigeria have led to the formulation of various policies by the monetary authorities. For example, the monetary authorities through Central Bank of Nigeria devise the means of managing macroeconomic variables via the money supply and the cost of credit in circulation. In a situation when an economy is expanding too quickly, Central Bank withdrawals some money from circulation and this invariable increases the cost of credit in order to discourage borrowing. Meanwhile, the Central Bank introduces expansionary monetary policy when an economy is slowing down to lower the interest rates with a view to encouraging borrowing for the productive activities in the economy.

However, it has been established in the literature that monetary policy plays a paramount role in achieving macroeconomic objectives in both developed and developing economies (Anna, 2012; Ezigbo, 2012: Senbet, 2011: Ajisaje and Folorunso, 2002). In Nigeria, despite the fact that available evidence is in support of monetary policy in propelling economic growth, yet the literature is controversial. For instance, it has been argued in some quarters that monetary policy rather than fiscal policy impacted a strong and significant influence on the growth of the Nigerian economy (Ajisafe and Folorunso, 2002; Adefeso and Mobolaji, 2010). In another perspective, studies have also reported significant role for fiscal policy (Medee and Menbee, 2011; Philip, 2009). Meanwhile, some scholars argued that none of the two policies is superior as each policy has important role to play in the economy (Enahoro, 2013; Effiong, 2012; Ogege and Shiro, 2012; Sanni et al, 2012). In view of the above inconclusive results of the past studies there is a critical need for further studies on impact of monetary policy on economic growth in the recent time.

In the same vein, the recent economic crisis coupled with double digit inflation and interest rates in Nigeria has now deepened further debate on the effectiveness of monetary policy among economic analysts. Therefore, this study intends to fill this gap by determining the appropriate policy instruments of monetary policy that has the capacity to catalyze economic growth in the country. Similarly, the uniqueness of this study also lies in the adoption of latest econometric technique in which the majority of the past studies have not fully explored.

Objective of the Study

The objective of the study is to examine the short run and the long run relationships between monetary policy and economic growth in Nigeria from 1990 to 2017.

Literature Review

This section presents a critical review of the empirical literature regarding the subject matter of this study.

Enahoro (2013) opined a decrease in financial indiscipline in both financial and fiscal systems in Nigeria is as a result of fiscal and monetary policies. This leads to efficiency in operations of financial institutions in the country. The study therefore concluded that fiscal and monetary policies made the Nigerian government to manage budgetary allocation in such a way to address the lapses in the financial system in the country. Amassoma, Wosa and Olaiya (2011) assessed the link between monetary policy and macroeconomic variables in Nigeria from 1986 to 2009 using a simplified Ordinary Least Squared technique and co-integration tests. They argued that the implementation of monetary policy has been improved over the years. Meanwhile, monetary policy had a significant positive relationship with money supply and exchange rate but an insignificant relationship on stability of price. Sanni et al (2012) enunciated that both the monetary and fiscal policies were not superior to each other. It was the appropriate policy mix that could ensure a better economic growth.

Moreover, Effiong (2012) put forward that monetary and fiscal policy mix could bring about a significant role on the development of stock market in Nigeria while examining the linkage between fiscal, monetary policies and the development of the Nigerian stock market. In another perspective, Umar (2013) investigated the nexus between monetary policy and exchange rate in Nigeria between 1980 and 2011 with the application of Granger causality test and Error Correction Model (ECM). The author concluded that the supply of money and exchange rate had a significant positive relationship with each other. However, reverse was the case of the relationship between monetary policy rate, liquidity ratio and exchange rate. Falade and Folorunsho (2015) utilized error correction mechanism to estimate the relative effectiveness of fiscal and monetary policy instruments on sustainable economic growth in Nigeria from 1970 to 2013. The authors submitted that the current level of exchange rate and its immediate past level, domestic interest rate, current level of government revenue and current level of money supply are the appropriate policy instrument mix to expand economic growth in Nigeria in both the short and long run.

Ogege and Shiro (2012) corroborated that both monetary and fiscal policy led to economic growth while addressing the dynamics of monetary and fiscal policies on economic growth in Nigeria. While investigating the relationship between the monetary and fiscal policy interactions in Nigeria between 1970 and 2008, Chuku (2010) used a vector auto-regression (VAR) model. It was discovered that monetary and fiscal policies have a counteractive interaction from 1980 to 1994, whereas no symmetric pattern of interaction was noticed between the two policies at other periods.

In conclusion, literature on monetary policy and economic growth is ongoing in Nigeria, and empirical studies are inconclusive in the country. Hence, the relevance of this study.

Methodology and Estimation

The data for the empirical analysis in this paper are extracted from secondary sources. To be explicit, data for exchange rate, broad money supply, inflation rate, government expenditure, revenue and real were sourced from CBN statistical Bulletin. E-Views software was employed for the running of the data.

Empirical Model

RGDP = F (Exch, BMS, MPR, CRR, Infl) -----------------------------------1

If model 1 is linearized to form model 2

$LnRGDP_t = \quad \propto_i + \beta 0 LnExch_t + \beta 1 LnBMS_t + \beta 2 Infl_t + \beta 5 MPR + \beta LnCRR + \mu_i$ ----2

The adoption of ARDL in this work is motivated by its advantageous positions over other econometric models like Granger causality, Engle and Granger (1987) and Johansen and Juselius (1990) which often stipulate that the variables should be of the same order of integration before it can ensure best estimate. Therefore, the variables of interest have different orders of integration that is the reason why this study utlized Autoregressive Distributed Lag (ARDL) model in addressing its objective.

ARDL Model Specification

In a general form, ARDL model can be specified as follows

$\Delta LnRGDP_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \ \Delta Ln\ RGDP_{t-1} + \sum_{i=0}^{p} \beta_2 \Delta Infl_{t-1} + \sum_{i=0}^{p} \beta_3 \Delta\ LnExch_{t-1} + \sum_{i=0}^{p} \beta_4 \Delta\ LnBMS_{t-1} + \sum_{i=0}^{p} \beta_5 \Delta\ LnMPR_{t-1} + \sum_{i=0}^{p} \beta_6 \Delta\ LnCRR_{t-1} + ECM_{t-1} + \sum_{i=1}^{p} \beta_7 \ Ln\ RGDP_{t-1} + \sum_{i=0}^{p} \beta_8 \ Infl_{t-1} + \sum_{i=0}^{p} \beta_9 \ LnExch_{t-1} + \sum_{i=0}^{p} \beta_{10} \ LnBMS_{t-1} + \sum_{i=0}^{p} \beta_{11} \ LnMPR_{t-1} \sum_{i=0}^{p} \beta_{12} \ LnCRR_{t-1} + \mu i$ --- 3

Where RGDP is used to proxy economic growth.
Infl is used to denote inflation rate.
Exch is used to represent exchange rate
BMS means broad money supply.
MPR is used to represent monetary policy rate
CRR is used to capture credit requirement ration
ECM means error correction model
μ_i is error term.
t =1990-2017. L is natural logarithm
Meanwhile, term β_1-β_6 is measures short run parameters/ coefficients meanwhile β_7-β_{12} measures long run parameters. It is expected that $\beta_1 - \beta_{12} > 0$.

Results

Table 2: Descriptive Statistics of Annual Data Series (1990-2017)

Descriptive Statistics	LExch	LRGDP	Infl,	LBMS	MPR	CRR
Mean	4.300743	42.44046	18.71679	28.24124	13.65393	7.733214
Median	4.815250	31.28159	12.55000	28.34417	13.50000	8.150000
Maximum	5.857933	346.1660	72.84000	30.73363	26.00000	14.80000
Minimum	2.084156	30.60445	5.380000	24.69091	6.250000	1.000000
Std. Deviation	1.061811	59.52657	17.42350	1.901245	3.888777	4.086862
Skewness	-0.709526	5.003169	1.958346	-0.258470	0.903222	-0.157772
Kurtosis	2.095351	26.03362	5.646040	1.794715	5.148707	1.846396
Jargue-Bera	3.304115	735.7866	26.06566	2.006593	9.193549	1.668764
Probability	0.191655	0.000000	0.000002	0.366669	0.010084	0.434143
Sum	120.4208	1188.333	524.0700	790.7547	382.3100	216.5300
Sum. Sq. Deviation	30.44095	95672.15	8196.619	97.59776	408.3099	450.9660
Observation	28	28	28	28	28	28

Source: Authors` Computation (2019)

It could be deduced that total number of 28 observations were considered in this study. Exchange rate deviates from its mean by 59.52657but ranging between 2.084156 and 5.857933. Real GDP deviates from its mean by 4.8295 but ranging between 30.60445and 346.1660. Inflation rate deviates from its mean by 17.42350 but ranging between 5.380000 and 72.84000. Broad money supply deviates from its mean by 3.888777but ranging between 24.69091and 30.73363. Monetary policy rate deviates from its mean by 3.888777but ranging between 6.250000and 26.00000 Credit reserve ratio deviates from its mean by 4.086862but ranging between 1.000000 and 14.80000.exchange rate, broad money supply and credit reserve ratio are negatively skewed while other variables are positively skewed. However, values of Kurtosis of variables like exchange rate, broad money supply and credit reserve ratio are not far from 3.

Table 2: Unit Root Test

Variables	ADF Test			PP Test		
	Level	1st Difference	Remarks	Level	1st Difference	Remarks
LRGDP	-2.976263*		I (0)	-2.976263*		I (0)
LExch	-2.976263*	-2.981038*		-2.976263*	-2.981038***	
LBMS	-2.976263*		I (0)	-2.976263*		I (0)
LCRR	-2.976263*	-2.981038*	I (1)	-2.976263*	-2.981038	I (1)
LMPR	-2.976263*		I (0)	-2.981038*		I (0)
Infl	-2.976263*	-2.981038*	I(1)	-2.976263*	-2.981038*	I(1)

Source: Author`s Computation (2019)

* %5 level

Unit root tests were estimated in the study to detect stationarity otherwise of all the variables. If variables are not stationary in the analysis, there is high tendency it leads to spurious estimates. Therefore, this study used the standard Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to examine the stationarity or otherwise of the data. Consequently, the results of the estimated Augmented Dickey-Fuller (ADF) and Philip Perron tests in the above table show that variables such as exchange rate, credit reserve ratio and inflation rate were not stationary in their level form, whereas real GDP, broad money supply and monetary policy rate were stationary in their native form. This implies that the variables in these study are mixture of I(1) and I(0).

Table 3: ARDL Bounds Test

Sample: 1992 2017
Included observations: 26
Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	3.868210	5

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79

Source: Authors` Computation (2019)

The dataset is a combination of stationarity and non-stationarity, as such the study utilized Bound Test to determine the existence or otherwise of the long run equilibrium relationship among these set of variables (Pesaran and Pesaran 1997: Pesaran, Shin and Smith 2001). Consequently, table 3 confirms a presence of cointegrating relationship among the variables in the model since the Null hypothesis of no long run relationship could not be accepted because the upper and lower Critical Value Bounds at all level of significance is less than the value of F-Statistic.

Table 3: Parsimonious Short Run and Long Run Regression Estimates

Dependent Variable: LnRGDP

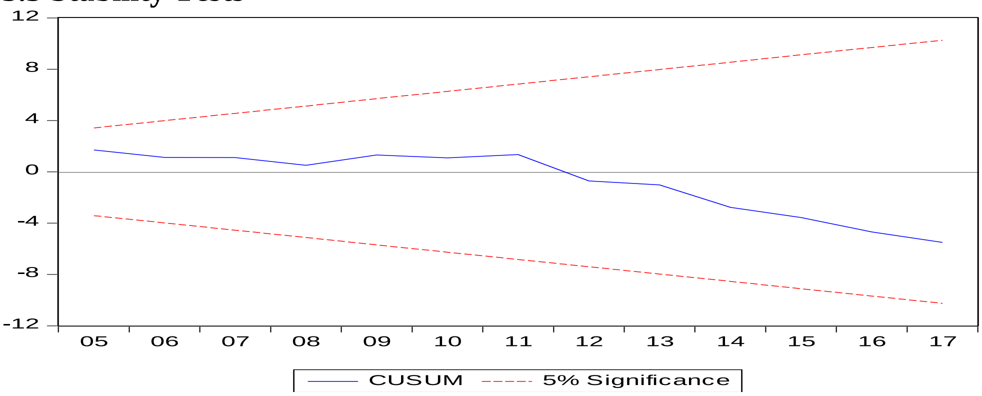
Short Run	coefficient	T-statistics	Long Run	coefficient	T-statistics
DLBMS	15.20934	1.528700	LBMS	17.62640	0.118240
DLExch	-11.18722	2.097244	LExch	11.71442	0.451914
DMPR	9.503586	3.229469	MPR	-4.627860	1.856683
DCRR	-4.442366	1.838641	CRR	-2.554641	0.754661
DInfl	5.449721	6.690797	Infl	2.896883	3.626512
ECM	-0.164870	3.980444	R-squared	0.699537	
R-Squared	0.882447		A.R-squared	0.519260	
Adj.R-Squared	0.804078		DWstat	1.617889	
DWstat	2.103195				

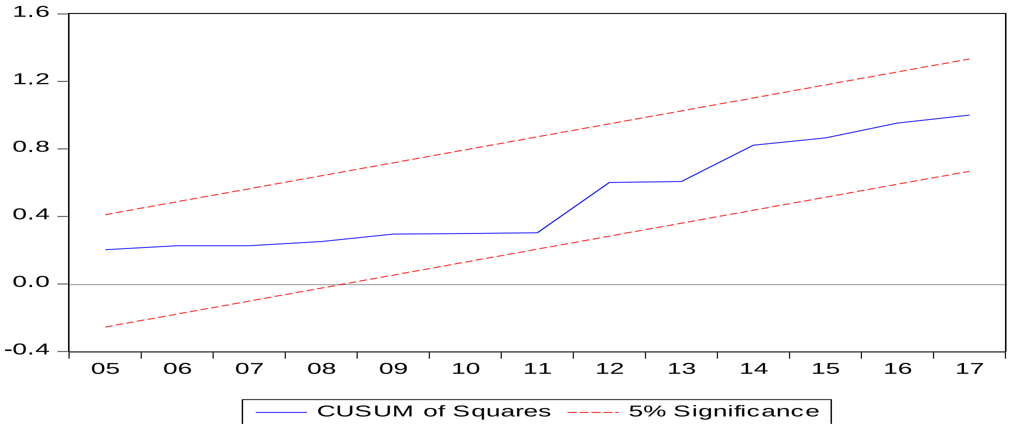
Source: Authors` Computation (2019)

The ARDL results of both the short and long run relationship between monetary policy and other macroeconomic variables are presented in the above table. From the results it could be deduced that when economic growth is the dependent variable, no significant relationship exists between economic growth and broad money supply in both short and long run. This implies that broad money supply has a positive but no significant effect and on economic growth. However, there is a significant relationship between exchange rate and economic growth in the short but the relationship becomes insignificant in the long run, therefore interest rate has a negative impact on economic growth. Also, there is a significant relationship between monetary policy rate and economic growth in the short run and the long run. Meanwhile, the relationship between economic growth and monetary policy rate is positive in the short run but negative in the long run. In addition, economic growth and credit reserve ratio have a negative relationship in both short run and long run, the short run is significant at 10% level of significance but long run relationship is not significant. Economic growth and inflation rate have a significant positive relationship in both short run and long run.

Consequently, the coefficient of Error Correction Model (ECM) which shows the speed of adjustments back to equilibrium in the estimated model is negative and significant at 5% level of significance. This implies that an approximately 16% of disequilibrium from the previous year's shock is corrected in the current year. In addition, the model adopted for this work is relatively good because the result of R-Squared in the short run and long run lies between 70% and 88%. This implies that 88% and 70% systematic variation in the dependent variable, economic growth is jointly explained by all the explanatory/ independent variables in the short run and in the long run respectively. Also, the result of the Durbin Watson statistic indicates that the model is free from first order autocorrelation.

3.3 Stability Tests





It is important to establish the appropriateness of the short run (parsimonious) model adopted for this work. In view of the above, further attempt was made to subject the data to stability tests using the cumulative sum of recursive residual (CUSUM) and the cumulative sums of squares (CUSUMQ) on the residual of the short run model. The results of cumulative sum (CUSUM) test shows that the residuals of the error-correction model lies within the critical bounds of five percent significant level. This confirms the stability of the estimated parameters over the period 1990-2017. Hence, the model has been reasonably specified.

Conclusion

This paper has examined the relationship between monetary policy and economic growth in Nigeria between 1990 and 2017 using Bound Test, ARDL and ECM model. The findings of this study could be summarized below; the error correction term showed that about 16% of the total disequilibrium in the previous year due to shock was corrected in the current year. There is no significant positive relationship between economic growth and broad money supply in both short and long run. However, there is a significant negative relationship between exchange rate and economic growth in the short but the relationship becomes insignificant in the long run, therefore exchange rate has a negative impact on economic growth. Also, there is a significant positive relationship between monetary policy rate and economic growth in the short run but becomes negative in the long run. In addition, economic growth and credit reserve ratio have a negative relationship in both short run and long run, the short run is significant but reverse is the case in the long run. Economic growth and inflation rate have a significant positive relationship in both short run and long run.

As a result of these important findings that came up, this study therefore makes the following recommendations for the policy makers and future researchers in Nigeria: the policy makers in Nigeria should increase the level of broad money supply **through the deposit money banks** in the country since both the broad money supply and inflation lead to economic growth in the short run and the long run. Also, the apex bank in Nigeria should embark on the use of appropriate monetary policy variables that will address non-performance of credit requirement ratio, monetary policy rate and exchange rate in contributing to the nation`s economic growth. Also this study serves as a foundation upon which future researchers can buld their studies.

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Modeling Exchange Rate Volatility in the Presence of Serial Correlations

Emmanuel Dodzi Kutor Havi, M.Phil.
Methodist University College Ghana, Ghana

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Abstract

The objective of this study was to model the volatility in GHC/US$ exchange rate series taking into consideration the presence of serial correlation. The data used was GHC/US$ exchange rate from January 2000 to August 2019. To select appropriate model for modeling volatility GARCH(p,q), TARCH(p,q) EGARC(p,q), PARCH(p,q) and APARCH(p,q) were estimated and evaluated. The ARMA(3,3)-TARCH(2,1)-GED was selected as the appropriate model. It was found out that the return series had serial correlation problem. It was found that heteroscedasticity was present and was captured by ARMA(3,3)-TARCH(2,1) model under general error distribution but could not account for the serial correlation in the return series. However, the corresponding GARCH-M-TARCH(2,1) model under general error distribution sufficiently captured the presence of serial correlation. From the results when the existence of serial correlations were ignored in the return series the parameters estimated will be bias and inefficient. Hence, the application of GARCH-M types of models provided possible feedback between the variance and the mean equations. It was also found out that previous information about volatility and the previous volatility had significant effect on the current day volatility. From the result there was no leverage effect and the impact of news was asymmetric.

Keywords: Exchange rate; serial correlations; volatility; GARCH-in-Mean-GARCH-type.

Introduction

The exchange rate movements and fluctuations over the past few years had become very important issue among economists, financial analyst and policy makers. More importantly, after the collapse of the Bretton Wood agreement of fixed exchange rates among major industrial nations. Exchange rate volatility is the risk associated with the unexpected movement in the exchange rate; that is, the risk associated with currency depreciation or appreciation over time. Since the collapse of fixed exchange rate, the issue of volatility of exchange rate and its influence on wellbeing and some macroeconomics variables and competitiveness of the economy in the world market. Also, the role it plays in security valuation; investment and profitability and risk analysis. As a result, various models had been developed to investigate this volatility across different nations and regions.

In the recent past the issue of modelling volatility in exchange rate has become very important as more countries shifted to flexible exchange rate regime. In modeling volatility on returns of exchange rates, analyst most often assumed that the series of the financial variable do not have serial correlation. However, it has been observed that financial variables with very small period between observations may have a significant autocorrelation; a relationship that exist between or among a variable and its lagged-value over a period of time. Therefore, this study aimed at investigating the existence of serial correlations in the effective exchange rate of the Ghana Cedis to the US Dollar, GHC/US$ series and also its effect on the parameter estimates of volatility model. This paper aimed at modelling the volatility in exchange rate of the GHC/US$ series considering high frequency daily and monthly observations. The following research questions will be used to guide the study.

- Does serial correlations exist in the GHC/US$ series?
- Which of the GARCH(p,q) best model volatility in the GHC/US$ series?
- Does serial correlation affect the parameters estimated?

Also, to guide the study the following hypotheses will be tested:

H_0: Serial correlations do not exist in the GHC/US$ series.

H_1: Serial correlations do exist in the GHC/US$ series.

H_0: The serial correlation does not affect the parameters of the estimates.

H_1: The serial correlation affects the parameters of the estimates.

Decision Rule: Accept the alternative hypothesis if the p-value associated with a parameter is less than or equal to 0.05 otherwise reject the alternative hypothesis.

The findings from this study will be useful for dealers in the exchange rate like the banks, import and export traders.

The rest of the study will be organized as follows, the review of literatures will be discussed in section two. Section three will present the methods used while section four will present the results and discussion. Finally, the conclusion and recommendations will be presented in section five.

Literature Review

Issues of exchange rate volatility has remained very vital because of its implications on individual and cooperate transactions as well as national policies. However, most researchers investigating volatility in financial variables, for example exchange rate, ignore the existence of serial correlation or autocorrelation in the return series generated. Some of the articles related to the current issue are reviewed below.

The conditional heteroscedasticity of the Yen against Dollar exchange rate was examined by Tse (1998). In this study a model was constructed by extending the APARCH model to a process that is fractionally integrated. It was found that, the appreciation and depreciation shocks of the yen against the dollar have similar effects on future volatilities. Although, the results rejected both the stable and the integrated models, the analysis of the response coefficients of the past shocks and the application of the models to the estimation of the capital requirements for trading the currencies showed that there were no substantial differences between both models estimated.

In the same vein, Clement & Samuel (2011) modelled the volatility persistence and asymmetry of naira-dollar exchange rate in interbank and Bureau de Change (BDC) using monthly data between January 2004 and November 2017. The study employed GARCH(1,1), TGARCH (1,1) and EGARCH(1,1)]. The findings showed that persistence was generally explosive in the BDC market as compared to interbank market where the persistence was high but not explosive especially under asymmetric models. Based on the model selection criteria, the symmetric GARCH model, appears to be better than the asymmetric ones in dealing with exchange rate volatility in the interbank market while asymmetric GARCH, especially TGARCH, seems to be better in the case of BDC market.

Also, Alam (2012) explored the application of GARCH type models to model the BDT against US dollar using daily exchange rate published by the Bank of Bangladesh. The study used AR and ARMA models as benchmark. The exchange rate from July 03, 2006 to April 30, 2012 was used. For the purpose of the study observations from July 03, 2006 to May 13, 2010 and May 14, 2012 to April 30, 2012 for in-sample and out-of-sample, respectively. The finding showed that in the GARCH models the previous had significant impact on the current volatility. Both AR and ARMA models were better in in-sample performance while TGARCH(1,1) was better in out-of-sample with transaction costs. The EGARCH(1,1) and TGARCH(1,1) were best in in-sample and out-of-sample trading performance, respectively, including transaction costs.

Ramasamy & Munisamy (2012) compared 2) compares three simulated exchange rates of Malaysian Ringgit with actual exchange rates using GARHC, GJR and EGARCH models. For testing the forecasting effectiveness of GARCH, GJR and EGARCH the daily exchange rates for four currencies viz Australian Dollar, Singapore Dollar, Thailand Bhat and Philippine Peso are used. The forecasted rates, using Gaussian random numbers, are compared with the actual exchange rates of year 2011 to estimate errors. Both the forecasted and actual rates are plotted to observe the synchronisation and validation. The results showed more volatile exchange rates were predicted well by these GARCH models efficiently than the hard currency exchange rates which were less volatile. Among the three models the effective model is indeterminable as these models forecast the exchange rates in different number of iterations for different currencies. The leverage effect incorporated in GJR and EGARCH models did not improve the results much.

Finally, Moffat & Akpan (2019) modeled heteroscedasticity of returns taking into consideration the presence of serial correlations. The study used stock prices from the Nigeria Stock Market from January 3, 2006 to November 24, 2016. The ARIMA-GARCH-type models such as ARIMA-GARCH, ARIMA-EGARCH and ARIMA- GJRGARCH using normal and student's distributions. Also, the GARCH-M-GARCH model corresponding to the selected model was used to capture the presence of autocorrelation. From the result, the presence of heteroscedasticity was confirmed and well capture by ARIMA(2,1,1)-EGARCH(1,1) with student-t distribution, but failed to account for the existence of serial correlation in the return series. However, the corresponding GARCH-M-EGARCH(1,1) account significantly for the serial correlation.

From the above empirical studies the issue of serial correlation was ignored except Moffat & Akpan (2019). However, when serial correlation is present in the return series but ignored in the estimation process according to Zhao, el al. (2014) the parameter estimates becomes bias and inefficient. For that matter when GARCH results are compared with other output like AR or ARIMA as the case in Alam (2012), the AR or ARIMA turned to outperform the GARCH results because the parameters from the GARCH model might had been bias. Therefore, this study used Ghanaian high frequency daily and monthly exchange rate from January 2000 to August 2019 to investigate the effect of serial correlation on the parameter estimates of the exchange rate volatility. This study will contribute to knowledge on modeling exchange rate volatility. The result will be useful to exchange rate dealers who might have been using bias estimates previously for their works.

Methodology

The presence of serial correlations in most financial variables are ignored when analyzing such series. However, according to Tsay (2010) the presence of serial correlation in the financial variables was the result of time varying heteroscedasticity process. Also, according to Zhao, el al. (2014) if the serial correlations are not taken into consideration when modelling the parameters estimated will be bias. Therefore, to account for the serial correlation in modelling volatility, Engle, el al. (1987) proposed the modification of standard GARCH type models assuming that the variance coefficient in the mean equation measures relative risk aversion. This modification to standard GARCH model is referred to as GARCH-in-Mean model. It allowed the conditional variance of the returns series to have impact on the conditional mean.

The data used in this study was daily and monthly exchange rate, GHC-US$, from January 2000 to August 2019, Bank of Ghana's database (www.bog.gov.gh). Since the nominal exchange rates series are non-stationary, it will be converted by logarithmic transformation into rate of return on the exchange rate as shown in equation [1] below. In this case, let E_t, t = 1, 2, …, n, be the exchange rate, therefore, the log-return (R_t) on E_t is expressed as:

$$R_t = \ln(E_t) - \ln(E_{t-1}) \quad \text{……….. [1]}$$

The mean equation formed is shown equation [2] below and various specifications of the mean equation will be estimated and tested for the presence of heteroscedasticity. The mean equation in this study is specified as;

$$R_t = c + a_1 AR(1) + k_1 MA(1) + ... + a_i AR(i) + k_i MA(i) + e_t \quad \text{............ …. [2]}$$

where *c* is constant term, *i* is the optimal lag of ARMA (Autoregressive Moving Average) term that makes coefficients significant, a_i and k_j are coefficients of the ARMA terms, respectively, and e_t – error term. To select appropriate model for volatility persistence and asymmetric effect GARCH(p,q), TARCH(p,q) and EGARCH(p,q), PARCH(p,q) and APARCH(p,q) will be used and their specifications are stated below.

The Generalized Autoregressive Conditional Heteroscedasticity, GARCH(p,q)

Bollerslev (1986) and Taylor (1986) introduced GARCH model that allows conditional variance to depend on its own previous lags and previous lag of square residuals of the mean equation. It is specified as:

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i e_{t-i}^2 + \sum_{ji=1}^{q} \beta_j \sigma_{t-j}^2 + \mu_t \quad \text{………………….. [3]}$$

where σ_t^2 – conditional variance or current day/month's variance of conditional volatility of exchange rate return, σ_{t-j}^2 – previous day/month's conditional variance or the GARCH term., e^2_{t-i} – previous day/month's news about conditional volatility or the ARCH term, ω – constant term, α_i – coefficient of ARCH term and β_j – coefficient of GARCH term. For the variance to remain well behaved $\alpha_i \geq 0$ and $\beta_j \geq 0$, also, the sum of coefficient of ARCH and GARCH terms should be less than one; $\alpha_i + \beta_j < 1$ to ensure that the series is stable and the variance is positive.

The Threshold GARCH, TARCH(p,q**)**

The TGARCH was introduced by Zakoan (1994) and Glosten et al (1993) to analyze the leverage effect and it `is specified as;

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i e_{t-i}^2 + \sum_{k=1}^{r} \lambda_k d_{t-k} e_{t-k}^2 + \sum_{ji=1}^{q} \beta_j \sigma_{t-j}^2 + \mu_t \text{ ………………….. [4]}$$

where $d_{t-k} = 1$ if $e_{t-i} < 0$ and zero otherwise. In this model, good news, $e_{t-i} > 0$ and bad news $e_{t-i} < 0$, have different effect on the conditional variance . Good news has impact of α_i while bad news has impact of $\alpha_i + \lambda_k$. If $\lambda_k > 0$, it means bad news increase volatility hence leverage effect, if $\lambda_k \neq 0$, the news impact is asymmetric.

The Exponential GARCH, EGARCH (p,q**)**

The EGARCH model was proposed by Nelson(1991) and was specified as:

$$\log(\sigma_t^2) = \omega + \sum_{i=1}^{p} \alpha_i \left| \frac{e_{t-i}}{\sigma_{t-i}} \right| + \sum_{k=1}^{r} \gamma_k \frac{e_{t-ik}}{\sigma_{t-k}} + \sum_{ji=1}^{q} \beta_j \log(\sigma_{t-j}^2) + \mu_t \text{ ………. [5]}$$

where $\log H_t^2$ – the natural logarithm of conditional variance, $\log(H_{t-1}^2)$ – previous day's natural log of conditional variance, ω – constant term, α – parameter represents a magnitude effect; γ - parameter measures the asymmetric or the leverage effect. If $\gamma = 0$, then the model is symmetric; if $\gamma < 0$, there is presence of leverage effect; finally, if $\gamma > 0$, the impact is asymmetric, β – measures the persistence in conditional volatility irrespective of what is happening in the foreign exchange rate market.

Power ARCH, PARCH(p,q)

Taylor(1986) and Schwert(1989) introduced the standard deviation form of GARCH model, where standard deviation was modelled rather than the variance. This model with other forms of specifications were generalized in Ding et al (1993) with power ARCH (PARCH) specification. In PARCH specification there is optional parameter added to capture asymmetry of up to order r:

$$\sigma_t^{\delta} = \omega + \sum_{i=1}^{p} \alpha_i (|e_{t-i}| - \gamma_i e_{t-i})^{\delta} + \sum_{ji=1}^{q} \beta_j \sigma_{t-j}^{\delta} + \mu_t \text{ …………………… [6]}$$

where $\delta > 0$, for $\gamma_i \leq 1$, for all $i = 1,...,r$, $\gamma_i = 0$, for all $i > r$ and $r \leq p$. For a symmetric model, $\gamma_i = 0$, for all *i* while asymmetric effects are present if $\gamma \neq 0$.

GARCH-in-Mean, GARCH-M, Model

The mean equation [2] is modified to obtain GARCH-M model in equation [7] such that the return series is influenced by the conditional variance. According to Tsay(2010) this specification implies that there are serial correlation in the series.

$$R_t = c + b\sigma^2 + a_i AR(i) + k_j MA(j) + e_t \quad \ldots\ldots\ldots.. \quad [7]$$

Where the parameter *b* is variance coefficient. The significance of the variance coefficient shows that the returns series has serial; the return series is related to its variance.

Model Evaluation

The error term from the variance equations estimated will be evaluated based on heteroscedasticity, serial correlation and normality tests. For good model the residual should not have serial correlation, should be homoscedastic and finally it should be normally distributed. But the error term from the GARCH results are usually not normally distributed. Therefore, for a model to be selected for estimation has to pass the test of serial correlation and heteroscedasticity. Hence, the following hypotheses will be tested at 5 percent level of significance on the error term of the various variance equations estimated. Firstly, the serial correlation will be tested using a correlogram of squared residuals.

H_0: There is no serial correlation in the error term.

H_1: There is serial correlation in the error term.

Also, the heteroscedasticity will be tested using an ARCH-LM test, the Chi-square and the corresponding probability will be examined.

H_0: There is no ARCH affect or there is no heteroscedasticity.

H_1: There is ARCH affect or there is heteroscedasticity.

Finally, histogram-normality test will be used to check the normality of the residual terms. Jarque-Bera statistics with the corresponding p-value will be examined.

H_0: The error term is normally distributed.

H_1: The error term is not normally distributed.

RESULTS AND DISCUSSION.

Preliminary analysis

The figure 4.1 showed the graph of exchange rate (EXC) and the return series (RT). The exchange rate from the plot was not stationary given the trending pattern it depicted in the graph. However, the return series was stationary as it was revolving around the mean as shown in the graph. Stationarity of the return series was achieved by transforming the exchange rate using equation (1) and the return series was found clustering round the common mean and hence indicating the presence of heteroscedasticity.

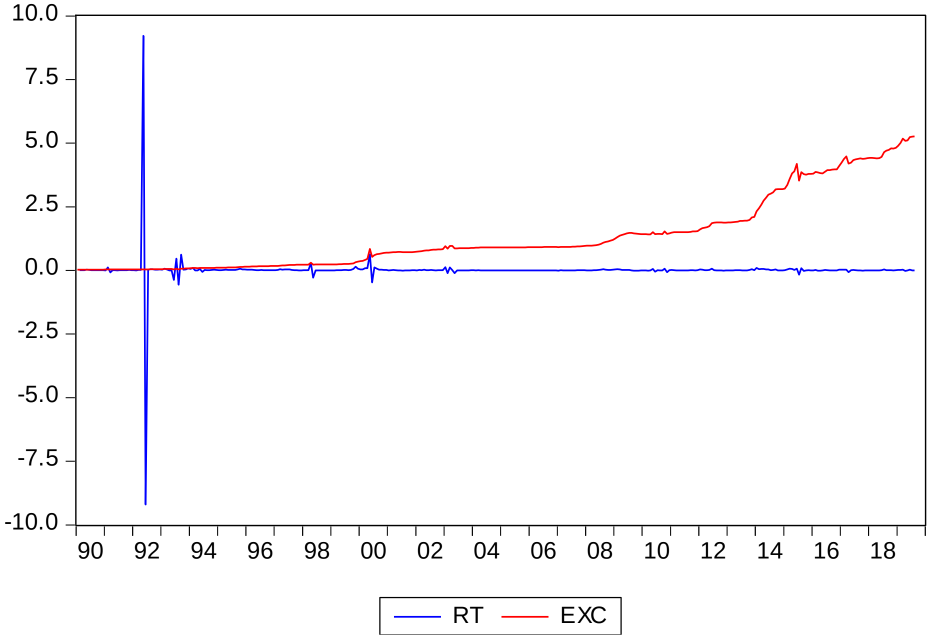

Figure 4.1: Exchange rate and its return series, Jan. 2000 to Aug. 2019

The Table 4.1 below showed the summary statistics of the daily and monthly returns on the exchange rate. From the table, the mean monthly returns was higher than the daily one with standard deviation of 0.059 and 0.0027, respectively. Considering the distribution both returns were positively skewed and leptokurtic. Considering the Jarque-Bera statistics with the corresponding probability, the returns on exchange rate were not normally distributed.

Table 4.1: The summary statistics of the daily and monthly returns, Jan. 2000 to Aug. 2019

	RT - daily	RT - monthly
Mean	0.000531	0.011533
Median	0.00019	0.004204
Maximum	0.037648	0.63255
Minimum	-0.02697	-0.47086
Std. Dev.	0.002698	0.059011
Skewness	2.482421	2.579061
Kurtosis	76.42087	72.28462
Jarque-Bera	1157515	47465.15
Probability	0	0
Sum	2.721842	2.721842
Sum Sq. Dev.	0.037333	0.818352
Observations	5130	236

The results of the Augmented Dickey-Fuller unit root tests on the exchange rate was shown in Table 4.2. Considering the daily return series, the t-statistics with the corresponding probability showed that in level the null hypothesis of unit roots existing is rejected. Also, considering the monthly return series, the t-statistics with the corresponding probability showed that in level the null hypothesis that there is a unit roots is rejected. Therefore, both daily and monthly the return series were stationary in level.

Table 4.2: ADF unit root test on exchange rate, Jan. 2000 - Aug. 2019

	none		constant		cons and trend	
	t-Statistic	Prob	t-Statistic	Prob	t-Statistic	Prob
Daily	-10.1688	0	-10.7602	0	-10.7725	0
Monthly	-4.05416	0.0001	-4.58659	0.0002	-4.54376	0.0016

The serial correlation test on return series for both daily and monthly data were shown in Table 4.3. From the table, lag 1, 10, 20, 30 and 36 of square residual of both series, the null hypotheses of no serial correlation were rejected. Therefore, there exist serial correlation in both return series.

Table 4.3: Serial correlation test on both return series, Jan. 2000 - Aug. 2019

	Daily				Monthly			
Lag	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
1	0.127	0.127	125.19	0	-0.501	-0.501	89.726	0
10	0.02	0.01	248.83	0	0.003	-0.079	89.735	0
20	0.005	0	259.72	0	-0.002	-0.046	92.781	0
30	-0.018	-0.011	275.17	0	0	-0.002	92.816	0
36	-0.031	-0.019	303.84	0	0	0.003	92.818	0

The result of Breusch-Pagan-Godfrey heteroscedasticity Test on the residual from the mean equation of ARMA(3,3) was shown in the table 4.4. Considering the daily return series, F-statistics (2.44) with the corresponding probability (0.04), since the p-value is less than 0.05 the null hypothesis of homoscedasticity is rejected. Considering the monthly return series, F-statistics (7.834) with the corresponding probability (0), since the p-value is less than 0.05 the null hypothesis of homoscedasticity is rejected. Therefore, in the daily and monthly return series alternative hypothesis was accepted; that is, there is Heteroskedasticity in both series to be modelled.

Table 4.4: Heteroscedasticity test on mean equation's residual, Jan. 2000 - Aug. 2019

Daily		Monthly	
F-statistic (2.442)	Prob. F(4,5125) = 0.045	F-statistic (7.83471)	Prob. F(4,231) =0
Obs*R-squ. (9.759)	Prob. Chi-Squ.(4) = 0.045	Obs*R-squ. (28.19)	Prob. Chi-Squ.(4) = 0

The results of symmetric and asymmetric GARCH models for both daily and monthly return series were shown in Table 4.5. Considering the models estimated, that is, ARMA(3,3)-GARCH(2,1), ARMA(3,3)-TARCH(2,1), ARMA(3,3)-EGARCH(2,1), ARMA(3,3)-PARCH(2,1) and ARMA(3,3)-APARCH(2,1), the ARMA(3,3)-APARCH(2,1)-std with Log likelihood of 44463.8 and AIC (-17.323) was best performing model and fitting the data for the daily return series and the corresponding monthly result with Log likelihood of 727.494 and AIC (-6.03809). This showed that the best model to fit this data was asymmetric model. However, there is a problem of convergence in ARMA(3,3)-APARCH(2,1)-std when the variance is introduced to the mean equation, therefore, the second best asymmetric model ARMA(3,3)-TARCH(2,1)-GED with log likelihood of 43197.3 with AIC (-16.84) for the daily return series and the corresponding monthly result with Log likelihood of 706.465 and AIC (-5.868) will be used instead. Therefore, the ARMA(3,3)-TARCH(2,1)-GED was the appropriate model selected for the examination of the effect of serial correlation on the parameters estimated.

Table 4.5: Result of GARCH models and model selection

	Daily				Monthly			
GARCH(1,2)	student t							
Variable	Coeff	Std. Error	z-Statistic	Prob.	Coeff	Std. Error	z-Statistic	Prob.
C	0.0000	0.0000	0.1080	0.9140	0.0005	0.0015	0.3315	0.7403
@TREND	0.0000	0.0000	0.1108	0.9118	0.0000	0.0000	0.3405	0.7335
RT(-1)	0.9737	10.405	0.0936	0.9254	-0.0613	0.5908	-0.1038	0.9173
RT(-2)	0.0198	12.339	0.0016	0.9987	0.6305	0.0477	13.2123	0.0000
RT(-3)	0.0001	3.5963	0.0000	1.0000	0.0743	0.3912	0.1899	0.8494
MA(1)	-0.0014	10.321	-0.0001	0.9999	0.3683	0.5780	0.6372	0.5240
MA(2)	-0.0012	3.6355	-0.0003	0.9997	-0.4312	0.2085	-2.0680	0.0386
MA(3)	0.0083	0.2109	0.0393	0.9686	-0.0838	0.2621	-0.3199	0.7491
	Variance Equation					Variance Equation		
C	0.0000	0.0000	32.3713	0.0000	0.0000	0.0000	3.5992	0.0003
RESID(-1)^2	0.2843	0.0240	11.8296	0.0000	0.9742	0.3101	3.1411	0.0017
GARCH(-1)	0.4223	0.0211	20.0000	0.0000	0.1343	0.0542	2.4802	0.0131
GARCH(-2)	-0.0498	0.0042	-11.7937	0.0000	-0.0106	0.0047	-2.2669	0.0234
	AIC	-16.62	Loglik	42655.7	AIC	-5.6378	Loglik	678.26
TARCH(2,1)	GED							
Variable	Coeff	Std. Error	z-Statistic	Prob.	Coeff	Std. Error	z-Statistic	Prob.
C	0.0000	0.0000	-4.5794	0.0000	0.0000	0.0002	0.2154	0.8295
@TREND	0.0000	0.0000	13.3659	0.0000	0.0000	0.0000	0.8774	0.3803
RT(-1)	0.9888	0.0267	37.1003	0.0000	0.2719	0.0651	4.1748	0.0000
RT(-2)	-0.0329	0.0274	-1.1968	0.2314	0.4504	0.0233	19.3666	0.0000
RT(-3)	0.0223	0.0061	3.6657	0.0002	-0.0055	0.0308	-0.1790	0.8579
MA(1)	-0.0028	0.0259	-0.1091	0.9131	-0.0009	0.0522	-0.0175	0.9860
MA(2)	0.1084	0.0052	21.0494	0.0000	-0.4098	0.0233	-17.5775	0.0000
MA(3)	0.0497	0.0027	18.4627	0.0000	-0.0533	0.0213	-2.5024	0.0123

	Variance Equation				Variance Equation			
C	0.0000	0.0000	55.2877	0.0000	0.0000	0.0000	2.4122	0.0159
RESID(-1)^2	1.1322	0.0364	31.1046	0.0000	3.7806	1.4635	2.5832	0.0098
RESID(-1)^2*(RESID(-1)<0)	0.1389	0.0451	3.0810	0.0021	-2.1710	1.5026	-1.4448	0.1485
RESID(-2)^2	0.0568	0.0077	7.3747	0.0000	-0.7619	0.7068	-1.0779	0.2811
GARCH(-1)	-0.0421	0.0065	-6.5054	0.0000	0.3583	0.1471	2.4350	0.0149
	AIC	-16.84	Loglik	43197.3	AIC	-5.868	Loglik	706.465
EGARCH(2,2)	student t							
Variable	Coeff	Std. Error	z-Statistic	Prob.	Coeff	Std. Error	z-Statistic	Prob.
C	-0.0001	0.0000	-1.2946	0.1955	0.0023	0.0001	21.5774	0.0000
@TREND	0.0000	0.0000	1.3166	0.1880	0.0000	0.0000	-3.1182	0.0018
RT(-1)	0.5768	0.5978	0.9648	0.3347	0.8055	0.0711	11.3333	0.0000
RT(-2)	0.0563	0.4114	0.1368	0.8912	0.4624	0.0676	6.8438	0.0000
RT(-3)	0.0350	0.3210	0.1091	0.9131	-0.4767	0.0530	-8.9930	0.0000
MA(1)	0.1497	0.6101	0.2454	0.8061	-0.6373	0.0787	-8.0974	0.0000
MA(2)	0.0178	0.4251	0.0420	0.9665	-0.4522	0.0495	-9.1354	0.0000
MA(3)	0.0302	0.0501	0.6022	0.5470	0.4452	0.0539	8.2551	0.0000
	Variance Equation				Variance Equation			
C(9)	-7.1216	0.2043	-34.8621	0.0000	-2.7018	0.3645	-7.4115	0.0000
C(10)	0.7882	0.0289	27.2273	0.0000	0.1198	0.0580	2.0659	0.0388
C(11)	1.3460	0.0339	39.6801	0.0000	-0.0882	0.0651	-1.3558	0.1752
C(12)	0.1537	0.0101	15.2763	0.0000	0.5652	0.0563	10.0430	0.0000
C(13)	0.0939	0.0267	3.5135	0.0004	0.6526	0.0503	12.9733	0.0000
C(14)	0.5370	0.0235	22.8736	0.0000	0.0577	0.0248	2.3297	0.0198
	AIC	13.554	Loglik	34781.6	AIC	-5.015	Loglik	606.8
PARCH(2,1)	student t							
Variable	Coeff	Std. Error	z-Statistic	Prob.	Coeff	Std. Error	z-Statistic	Prob.
C	0.0000	0.0000	-9.8450	0.0000	-0.0010	0.0002	-6.4469	0.0000
@TREND	0.0000	0.0000	10.5160	0.0000	0.0000	0.0000	6.9439	0.0000
RT(-1)	0.9988	0.1314	7.5993	0.0000	0.6992	0.0703	9.9406	0.0000
RT(-2)	0.0085	0.1729	0.0493	0.9607	0.4177	0.0682	6.1252	0.0000
RT(-3)	-0.0279	0.0439	-0.6350	0.5254	-0.2397	0.0295	-8.1380	0.0000
MA(1)	0.1780	0.1309	1.3605	0.1737	-0.2849	0.0698	-4.0786	0.0000
MA(2)	0.0153	0.0201	0.7645	0.4446	-0.5090	0.0473	-10.7641	0.0000
MA(3)	0.0085	0.0030	2.8295	0.0047	0.0465	0.0138	3.3626	0.0008
	Variance Equation				Variance Equation			
C(9)	0.0000	0.0000	2.9205	0.0035	0.0232	0.0221	1.0485	0.2944
C(10)	1.1940	0.0194	61.4268	0.0000	0.7186	0.2309	3.1124	0.0019
C(11)	-0.0348	0.2138	-0.1629	0.8706	-0.5390	0.2099	-2.5678	0.0102
C(12)	0.0308	0.1764	0.1747	0.8613	0.8180	0.1048	7.8038	0.0000
C(13)	1.0398	0.0227	45.7814	0.0000	0.1912	0.1723	1.1101	0.2669
	AIC	-17.11	Loglik	43912.5	AIC	-5.846	Loglik	703.81

APARCH(2,1)	student t							
Variable	Coeff	Std. Error	z-Statistic	Prob.	Coeff	Std. Error	z-Statistic	Prob.
C	0.0000	0.0000	0.4782	0.6325	0.0002	0.0002	0.9193	0.3579
@TREND	0.0000	0.0000	0.4544	0.6495	0.0000	0.0000	-0.4974	0.6189
RT(-1)	1.0209	0.4909	2.0798	0.0375	0.7740	0.1260	6.1414	0.0000
RT(-2)	0.0058	0.5390	0.0107	0.9914	0.3988	0.1001	3.9821	0.0001
RT(-3)	-0.0288	0.0638	-0.4512	0.6518	-0.3024	0.0538	-5.6222	0.0000
MA(1)	0.0668	0.4910	0.1360	0.8919	-0.3090	0.1252	-2.4692	0.0135
MA(2)	-0.0230	0.0430	-0.5339	0.5934	-0.5074	0.0693	-7.3249	0.0000
MA(3)	-0.0019	0.0039	-0.4903	0.6239	0.0705	0.0332	2.1228	0.0338
	Variance Equation				Variance Equation			
C(9)	0.0000	0.0000	1.7807	0.0750	0.0021	0.0017	1.2074	0.2273
C(10)	0.6857	0.0372	18.4393	0.0000	1.0760	0.3620	2.9722	0.0030
C(11)	0.0378	0.0187	2.0172	0.0437	-0.2015	0.0843	-2.3910	0.0168
C(12)	0.1534	0.0154	9.9515	0.0000	-1.1429	0.3580	-3.1930	0.0014
C(13)	-0.0355	0.0003	-119.1100	0.0000	1.0009	0.0299	33.4440	0.0000
C(14)	1.3818	0.0452	30.5898	0.0000	0.5371	0.1390	3.8649	0.0001
	AIC	-17.32	AIC	44464	AIC	-6.038	Loglik	727.5

NB: AIC - Akaike info criterion; Loglik - Log likelihood

The evaluation of serial correlation for the selected model and the corresponding GARCH-M estimates were shown in Table 4.6. From the table, the 5, 20, 30 and 36th lags were considered. The correlogram of square residual of ARMA(3,3)-TARCH(2,1)-GED showed that the null hypothesis of no serial correlation existing among the residuals was accepted for both daily and monthly residual. Considering the corresponding GARCH-M estimates, the correlogram of square residual showed that the null hypothesis of no serial correlation existing among the residuals was accepted for both daily and monthly residual. Therefore, there is no serial correlation existing among the residuals of the model selected and the corresponding GARCH-M.

Table 4.6: Evaluation of serial correlation for selected model and its GARCH-M, Jan. 2000 - Aug. 2019

None	Lag	Daily				Lag	Monthly			
	5	-0.001	-0.001	0.0191	0.99	5	-0.018	-0.022	0.8354	0.361
	20	0.008	0.008	0.4115	1	20	-0.002	0.009	28.039	0.083
	30	0.004	0.004	0.4779	1	30	-0.023	-0.005	29.225	0.35
	36	0.023	0.023	3.1463	1	36	-0.014	-0.005	32.702	0.482
GARCH-M		Daily					Monthly			
	5	-0.001	-0.001	0.0218	0.989	5	0.112	0.111	3.334	0.189
	20	0.011	0.01	0.6511	1	20	0.002	-0.001	3.8146	1
	30	0.004	0.004	0.7552	1	30	-0.009	-0.01	4.1814	1
	36	0.025	0.025	3.9105	1	36	-0.01	-0.01	4.6716	1

The evaluation of heteroscedasticity of the residual the selected models and the corresponding GARCH-M estimates were shown in Table 4.7. From the table, the ARCH test on residual of TARCH showed that null hypothesis of homoscedasticity is not rejected for both daily and monthly output. Considering the corresponding GARCH-M estimates, the ARCH test on residual of TARCH showed that null hypothesis of homoscedasticity is not rejected for both daily and monthly output. Therefore, the residuals of the estimated models were homoscedastic.

Table 4.7: ARCH-LM Heteroskedasticity Test for selected model and its GARCH-M, Jan. 2000 - Aug. 2019

None	Daily			Monthly		
TARCH	F-statistic	0.00435	Prob. F(1,5127) = 0.9474	F-statistic	0.1938	Prob. F(1,233) =0.6602
	Obs*R-squ.	0.00435	Prob. Chi-Squ. = 0.9474	Obs*R-squ.	0.1953	Prob. Chi-Squ. =0.6586
GARCH-M						
TARCH	F-statistic	0.00379	Prob. F(1,5127) = 0.9509	F-statistic	0.0290	Prob. F(1,233) = 0.865
	Obs*R-squ.	0.00379	Prob. Chi-Squ. = 0.9509	Obs*R-squ.	0.0292	Prob. Chi-Squ. = 0.8643

The result of the asymmetric GARCH-M ARMA(3,3)-TARCH(2,1)-GED for the daily and monthly estimations were shown in Table 4.8. Considering the daily result, from the table, all the parameters of the estimate were significant at 5% level of significance except AR(2), AR(3), MA(1), MA(1) terms and second day's information about volatility. The coefficient of the GARCH-M was 1.15E-05 with p-value of zero which shows that GARCH-M coefficient is significance. This confirmed the presence of serial correlation in the return series as shown by the correlogram in Table 4.4. This showed that daily volatility increased future returns on the daily exchange rate, therefore, lower daily volatility will help stabilize daily exchange rate. From the table, the previous day's one and day two information about volatility had 0.14 units and -0.09 unit effect on current day's volatility but the second day's effect was not significant. Also, the previous day's volatility had 0.5 unit effect on the current day volatility. The asymmetric coefficient was -0.089 unit with p-value of zero which shows that the coefficient was significance. Since, the coefficient was negative it showed that bad news decreased volatility, hence, there is no leverage effect. The good news had an impact of α_i = (0.1434-0.0042) = 0.1392 unit on current day's volatility while bad news has an impact of $\alpha_i + \lambda_j$ = (0.1392-0.0890) = 0.0502 on current day's volatility. Also, as λ was significantly different from zero, this implied that the impact of news is asymmetric.

Considering the monthly result, from the table, all the parameters of the estimate were significant at 5% level of significance except AR(3) and previous second month's information about volatility. The coefficient of the GARCH-M is -0.045 unit with p-value of zero which show that the coefficient was significance. This also confirmed the presence of serial correlation in the return series as shown by the correlogram in table 4.4. This showed that monthly volatility decreased future returns on the monthly exchange rate. From the table, the previous first month's and second month's information about volatility had 0.14 unit and 0.006 unit effect on current month's volatility. Also, the previous month's volatility had 0.119 unit effect on the current day volatility. The asymmetric coefficient was -0.1803 unit with p-value of zero which shows that the coefficient was significance. Since, the coefficient was negative it showed that bad news decreased volatility hence there is no leverage effect. The good news had an impact of α_i = (0.1416-0.0061) = 0.1355 unit on current day's volatility while bad news had an impact of $\alpha_i + \lambda_j$ = 0.1355-0.1803) = -0.0448 on current day's volatility. Also, as λ was significantly different from zero, this implied that the impact of news is asymmetric.

Table 4.8: Modeling GARCH-M-TARCH Processes on return series, Jan. 2000–Aug. 2019

	Daily				Monthly			
Variable	Coeff	Std. Error	z-Stat	Prob.	Coefficient	Std. Error	z-Statistic	Prob.
LOG(GARCH)	1.2E-05	2.5E-06	4.62	0	-0.0446	0.0096	-4.6538	0
C	2.4E-04	5.2E-05	4.55	0	-0.3365	0.0710	-4.7384	0
@TREND	8.7E-10	3.9E-10	2.24	0.0253	0.0000	0.0000	11.1033	0
AR(-1)	1.0E+00	1.6E-01	6.48	0	-0.4333	0.0359	-12.0616	0
AR (-2)	1.2E-02	2.3E-01	0.05	0.9573	0.3098	0.0130	23.8923	0
AR (-3)	-7.5E-02	8.3E-02	-0.90	0.3675	-0.0095	0.0180	-0.5287	0.597
MA(1)	9.8E-02	1.6E-01	0.62	0.5329	0.7380	0.0284	25.9889	0
MA(2)	8.4E-02	6.3E-02	1.34	0.1812	0.1955	0.0212	9.2380	0
MA(3)	8.2E-02	2.0E-02	4.19	0	0.2391	0.0119	20.1658	0
	Variance Equation				Variance Equation			
C	2.0E-09	1.3E-10	14.64	0	0.0011	6.8E-05	16.4180	0
RESID(-1)^2	1.4E-01	1.7E-02	8.65	0	0.1416	3.4E-02	4.1392	0
RESID(-1)^2*(RESID(-1)<0)	-8.9E-02	1.1E-02	-8.40	0	-0.1803	4.2E-02	-4.2860	0
RESID(-2)^2	-4.3E-03	2.0E-02	-0.21	0.8333	0.0061	4.2E-03	1.4688	0.1419
GARCH(-1)	5.0E-01	3.3E-02	15.31	0	0.1192	5.0E-02	2.3657	0.018
	AIC	-15.898	Loglik	40793.7	AIC	-5.2666	Loglik	636.46

Effects on the parameters

The table 4.9 showed possible biases that were introduced into the parameters of the ARMA(3,3)-TARCH(2,1)-GED model for daily and monthly estimates when the possible existence of serial correlation was ignored. Considering the daily result, if serial correlations were ignored, the constant term of the mean equation, AR(2), AR(3), MA(2) and MA(3) terms, asymmetric coefficient, ARCH(2) and GARCH(1) were reduced by 0.0002, 0.0035, 0.2365, 0.1516, 0.0740, 0.0808 and 0.0619, respectively, while AR(1), MA(1) and ARCH(1) terms were inflated by 0.2589, 0.1046 and 0.1489, respectively. Considering the monthly result, if serial correlations were ignored, MA(1), MA(2) and MA(3) terms, constant term of the variance equation, asymmetric coefficient and ARCH(2) were reduced by 0.7389, 0.6054, 0.2923, 0.0011, 1.9906 and 0.7680, respectively, while constant term of the mean equation, AR(1), AR(2), AR(3), ARCH(1) term and GARCH(1) were inflated by 0.3365, 0.7051, 0.1406, 0.0040, 3.6390 and 0.2391, respectively. In sum, ignoring serial correlations in the return series made parameter estimated bias and efficient. This confirmed Moffat, I., & Akpan, E. (2019) who concluded that GARCH-in-Mean-EGARCH(1,1) model under student-t distribution sufficiently appraised the existence of serial correlations.

Table 4.9: Bias cause by the existence of serial correlation on parameters

	ARMA(3,3)-APARCH(2,1)	ARMA(3,3)-APARCH(2,1)-M	Bias	ARMA(3,3)-APARCH(2,1)	ARMA(3,3)-APARCH(2,1)-M	Bias
LOG(GARCH)		1.15E-05			-0.044615	
C	9.74E-07	0.000238	-0.0002	4.61E-05	-0.336498	0.3365
@TREND	1.61E-10	8.69E-10	0.0000	8.49E-07	3.15E-05	0.0000
AR(-1)	1.290626	1.031762	0.2589	0.271859	-0.433286	0.7051
AR (-2)	0.009012	0.012488	-0.0035	0.450411	0.30978	0.1406
AR (-3)	-0.311399	-0.074943	-0.2365	-0.005514	-0.009515	0.0040
MA(1)	0.202239	0.097654	0.1046	-0.000915	0.738013	-0.7389
MA(2)	-0.067242	0.084335	-0.1516	-0.409844	0.195536	-0.6054
MA(3)	0.008394	0.082373	-0.0740	-0.053257	0.239083	-0.2923
C	6.24E-10	1.95E-09	0.0000	3.22E-05	0.001124	-0.0011
RESID(-1)^2	0.292326	0.143412	0.1489	3.780556	0.141568	3.6390
RESID(-1)^2*(RESID(-1)<0)	-0.169793	-0.089041	-0.0808	-2.170952	-0.180334	-1.9906
RESID(-2)^2	-0.0662	-0.004254	-0.0619	-0.76187	0.006146	-0.7680
GARCH (-1)	0.337137	0.499887	-0.1628	0.358267	0.119183	0.2391

Summary and Conclusion

The main objective of this paper was to model the exchange rate volatility of the GHC/US$ series in the presence of serial correlations. The data used was daily and monthly average effective exchange rate, GHC-US$, from January 2000 to August 2019. Based on the evaluation, the ARMA(3,3)-TARCH(2,1)-GED was the appropriate model selected for the examination of the effect of serial correlation on the parameters estimated. The correlogram of the return series showed that serial correlation exist in the return series. The findings showed that heteroscedasticity exists and appeared to be adequately captured by ARMA(3,3)-TARCH(2,1) model under general error distribution but failed to account for the presence of serial correlations in the return series. But the corresponding GARCH-M-TARCH(2,1) model under general error distribution sufficiently appraised the existence of serial correlations. From the results when the existence of serial correlations were ignored in the return series the parameters estimated will be bias and inefficient. Hence, the application of GARCH-M-GARCH-type model possibly provides the feedback mechanism or interaction between the variance and mean equations. It was also found out that previous information about volatility and the previous volatility had significant effect on the current day volatility. From the result there was no leverage effect and the impact of news was asymmetric.

Therefore, it is recommended that the existence of serial correlation in the financial variables should not be ignored when modelling volatility. Also, the central bank should put measures in place to stabilize the cedi since increase impacted on the future return on the GHC/US$ exchange rate. For further study, other researchers can also consider the weekly or the yearly exchange rate and examine the issues of volatility, serial correlations and its impact on the parameter estimate.

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