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FORECASTING EXCHANGE RATE VOLATILITY USING INTEGRATED GARCH MODEL: EVIDENCE FROM GHANA

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ABSTRACT

Just like most developing, the characteristics of the foreign exchange market in Ghana economies have vital policy implications. This study investigates the volatility in Ghana's exchange rate. The study determines whether exchange rate has a volatile property in the Ghanaian foreign exchange market. The policy implications therefore suggest that the Bank of Ghana should give priority to the attainment of exchange rate equilibrium.
Keywords: Exchange rate volatility, integrated garch model, Ghana.

1. INTRODUCTION

In a small open economy like Ghana, economic policies by government as well as individual and firm decisions are susceptible to the features shown by its exchange rates. Price stability, real and financial sectors profitability and general macroeconomic stability are channels through which exchange rate volatility costs an economy. The engagement of Ghana in international trade with its trading partners strengthens the need to investigate the volatility of exchange rates as it engages in these trades.

The Economic Recovery Program (ERP) introduce in 1983 saw the replacement of the fixed exchange regime that was adopted after independence in 1957 with the floating regime. Thus exchange rates will largely depend on the interactions of market forces. This is attributable to the Financial Sector Adjustment Program (FINSAP) launched as a major part of the ERP. Ghana's currency, Cedi, depreciated up to 96% in 1987 after the adaptation of the floating exchange rate regime a year earlier (Tarawalie, et at., 2012). Between 2001 and 2006 the depreciation of Cedi stabilized. On July 1, 2007, Ghana undertook a redenomination of its currency –the Cedi- and adopted a new currency –the Ghana Cedi. The new currency had the same purchasing power as the old. For instance, the Cedi/(US)$ exchange rate was 9,200 Cedis for (US)$1, and for the new Ghana Cedi (GHS), the exchange rate was

GHS 0.92 for (US)$1. After the redenomination however, the Ghana Cedi depreciated to GHS 1.89 to (US)$1 by August 2012. This consequently translated into consumer prices and input costs thereby affecting individual economic conditions as well as firm's profitability. By the end of January 2018 the Ghana Cedi was exchanged at GHS4.50 for (US)$1.

History has seen Ghana gone through both the fixed and floating exchange rate regimes as well as policy adjustments aimed at getting Ghana's exchange rate volatility in check. It would therefore be useful for Policymakers to give priority to the attainment of exchange rate equilibrium.

2. REVIEW OF LITERATURE

Studies on the volatility in exchange rates ranges from its possible causes to implications on an economy as well as how to check it take enormous space in the finance literature. Some of these notable studies both internationally and on Ghana are reviewed below:

Osler (1995) argues that, in an exchange rate market, regardless of the main determinants of speculative activities in the market the market is most likely a random-walk process. Further suggests in the study that the speculative activities in normal markets are the potential source of the random-walk behavior of exchange rate. Study by Carlson and Osler (2000) arrived at a corroborating results and further postulates that exchange rate volatility is increased by these speculative activities.

Tweneboah (2015) studies efficiency of the Ghanaian exchange rate market using a chain of parametric and non-parametric tests of Variance Ratio (VR) and conclude inefficiency in the market. The study further identifies that the volatility of nominal bilateral exchange rates between GHS/(US)$ is greatly affected positively as a result of dollarization. Aidoo et al.,(2012) carried out similar study using observed monthly GHS/(US)$ rates, their results corroborates that of Tweneboah (2013).

Ali et al.,(2015) and Ashok and Vikram (2016) both finds that interest rate was statistically significant fact that influenced exchange rate volatility in Pakistan and Indian economies respectively. Whereas Ali et al.,(2015) employed the Vector Error Correction Model (VECM) and Granger causality test on monthly data from July 2000 to June 2009, the latter relied on linear regression analysis of impacts of macroeconomic variables on exchange rate volatility using data from 1996 to 2014. These studies however failed to consider the fact that interest rate and money supply are connected in economic theory, thus including both as explanatory variables could cause thee model to suffer from multicollinearity.

Alagidede and Mazu (2016) on the causes and effects of exchange rate volatility on economic growth in Ghana, identifies the causes of exchange rate volatility in Ghana to include growth in money supply, government expenditure, output shocks and terms of trade. The study further suggests that real exchange rate market shocks for some three quarters. The study however was silent as to the actual cause of these shocks.

This study tries to assess the to what extent is volatility of exchange rate in Ghana and suggest possible measures that policy makers should prioritize in dealing with such uncertainty in the Ghanaian exchange market.

3. METHODOLOGY

In econometric models that uses time series data, it is assumed that the variables have stable means and variances which do not change over time (Sevüktekin and Nargeleçekenler, 2005: 37). When a series is stationary; it means that the variance and the mean are constant over time and that the covariance of the variables depends on the lags between the variables and is independent of time (Gujarati, 1995: 712). As stated by Granger and Newbold (1974), porous regression problems can be encountered when working with non-stationary time series data. In this case, the results obtained by regression analysis do not reflect the actual relationship, however, if there is a cointegration relationship between these series, the real relationship can be observed (Karaca, 2003: 249).

Stationarity Tests (Unit root Tests)

Augmented Dickey-Fuller (ADF) test

In this study, the stationarity test of the real exchange rate index series was performed using the Augmented Dickey-Fuller (ADF) test. The following regression equation is used to test the unit root (Stationarity) property of Yt series (Günaydın, 2004: 172-173):

$$\Delta Y_t = \alpha_0 + \alpha_1 t + \delta Y_{t-1} + \sum_{i=1}^{N} \Psi \Delta Y_{t-i} + \varepsilon_t \qquad \textbf{(3)}$$

Where:

Δ the first difference processor; t is a time trend; N is the number of lags of the dependent variable determined by the Akaike Information Criteria in order to eliminate the successive dependence of the error terms, Yt used series (real exchange rate index in our case) and $\varepsilon_t$is the error term.

This type of unit root test is known as ADF tests. The null hypothesis is that the series is not stationary with an alternative hypothesis of stationary series. The null hypothesis is if absolute value of the test statistic if lesser than the absolute value of the critical values. Otherwise, the series is stationary. However, a problem with the ADF test is that it requires the inclusion of additional differences of terms in the test equation. This results in loss of degrees of freedom and a reduction in the strength of the test procedure.

Phillip-Peron (PP) Tests

Alternatively, the PP approach takes into account the presence of unknown forms of autocorrelation and the conditionally changing variance status in the error term and uses a non-parametric correction for the serial relationship. Thus statistics are converted to remove the effects of the serial relationship on the asymptotic distribution of the test statistics. In both tests, t statistics are larger than the critical values and hence the rejection of the null hypothesis of unit root (Uysal et al., 2009: 6).

AR or ARMA model

Engle in his studies in 1982 and 1983, his examination of the UK inflation data proved that the variance of error terms is not fixed. This study by Engle has entered the literature with the name of Autoregressive Conditional Variable Variance (ARCH) (Aktaş, 2007: 151).

In an AR or ARMA model, the conditional mean equation is in the following;

$$\text{AR(1):} \qquad y_t = \beta_0 + \beta_1 y_{t-1} + u_t, \qquad \textbf{(4)}$$

Equation (4) is under the assumption that the error term obtained from the period (t-1). Moreover error term of the autoregressive average equation (4) is conditionally distributed as follows:

$$u_t \approx N[0, (\alpha_0 + \alpha_1 u_{t-1^2})] \qquad \textbf{(5)}$$

The u_t expressed in the equation (5) has a normal distribution with a mean of zero and $(\alpha_0 + \alpha_1 u_{t-1^2})$ as variance. Also there is consecutive dependency. Thus when the variance of u in the t period depends on the square of the error term in the period (t-1). Since the variance of u_t in equation (5) depends on the square of the error term of the previous period, this process is called the process of ARCH (1). This process can be formulated as follows;

$$h_t = \sigma_{t^2} = V(u_{t^2}/I_{t-1}) = \alpha_0 + \alpha_1 u_{t-1^2} \qquad \textbf{(6)}$$

The I_{t-1} expressed in the equation shows all the information at (t-1) and (V) the conditional variance of the error terms. The importance of the equation is to allow parametric modeling of conditional variance of error terms. Thus, it can be used to model how new information obtained from the es timation of financial data affects the variance or volatility over time. Accordingly, it is also possible to have an idea about how volatility changes over time. With the help of equation (6), unexpected flactuations can be determined. In this model, conditional variance is defined as a function that depends on the square of unexpected error terms (Turanlı, Özden and Vural, 2007: 3).

ARCH (1) process, as ARCH (q) process;

Variance $u_t = \sigma^{2t} = \alpha_{0+}\alpha_1 u^{2t-1} + \alpha_2 u^{2t-2} + \ldots\ldots + \alpha_p u^{2t-p}$ **(7)**

Equation (7) can be generalized and written in the form ARCH (q) process as follows;

$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i u^{2t-1}$ **(8)**

If there is no consecutive dependency in the error, $\alpha_1 = \alpha_2 = \ldots = \alpha_q = 0$, the calculated variance is simply equal to α_0. Thus, error terms can have constant variance.

The null hypothesis can be easily tested by calculating equation (9) expressed by Engle;

$u^2{}_t = \beta_0 + \beta_1 u^2{}_{t-1} + \beta_2 u^2{}_{t-2} + \ldots\ldots + \beta_q u^2{}_{t-q} + v_t$ **(9)**

The equation expressed in equation (9) is known as autoregressive conditional heteroscedasticity variance. The term (u) is the error term derived from the conditional mean equation. This model is also defined as a function of the squares of the past values of the residual variance equation.

ARCH models allow the variance to change as a function of lagged prediction of error terms, leaving aside the variance of constant variance in traditional time series methods. Therefore, ARCH models are suitable for regression of varying variance in the estimation process. In the ARCH model, it is assumed that the characteristic behavior of the estimation errors is based on regression residuals. As a result of this assumption, regression residuals will be autocorrelated (Turanlı et al., 2007: 4).

The ARCH effect can be tested with the Lagrange Multiplier (LM) test using the least squares residues for ARCH models.

$$h_t = \alpha_0 + \alpha_1 u^{2t-1} + \alpha_2 u^{2t-2} + \ldots\ldots + \alpha_q u^{2t-q} \quad \textbf{(10)}$$

For this purpose, the null and alternative hypotheses for testing ARCH effect in conditional variance model with lag length (q) are given below;

$H_0 = \alpha_1 = \alpha_2 = \ldots. = \alpha_q = 0$

$H_A = \text{at least } \alpha_i > 0 (i = 1,2,\ldots,q)$

As seen in the hypotheses above, H_0 hypothesis suggests that there is an ARCH effect, while H_A hypothesis is the claim that ARCH effect is not present. The test statistic is LM =T *(R^2).

The T^* (R^2) statistical value is calculated with the help of the coefficient of (R^2) which obtained from the estimation of the auxiliary regression. In order to show the number of observations, the LM statistic has chi-square distribution with q-degrees of freedom. With the rejection of the H_0 hypothesis, the squares of the least squares residuals, which seems to be autocorrelated, reveal the existence of the ARCH effect in the model. After uncovering this effect, regression equation can be estimated with the regression equation in the model (Turanlı, Özden and Vural, 2007: 5).

In the implementation of the ARCH model, due to the use of relatively long lags and the proposition of a fixed lag structure, some restrictions have been imposed on the parameters of the conditional variance equation.

However, Bollerslev (1986) has developed a model that has both more historical information and a more flexible lag structure by expanding the ARCH model, in order to avoid these constraints and to eliminate the disadvantage of reaching negative variance parameter estimates. This model is called generalized ARCH (GARCH) (Isığıçok, 1999: 7).

The GARCH (p, q) model proposed by Bollerslev (1986) based on the ARCH model is as follows:

$$u_t = \eta_t \sqrt{h_t}$$

$$h_t = \alpha_0 + \sum_{i=p}^{p} \alpha_i u^{2t-1} + \sum_{i=p}^{q} \beta_i h_{t-i}$$

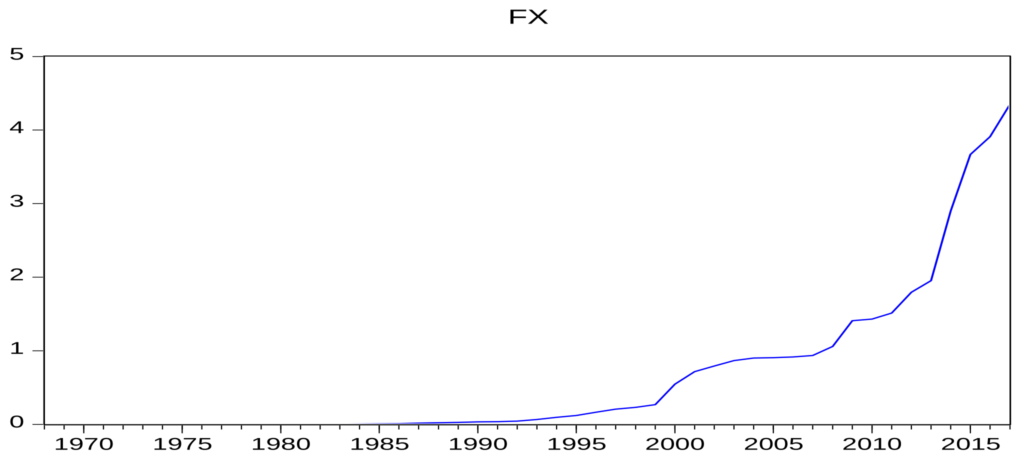
Where:

for $h_t > 0$, $\alpha_0 > 0$, $\alpha_i \geq 0$, $\beta i \geq 0$, (i = 1,2, t .., p) and h_t has a mean of zero and a variance of which is a random variant (Aktas and Akkurt, 2006: 93) .

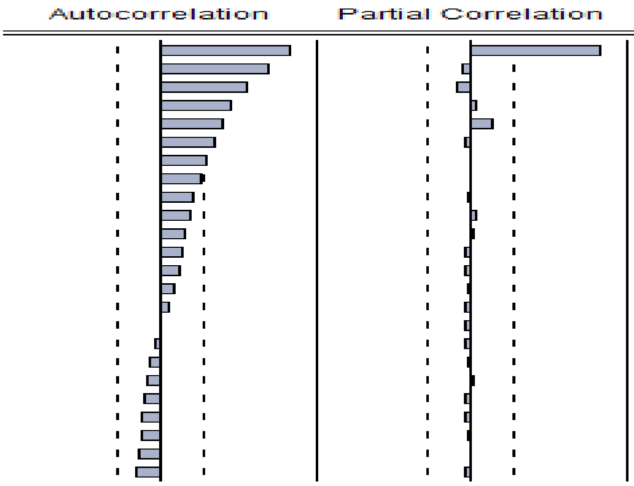
The ARCH LM test, a Lagrange test, was developed to determine whether the model has an autoregressive conditionally changing variance effect in error terms. The effectiveness of the estimates is reduced when the ARCH effect is ignored in time series.

4. DATA AND FINDINGS

This study uses the data of GHS/USD exchange rate index obtained from World Development Indicators. The data covers the periods from 1968 to 2017. The exchange rate series will be expressed in the tables and graphs using the abbreviation FX (Foreign Exchange) in the econometric analysis section The progression of the exchange rate over time is shown in Graph 1.



Graph 1: The Progression of the Exchange Rate in the Period of 1968-2017



	AC	PAC	Q-Stat	Prob
1	0.854	0.854	38.726	0.000
2	0.713	-0.061	66.281	0.000
3	0.569	-0.094	84.195	0.000
4	0.459	0.037	96.124	0.000
5	0.406	0.137	105.65	0.000
6	0.353	-0.045	113.02	0.000
7	0.310	-0.007	118.83	0.000
8	0.267	0.002	123.26	0.000
9	0.220	-0.022	126.32	0.000
10	0.192	0.037	128.72	0.000
11	0.170	0.011	130.65	0.000
12	0.146	-0.033	132.10	0.000
13	0.117	-0.032	133.06	0.000
14	0.083	-0.018	133.55	0.000
15	0.042	-0.049	133.68	0.000
16	0.000	-0.046	133.68	0.000
17	-0.041	-0.038	133.82	0.000
18	-0.074	-0.022	134.27	0.000
19	-0.091	0.015	134.97	0.000
20	-0.107	-0.031	135.97	0.000
21	-0.123	-0.035	137.33	0.000
22	-0.138	-0.014	139.09	0.000
23	-0.150	-0.006	141.26	0.000
24	-0.161	-0.029	143.86	0.000

Graph 2: Correlogram of FX Series

As can be seen clearly in Graph 2; The FX series is not stationary in its level form.

Table 1 shows the results of the ADF Unit Root Test conducted to determine whether the FX series contains unit roots (non-stationary).

Table 1: Results of ADF Unit root Test in FX Series

ADF	ADF test statistic	Mac Kinnon Test critical values			Prob.
	5.302232	1%	5%	10%	1.000
		-4.211868	-3.529758	-3.196411	
ADF (-1)	ADF test statistic.	Mac Kinnon Test critical values			Prob.
	1.492134	1%	5%	10%	0.9990
		-3.588509	-2.929734	-2.603064	
ADF (-2)	ADF test statistic	Mac Kinnon Test critical values			Prob.
	-7.470471	1%	5%	10%	
		-2.618579	-1.948495	-1.612135	0.0000

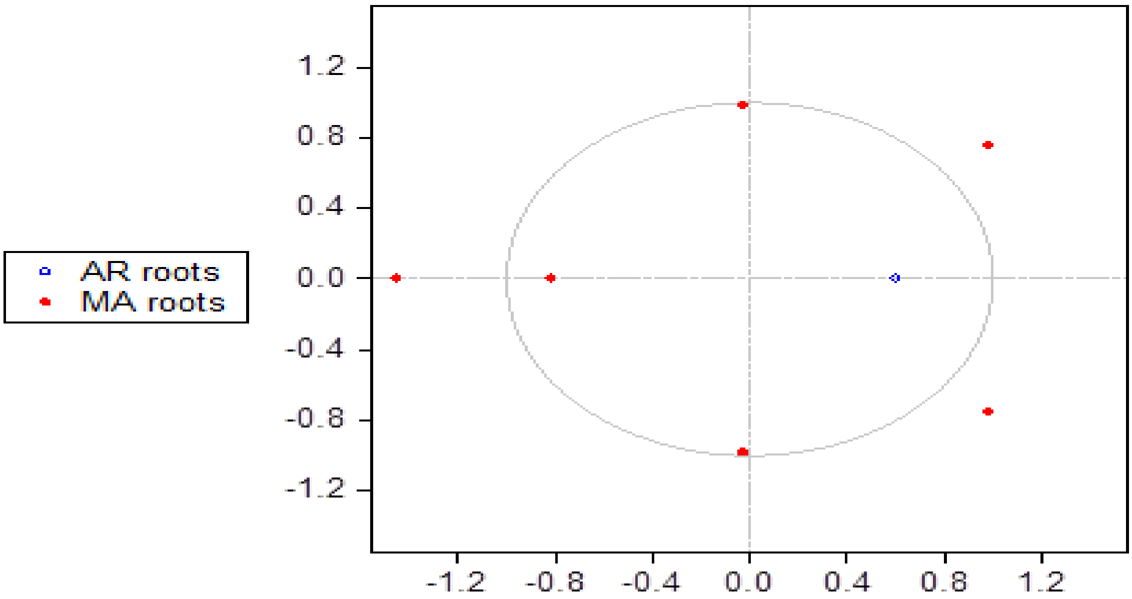
As can be seen from Table 1, the null hypothesis that the FX series is not stationary cannot be rejected because the prob. values are greater than 0.05 and the first difference is greater than 0.05. So the series is considered to be non-stationary in these two cases. When the test statistics, critical values and probability values are examined for the second difference of the series, it is seen that the unit root problem has disappeared.

When the correlogram and unit root test results are examined, it is concluded that it is appropriate to estimate the model with ARIMA Model. The ARIMA model estimated in Table 2;

Table 2. ARIMA Model Estimation for FX Series

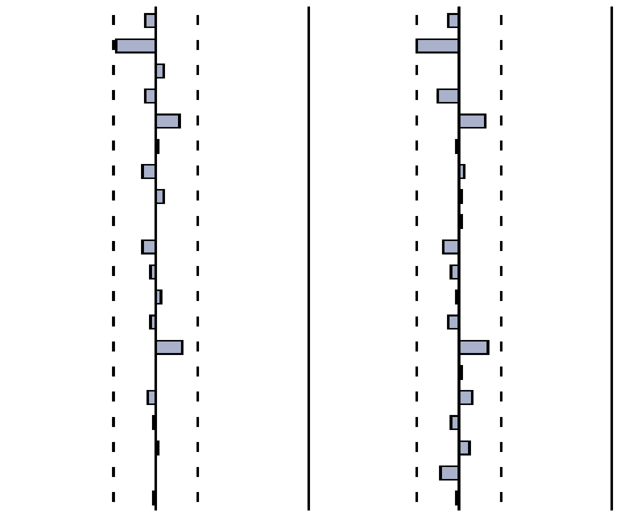
Variable	**Coefficient**	**Standard error**	**t-statistic**	**Prob.**
C	0.000144	0.000136	1.064693	0.2934
AR(1)	0.603129	0.153475	3.929814	0.0003
MA(1)	0.348086	0.168524	2.065502	0.0454
MA(2)	-0.753856	0.235755	-3.197625	0.0027
MA(3)	1.346002	0.238425	5.645385	0.0000
MA(4)	0.185488	0.230956	0.803132	0.4266
MA(5)	1.200525	0.234875	5.111328	0.0000
rMA(6)	1.742744	0.357281	4.877799	0.0000

In order to determine whether the applied ARMA model is a stable model, it is necessary to perform some tests; one of them is the test showing whether the reverse roots of the AR polynomial are inside the unit circle;



Graph 3. Polynomial of AR / MA of Inverse Root (s)

As can be clearly seen from Graph 3, none of the reverse roots of the AR Polynomial appear to be outside the unit circle. Likewise, another test is applied is that, the predicted model's error terms residuals should be purely random. With the help of Graph 4, this is shown clearly.



	AC	PAC	Q-Stat	Prob
1	-0.074	-0.074	0.2783	
2	-0.275	-0.282	4.2199	
3	0.050	0.004	4.3546	
4	-0.066	-0.151	4.5908	
5	0.168	0.184	6.1711	
6	0.017	-0.022	6.1880	
7	-0.086	0.034	6.6167	
8	0.046	0.018	6.7454	0.009
9	-0.005	0.019	6.7472	0.034
10	-0.086	-0.108	7.2156	0.065
11	-0.029	-0.059	7.2684	0.122
12	0.031	-0.019	7.3305	0.197
13	-0.038	-0.075	7.4306	0.283
14	0.174	0.193	9.5632	0.215
15	0.006	0.024	9.5660	0.297
16	-0.065	0.093	9.8859	0.360
17	-0.009	-0.053	9.8927	0.450
18	0.010	0.072	9.9005	0.539
19	-0.008	-0.118	9.9055	0.624
20	-0.010	-0.015	9.9132	0.701

Graph 4. Correlegram of the Model of Estimated ARMA (1,6)

In the ARMA model, which is clearly seen from Graph 4 above, the autocorrelation problem is non-existent. This shows that the ARMA model is a stable model.

After this stage, the volatility of the exchange rate series will be tested by the ARCH LM Test. The hypotheses about the test are:

Ho: No ARCH effect.

H1: ARCH effect.

Table 3. Volatility Test ARCH LM Tests

ARCH LM Test (1)			
F-statistic	Obs*R-squared	Prob. F(1,45)	**Prob. Chi-Square (1)**
15.52157	12.05378	0.0003	0.0005
ARCH LM Test (4)			
F-statistic	Obs*R-squared	Prob. F(4,39)	**Prob. Chi-Square (4)**
3.438775	11.47234	0.0168	0.0217
ARCH LM Test (8)			
F-statistic	Obs*R-squared	Prob. F(8,31)	**Prob. Chi-Square (8)**
2.294356	14.87582	0.0465	0.0616
ARCH LM Test (12)			
F-statistic	Obs*R-squared	Prob. F(12,23)	**Prob. Chi-Square(12)**
30.01495	33.83913	0.0000	0.0007

According to the results of ARCH LM Test conducted above to determine the volatility in the exchange rate series, the null hypothesis cannot be rejected and it is concluded that the series is volatile. Consequently, a fitting GARCH model will be used to model volatility. In the modeling process, it is decided to use one AR and four MA root according to parsimony principle. Table 4 reports the IGARCH (1,1) model calculated for D(FX) series.

Table 4. Results of IGARCH (1,1) Model of D(FX) Series

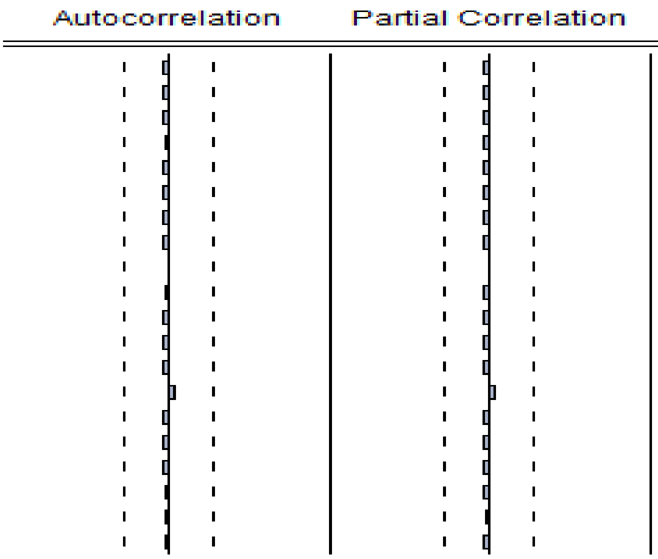
	Coefficient terms	**Standard error predictions**	**Z- Statistical Value**	**Prob. value**
C	0.018148	0.001997	9.089435	0.0000
AR(1)	-0.633441	0.027234	-23.25885	0.0000
MA(1)	1.269375	0.023221	54.66600	0.0000
MA(2)	0.636990	0.018350	34.71347	0.0000
MA(3)	0.809099	0.032642	24.78671	0.0000
MA(4)	0.636228	0.027800	22.88553	0.0000

In order to test whether the ARCH effect is still present in the model, the ARCH-LM test is reapplied and the results in Table 5 are obtained.

Table 5. Volatility Test ARCH LM Tests

ARCH LM Test (1)			
F-statistic	Obs*R-squared	Prob. F(1,45)	**Prob. Chi-Square (1)**
0.034928	0.036453	0.8526	0.8486
ARCH LM Test (4)			
F-statistic	Obs*R-squared	Prob. F(4,39)	**Prob. Chi-Square (4)**
0.032398	0.145723	0.9979	0.9975
ARCH LM Test (8)			
F-statistic	Obs*R-squared	Prob. F(8,31)	**Prob. Chi-Square (8)**
0.034648	0.354487	1.0000	1.0000
ARCH LM Test (12)			
F-statistic	Obs*R-squared	Prob. F(12,23)	**Prob. Chi-Square(12)**
0.031872	0.588843	1.0000	1.0000

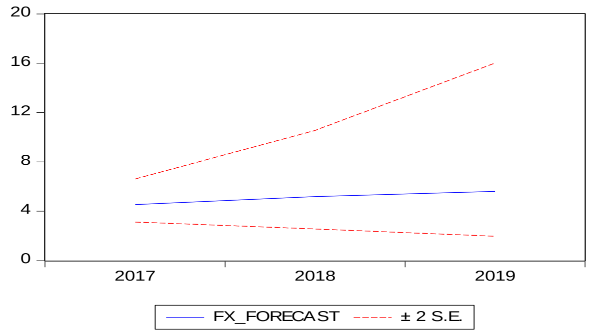
According to the results of ARCH LM Test applied to IGARCH (1,1) model modeled and reported for volatility D(FX) series, the null hypothesis that no ARCH effect exists in the newly adopted model cannot be rejected. Thus, IGARCH (1,1) model seems to model the existing volatility in the best fitting way. Correlogram of Standardised Residuals Squared in Graph 5 also supports this result.



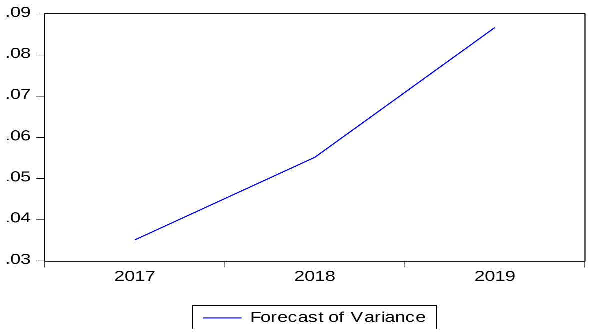
	AC	PAC	Q-Stat	Prob*
1	-0.028	-0.028	0.0395	0.842
2	-0.029	-0.030	0.0829	0.959
3	-0.025	-0.027	0.1170	0.990
4	-0.024	-0.026	0.1474	0.997
5	-0.026	-0.029	0.1854	0.999
6	-0.028	-0.032	0.2309	1.000
7	-0.027	-0.032	0.2738	1.000
8	-0.029	-0.035	0.3237	1.000
9	0.007	-0.000	0.3265	1.000
10	-0.023	-0.029	0.3589	1.000
11	-0.030	-0.037	0.4167	1.000
12	-0.031	-0.040	0.4808	1.000
13	-0.028	-0.039	0.5360	1.000
14	0.039	0.028	0.6433	1.000
15	-0.033	-0.041	0.7202	1.000
16	-0.034	-0.043	0.8050	1.000
17	-0.033	-0.045	0.8887	1.000
18	-0.010	-0.026	0.8976	1.000
19	-0.010	-0.024	0.9052	1.000
20	-0.012	-0.026	0.9171	1.000

Graph 5: Correlogram of Standardized Residuals Squared

After modeling of volatility; a projection was made for the exchange rate series for the future.



Forecast: FX_FORECAST
Actual: FX
Forecast sample: 2017 2019
Included observations: 1
Root Mean Squared Error 0.190017
Mean Absolute Error 0.190017
Mean Abs. Percent Error 4.367582



Graph 6: 1968-2019 Forecast of the Real Effective Exchange Rate Index

5. CONCLUSION

After the stationarity of the series is determined, the ARCH LM Test is employed to determine whether the variance of the error terms in the annual exchange rate of Ghana is constant over the period 1968 – 2017. Next, the stationarity and autocorrelation function and Cartesian graph of the exchange rate series are analyzed together to determine the existence of unit roots in the series. Given the non-stationarity of exchange rate series, we used the first difference of exchange rate series to achieve the stationarity condition. Partial and Autocorrelation functions of the series are determined using the Box-Jenkins method and the best fitting ARIMA model is found. The ARCH effect of the suitable ARIMA model is tested by ARCH-LM Test. The results suggest the feature of volatility of the exchange rate series.

Following the results from the analysis conducted for modeling volatility, it is seen that the most suitable model is IGARCH (1,1) model. The reliability of this model is again tested with the ARCH LM test and the model is found to be free of volatility. Hence, it is believed that the volatility of exchange rate series will be predicted more effectively with conditionally changing variance models.

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