American Journal of Applied Mathematics and Statistics, 2023, Vol. 11, No. 4, 100-107
Available online at http://pubs.sciepub.com/ajams/11/4/1
Published by Science and Education Publishing
DOI:10.12691/ajams-11-4-1

A Comparative Study of Volatility of Consumer Price Index and Exchange Rate of Ghana Using GARCH Models

Mary Ann Yeboah[1], David Benteh[2], Francis Yao Anyan[1,*], Philip Nyarko Kwakye[2], Kofi Mensah[2], Sulemana Mahawiya[1]

[1]Kumasi Technical University, Kumasi- Ghana
[2]Kwame Nkrumah University of Science and Technology, Kumasi- Ghana
*Corresponding author: anyanfrancis@ymail.com

Received October 28, 2023; Revised November 30, 2023; Accepted December 06, 2023

Abstract This research focused on comparing volatility of Consumer Price Index and Exchange Rate of Ghana using GARCH models. The main purpose of the study was to establish a relationship between the Consumer Price Index (CPI) and the Exchange Rate and thereby finding the best modeling for volatility of the CPI and Exchange Rate of Ghana. Simple linear regression analysis was used to describe the relationship between CPI and the Exchange Rate. The results showed that CPI has a positive significance influence on Exchange Rate in both the ARCH and GARCH model fits of the data. The comparison test of symmetric (GARCH and GARCH-in-Mean (GARCH-M models) and asymmetric GARCH models (exponential GARCH (EGARCH), Glosten, Jagannathan, and Runckle GARCH (GJR-GARCH or TGARCH) and the Power GARCH (PGARCH models)) were the methods used in the analysis. The results showed that EGARCH models produced the highest log-likelihood value compared with the other asymmetric models in both data. Hence, this study concludes that exponential GARCH (EGARCH) is the best model for modeling CPI volatility and Exchange Rate volatility of Ghana. This study only compared the different GARCH (1, 1) models however could not consider the GARCH models at different lags and this is recommended for further studies.

Keywords: *CPI, exchange rate, volatility, GARCH, EGARCH*

Cite This Article: Mary Ann Yeboah, David Benteh, Francis Yao Anyan, Philip Nyarko Kwakye, Kofi Mensah, and Sulemana Mahawiya, "A comparative study of volatility of Consumer Price Index and Exchange Rate of Ghana using GARCH models." American Journal of Applied Mathematics and Statistics, vol. 11, no. 4 (2023): 100-107. doi: 10.12691/ajams-11-4-1.

1. Introduction

Volatility in finance and other related fields refers to the pace wherein the cost of a security rises or falls for a certain amount of proceeds. It is utilized in option pricing to gauge the varied returns of the underlying assets. Volatility is characterized among other things by quick and notably unanticipated changes in a series from one period to the next. Again time-varying volatility is experienced when there are times one big change is followed by another and one tiny change is followed by another small change. According to [1] volatility measurement has been at the centre stage for risk management in securities market. Risk management has also become very essential for institutions in all sectors of the economy. Like in any economy, policy makers, Governments, investors and all consumers in Ghana are all adversely been affected by the consumer price index (CPI) and hence the interest in consumer price index volatility. The CPI has not been stable in the last ten years according to the Ghana Statistical Service. These unpredictable changes or fluctuations of the CPI will undoubtedly have debilitating impact on various sectors of the economy.

The CPI gauges the alteration in the general price level of services and goods consumed by households. The unpredictable changes in prices affect not the cost of living but also production, trade, consumption, etc. Thus price changes have great effect on great governments as well as academia. CPI is one of the most commonly used tools for measuring inflation. Theoretically CPI impacts on the exchange rate and other variables of the economy. Due to the crucial role CPI plays in its relationship with other macroeconomic variables it is always part of monetary policy of governments, thus it forms one of the major essential statistics for the economy. In Ghana, the CPI is reported monthly in the CPI statistical bulletin by the Ghana Statistical Service. As at April 2022 the CPI was 156.5 which showed an increase of 5.17% from March 2022. This increase is of great concern since its impact is felt on many sectors of the economy, especially the ordinary consumer.

The percentage changes in the national price levels is equivalent to the percentage change in the exchange rate between two currencies over any period. According to [2] the exchange rate indicates the amount of money from one country that can be bought with one unit of local currency. In other words exchange rate is the value of one nation's currency versus currency of another nation on the stock exchange. Ghana has implemented a number of initiatives and programs to stabilize exchange rate. Due to its volatility policy makers are unsure of the factors that influence currency movements [3]. When a new currency was introduced in 2007 and the new GH¢ 1 was equal to US $ 1, it indicated that the cedi was strong and the weight of depreciation had stabilized. The strength of the cedi in 2007 made it possible for many investors to enter the nation, but starting in 2013, the cedi value declined at an extreme rapid rate, at the moment GH¢ 12.00 equals US $ 1. Furthermore, one euro equals GH¢ 5.94, and one pound sterling equals GH¢ 6.81. It is evident from the points raised above that the cedi's value has fluctuated, posing risks to investors, individuals and policy makers alike. This makes the currency unsecured and consequently investors must find an asset that can act as a safe haven or a hedge against Ghana's currency crises. Planning is disrupted by ongoing exchange rate fluctuations, which is bad for economic growth. CPI changes as well as exchange rate changes are of great concern in academic research and national policy discussions of every economy. These two important policy variables if not properly manage can lead to the country deviating from its trajectory. Hence, uncertainty surrounding these policy variables may lead to undesirable consequences to national development and economic growth.

The GARCH model can be used to test volatility for these changes or fluctuations in the CPI and other variables such as the exchange rate. Several approaches have been used in measuring the changes or volatility in both variables with the GARCH family at the center stage of these models. In this study, our core aim and objective is the comparison of the GARCH family of models using CPI and Exchange Rate data. There are many GARCH models used in estimating volatility such as GARCH itself, TGARCH, PGARCH, EGARCH, GARCH-M etc. Some previous researches have looked at some of these methods in relation to different types of data sets. For instance, Dohyun, Hoon and Jihun (2019), compared volatility models using crude oil price shocks. Also, [4] looked at the review and comparison of modern volatility models using carbon dioxide emission allowance prices.

Some plethora of studies exists on volatility measures. Some of these studies include the works of [5] and [6]. These studies looked at CPI prediction in Indonesia using Support Vector Regression (SVR) and MAPE as an accuracy metric to predict CPI using the housing group for fuel, water, gas and electricity. The aforementioned research only employed CPI variables in its input and output prediction models. [7] also used the SVR method with four types of kernel variations to predict the Daily Consumer Price Index.

In a study by [3] nine emerging markets with momentarily high interest rates were examined using simple regression analysis to determine the concurrent relationship that exists between interest rate and exchange rate. They came to a conclusion that exchange rate depreciation was related to the amount and duration of the high interest rates. As a result, their analysis of the data calls into question the justification for increasing interest rates in order to defend exchange rates. [5], on the other hand challenged this conclusion by employing simple correlations to examine the relationship between monetary policy and exchange rates in five Asian countries impacted by the financial crisis. The study concentrated on how monetary policy helps stabilize exchange rates following a significant decline. Contrary to the findings of [8] the study's results did not support the notion that high interest rates had an effect on volatile exchange rates. Again, [5] investigate how the dynamics had changed in the wake of the financial crisis of Asia by employing a bivariate VAR-GARCH model to examine the empirical link between exchange rates and interest rates in Thailand, Korea, Indonesia and Philippines. The findings imply that interest rates have little effect on keeping exchange rates stable and this is because with greater flexibility in exchange rates, interest rates did not become steady.

However, after three and a half years of implementation, [8] also looked at the challenges posed by Brazil's consumer price index targeting regime. In addition to performing an OLS regression of the consumer price index target, the interest rate, and the 12-month consumer price index rate, they used a VAR to model consumer price index targeting. The results indicated that the macroeconomic stabilization process had been aided by consumer price index targeting framework. [9] looked into "Consumer Price Index Targeting under Weak Macroeconomic Fundamentals" in an effort to determine whether Ghana's monetary policy needed to be redirected. He recommended revising Ghana's Consumer Price Index targeting (IT) policy to hasten the socioeconomic advancement of the country. The study discovered that while IT had been successful in maintaining low levels of Consumer Price Index, a consumer price index target could seriously restrict the central bank's ability to react to shifting economic conditions if the regulation was applied very strictly. Accordingly, the study came to a conclusion that additional interventions would seem to be required to increase its efficacy. The volatility of returns on the Ghana stock exchange was modeled and forecasted by [10] using GARCH models, however little research has been done on the various competing GARCH models using CPI and exchange rate data particularly using Ghanaian data.

Thus, the following observations were made based on the reviewed literature: The majority of earlier research has not looked into how much the consumer price index and exchange rate affect the Ghanaian consumer prices. As a result, when analysing the exchange rate and consumer price index in Ghana, a significant explanatory variable is left out. This research closes the gap in the literature by investigating the impact of the exchange rate and the consumer price index on consumer prices in Ghana Therefore, an important omitted in the analysis of– dynamics in Ghana in addition to exchange rate pass-through. Hence, we have confined the study to Ghanaian data due to the geographic nature of the study.

2. Methodology

The study follows a proposed GARCH model by [11] which necessitates that the conditional variance be dependent on previous lags and an ARCH model introduced by [12]. Furthermore, GARCH models can parsimoniously symbolize higher order ARCH processes. The study aims to determine what lag value the volatility of consumer price index and exchange rate is stationary at. Moreover, The GARCH model uses the lagged conditional variance terms as autoregressive terms.The data for the analysis was obtained from the International Financial Statistics. The data is a time series data collected monthly over a period of 20 years from 2001 to 2020 in Ghana. We are using these data due to its availability at the moment even though not up to the current year.

Modeling Volatility

Consider a model with an AR(1) error term

$$y_t = \varphi + \varepsilon_t \tag{1}$$

Where $\varepsilon_t = \rho\varepsilon_{t-1} + v_t$ and $v_t \sim N\left(0, \sigma_v{}^2\right)$

The conditional mean of the error term is $E\left(\varepsilon_t | I_{t-1}\right) = E\left(\rho\varepsilon_{t-1} | I_{t-1}\right) + E\left(v_t\right) = \rho\varepsilon_{t-1}$.

The conditional variance of the error term is $E\left[\left(\varepsilon_t - \rho\varepsilon_{t-1}\right)^2 | I_{t-1}\right] = E\left[v_t{}^2 | I_{t-1}\right] = \sigma_v{}^2$.

If the conditional variance modifies over time, then $\varepsilon_t | I_{t-1} \sim N\left(0, h_t\right)$

Where

$h_t = \alpha_0 + \alpha_1\varepsilon_{t-1}^2$ for $\alpha_0 > 0$ and $0 \le \alpha_1 < 1$

defines the ARCH effect in the error term

Constructing a volatility model for an asset return series in line with Tsay (2005) consists of the following steps:

i. Determine a mean equation by examining the data for serial dependence
ii. Utilizing the residual of the mean equation, check for ARCH effect
iii. if ARCH effects are statistically significant, specify a volatility model and estimate the mean and volatility equations jointly.
iv. Examine the fitted model closely, making any necessary adjustments

In the study, monthly CPI and exchange rate of returns (r_t) were computed as the continuously compounded returns which are the first variation the series data's logaritm for the current and successive months

$$r_t = log\, log \frac{P_t}{P_{t-1}} \tag{2}$$

Where P_t *and* P_{t-1} are the values for current and previous monthly series.

Modeling volatility of Ghana's exchange rate and Consumer Price Index (CPI)

To specify the distributional properties of the monthly exchange rate and CPI of Ghana numerous descriptive statistics were computed and presented in Table 1for the study period, Shapiro test of normality was employed to check the normality of the data.

Test for Stationarity

The study starts with stationarity test due to the nature of the data which is monthly covering 2001 to 2020. The check is necessary to avoid spurious results. To check for the stationarity in the series of the data used in the study, Augmented Dickey-Fuller test was employed for unit roots is conducted on both series which showed rejection of the null hypothesis of stationarity in both cases. The data then become stationary before models are fitted.

Test for Autoregressive Conditional Heteroscedasticity (ARCH) Effects

To apply volatility model to data, ARCH effects are among the most crucial problems to be checked. This is done before ARCH models, Generalized Autoregressive Conditional Heteroscedasticity (GARCH), GARCH-M, EGARCH, PGARCH etc., are fitted in the residuals to look for heteroscedasticity evidence. In order to determine whether heteroscedasticity eists in residuals of each individual series, [12] Lagrange Multiplier (LM) test for ARCH effects is utilized. In conclusion, the test procedure starts with obtaining the residuals ε_t from the ordinary least squares regression of the conditional mean equation. A significant test leads to the application of the above model to the series.

Model the squared errors with a constant term and at lags = q as

$$\varepsilon_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \alpha_2\varepsilon_{t-2}^2 + \ldots + \varepsilon_{t-q}^2 + v_t \tag{3}$$

With null and alternate hypothesis as;

$$H_0 : \alpha_1 = \alpha_2 = . . . = \alpha_q = 0$$ vrs

$H_1 : \alpha_1 > 0$ for at least one $i = 1, 2, . . ., q$

The LM test is given by;

$LM\ \ test\ \ statistic = (T - q)R^2$. This test is a $\chi_q{}^2$

Where T is the sample size, q is the number of lags and R^2 is the correlation coefficient of the model.

Modeling Technique

Volatility models have been classified into symmetric models and asymmetric models, which are the two main categories. In models with symmetry, the magnitude not the sign, determines the conditional variance whiles in asymmetric models the shock depends on the same degree either, positively or negatively and influence volatility in the future. Several symmetric and asymmetric volatility models are being considered in the study in order to examine the impact of exchange rate volatility and the Consumer Price Index (CPI) in Ghana.

The GARCH Model

In the GARCH model, the conditional variance is expressed as a function of its own lags. The general specification of GARCH is GARCH (p, q) which is expressed as

$$\sigma_t^2 = \omega + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-1}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-1}^2 \tag{4}$$

where p is number of lagged σ^2 and q is number of lagged ε^2 term.

Moreover the simplest model specified is GARCH (1,1) model

Mean equation $r_t = \phi + \varepsilon_t$

Variance equation $\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2$

r_t is the asset return at time t, ϕ is the mean return and ε_t is the residual return.

GARCH-in-Mean (GARCH-M) Model

The GARCH-M model is proposed by Engle, Lilien, and Robins in 1987. The model is an extension of the GARCH-M (1,1) model frame work with mean and variance equations as

Mean equation $r_t = \mu + \lambda \sigma_t^2 + \varepsilon_t$

Variance equation $\sigma_t^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2$

Where λ the risk premium parameter demonstrates that the correlation between return and volatility is positive

Asymmetric GARCH Models

Assets prices have a feature of good and bad news in which bad news has more pronounced greater impact on volatility than positive. In symmetric models, the conditional variance is unable to capture the leverage (asymmetric) rise and fall in ε_t. Moreover, when there is leverage effects, symmetric models cannot account for them, hence the needs for asymmetric models. The asymmetric models used in the study includes exponential GARCH (EGARCH), [13] GARCH (GJR-GARCH or TGARCH) and the Power GARCH (PGARCH).

Exponential GARCH (EGARCH) Model

Exponential GARCH model is asymmetric model which deals with time-varying variance to shocks and concurrently guarantees that the variance is consistently positive. As Nelson (1991) developed it using the generalized form EGARCH (p, q) is

$$ln\left(\sigma_t^2\right) = \omega + \sum_{j=1}^{q} \beta_j \, ln\left(\sigma_{t-j}^2\right) + \sum_{i=1}^{p} \alpha_i \left\{\left|\frac{\varepsilon_{t-i}}{\sigma_{t-i}}\right| - \sqrt{\frac{2}{\pi}}\right\} - \gamma_i \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \quad (5)$$

Where γ is the leverage parameter which is expected to be positive such that future volatility is increased by negative shock and positive shock lessens the effects on the uncertainty of the future.

The EGARCH (1, 1) is also specified as

$$ln\left(\sigma_t^2\right) = \omega + \beta_1 \, ln \, ln\left(\sigma_{t-1}^2\right) + \alpha_1 \left\{\left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| - \sqrt{\frac{2}{\pi}}\right\} - \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \quad (6)$$

The Glosten, Jagannathan, and Runckle GARCH (GJR-GARCH (1, 1)) Model

To handle leverage effects, one of the models commonly used is the threshold GARCH model.

According to [13] which is also known as TGARCH (1,1) version model has the conditional variance form as

$$\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \gamma d_{t-1} \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \quad (7)$$

Where

$$d_{t-1} = \begin{cases} 1 & \text{if } \varepsilon_{t-1} < 0, \text{ bad news} \\ 0 & \text{if } \varepsilon_{t-1} \geq 0, \text{ good news} \end{cases}$$

γ is the leverage term, which determines the effects of the leverage on the returns. For good news (positive shock) volatility is α_1 and for bad news (negative shock) volatility effect is $\alpha_1 + \gamma$.

Generally TGARCH (p, q) is

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \left(\alpha_i + \gamma_i d_{t-1}\right) \varepsilon_{t-1}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2 \quad (8)$$

where α_i, γ_i and β_j are non-negative.

Power GARCH (PGARCH) Model

The power GARCH (PGARCH) model as introduced by [14] is also to deal with leverage effects (asymmetric). PGARCH models unlike other asymmetric models deals with the standard deviations instead of variance. One good thing about the PGARCH model is its ability to estimates the power δ.

The asymmetric PGARCH models specify the standard deviation models of the form;

$$\sigma_t^\delta = \omega + \sum_{j=1}^{q} \beta_j \sigma_{t-1}^\delta + \sum_{i=1}^{p} \alpha_i \left(\left|\varepsilon_{t-i}\right| - \gamma_i \varepsilon_{t-1}\right)^\delta \quad (9)$$

With $\delta > 0, \ \left|\gamma_i\right| \leq 1 \ \ for \, i = 1, 2, \ldots, r$.

The above model analysis is applied to data on exchange rate and consumer price index of Ghana using R package version 1.4.1106

3. Analysis and Results Discussion

Table 1. Descriptive Statistics of the Data

Statistics	CPI	Exchange
Minimum	17.7662	0.363900
Maximum	235.7125	4.525600
Range	217.9463	4.161700
Median	78.26811	1.166820
Mean	92.42065	1.656095
Variance	3308.443	1.254403
Std dev.	57.51907	1.120000
Skewness	0.765094	1.212241
Kurtosis	-0.37744	0.104351
Shapiro Test, W	0.91786	0.79272
Prob. of Shapiro Test	0.00000	0.00000

Accessing the distributional assumptions of the data for the analysis, basic statistics in both data set, exchange rate

(ER) and consumer price index (CPI) was conducted and the results presented in Table 1.

The distributional characteristics of the two data sets utilized in the research were examined and the results presented in Table 1 indicate a significant difference in the value of variance and mean of exchange rate and consumer price index. Also, skewness and kurtosis values are clearly observed in the CPI and ER indicating the departure from normality of the CPI and exchange rate data. The Shapiro test for normality of exchange rate and CPI data is also significant at 1% which confirms that data on exchange rate and consumer price index for Ghana is not normally distributed. In identifying the influence of consumer price index on exchange rate, correlation test was performed and the results of all the three different correlation test was significant at 1% confidence level which also indicates that consumer price index (CPI) significantly affects exchange rate.

The scatter plots of the two data are presented in Figure 1 below. It can be seen from the figure that there is a very strong positive correlation between the two data.

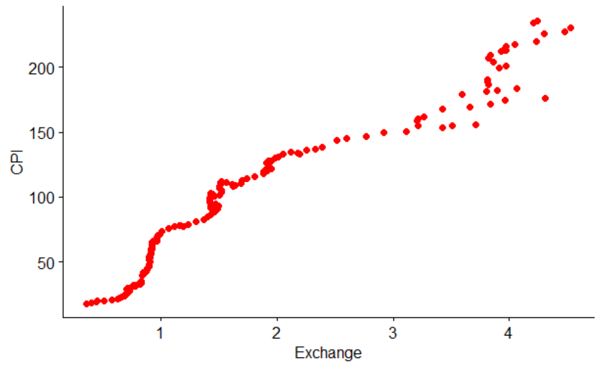

Figure 1. Scatterplot of CPI against exchange rate of Ghana

The results of the stationarity test are shown in Table 2.

Table 2. Stationary Test (Dickey-Fuller Test)

Data	Dickey-Fuller	P value
Consumer Price Index (CPI)	3.165	0.9900
Exchange Rate	-0.43856	0.9838
Fixing Stationary after differencing (Augmented Dickey-Fuller Test)		
Consumer Price Index (CPI)	-8.2064	0.01
Exchange Rate	-10.084	0.001

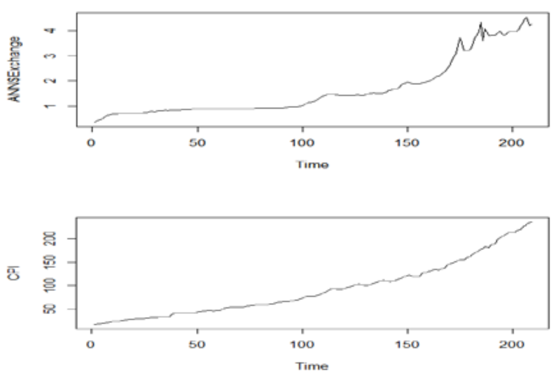

Figure 2. Plots of data for exchange rate and consumer price index of Ghana

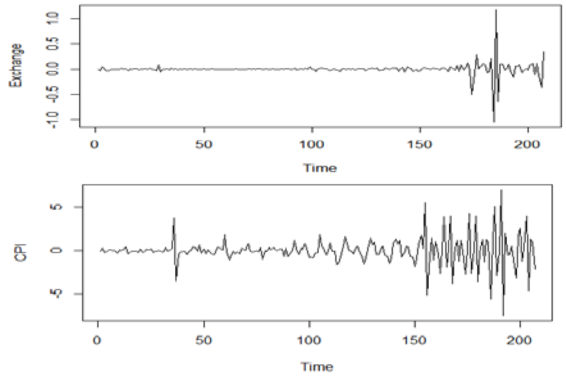

Figure 3. Plots of exchange rate and consumer price index of Ghana after differencing for Stationarity

After non-normality of the data has been confirmed further analysis of stationarity in the data sets was carried out. The plots of exchange rate and consumer price index data shown in Figure 2 indicates, non-stationarity in the two data sets. The Augmented Dickey-fuller (ADF) test is the unit roots test applied in the study for the stationarity which was significant at 1% indicating non-stationarity in the original data. After taking logarithm of the first differencing the plots in Figure 3 and the results in Table 2 show stationarity and hence further analysis can be carried out.

Volatility Models

Table 3. Estimate of the mean equations

Data	Estimate	Std Error	T value	rp (>ltl)
Consumer Price Index (CPI)	0.005232	0.109948	0.048	0.962
Exchange Rate	-0.000043	0.009437	0.005	0.996

The mean equation is estimated for both data and the results are presented in Table 3. These equations are constants model equations. The residual analysis is based on the residual of this model.

Table 4. Test of the ARCH effect (LM test) for Exchange rate and the CPI

Data	Chi2	Degree of freedom	P-value
Consumer Price Index (CPI)	31.824	2	0.00000
Exchange Rate	102.53	2	0.00000

For every lag shown in the analysis, the ARCH-LM test results in Table 4 offer compelling evidence to reject the null hypothesis and this shows that ARCH effects are present in the residuals series and consequently, the variance of the return series of exchange rate and consumer price index is non-constant for all designated periods. This provides ideal information for the analysis of volatility models both symmetric and asymmetric to identify the good model for exchange rate and consumer price index for Ghana. Again, diagnostic test are provided for each GARCH model to check whether there is an ARCH effect left in the estimated models. AIC, Bayes and log-likelihood estimates of each model is also stated to the performance of each model with respect to the data study.

Symmetric GARCH

The mean equation provides significant estimates for the mean parameter (constant) at 1% significant level but the variance model estimates of the mean parameter (constant) is not significant in the exchange rate for Ghana. In the consumer price index (CPI) of Ghana, model provides significant estimate for the mean (constant) for both the mean equation and the variance equation. A highly 1% significant level estimates of α and β also indicates the presence of ARCH and GARCH effect in the model for both data. These significant estimates indicates that lagged variance and squared disturbances has impact on the conditional variance, which provides evidence that volatility from previous period has influence on current volatility.

Table 5. Estimation results from GARCH (1, 1) model

Statistics	Parameters	Exchange rate	CPI
Mean Equation	ϕ (constant)	0.00008*	0.3292*
Variance Equation	ω (constant)	0.00000	2.5056*
	α (ARCH effect)	0.72499*	0.6288*
	β (GARCH effect)	0.15040*	0.3702*
	$\alpha+\beta$	0.87539	0.9990
AIC		-11.722	2.4845
Log-likelihood		1219.188	-251.143
	ARCH-LM Test		
ARCH-LM test statistics		0.039931	0.0573
Prob. Chi-square		0.8428	0.8108

*Indicates significance at 1% level.

The persistent coefficient $(\alpha+\beta)$ of the GARCH (1, 1) model is less than one (1) in both data which indicates that persistent exit but not high. The model ARCH-LM test gives a p-value greater than 0.8 for both data indicating that the null hypothesis of no ARCH effect cannot be rejected. Hence the variance model equation the correctly specified for both data.

In modeling the GARCH-M (1, 1) the mean equation of the returns of both exchange rate and CPI of Ghana is allowed to be a function of the conditional variance σ^2 in order to assess the risk on the mean returns. A highly positive significant value of risk premium parameter is observed in exchange rate and negative in the CPI. This indicates that the returns of the exchange rate of Ghana is associated the conditional variance used as proxy and also the return risk is positively related to the level of returns.

The findings indicate that, returns on exchange rate rise by 1.65386 and that of CPI decreases by 0.0136 in tandem with volatility. The results of the exchange rate is in line with the positive risk premium theory, which states that the higher the returns the higher the risk level associated. The model also provides significant estimates for ARCH and GARCH effect for both data used in the study. The persistent coefficient of the GARCH-M (1, 1) is also less than one (1) for both data indicating the presence of persistency in the data. The model ARCH-LM test also shows no ARCH effect and variance equation is also correctly specified.

Table 6. Estimation results from GARCH-M (1, 1) model

Statistics	Parameters	Exchange rate	CPI
Mean Equation	ϕ (constant)	0.00019*	0.2558*
	λ (Risk premium)	1.65386*	-0.0136*
Variance Equation	ω (constant)	0.00000	0.4620*
	α (ARCH effect)	0.87956*	0.8131*
	β (GARCH effect)	0.08968*	0.1859*
	$\alpha+\beta$	0.96924	0.9990
AIC		-11.954	2.3149
Log-likelihood		1244.22	-232.596
	ARCH-LM Test		
ARCH-LM test statistics		0.0204	0.1267
Prob. Chi-square [3]		0.8865	0.7219

* Indicates significance at 1% level.

Asymmetric models

To determine the presence of leverage effect in the data for Exchange Rate and Consumer Price Index (CPI) for Ghana some asymmetric models were employed in the study. These models were considered due to the behaviour of the data on the model.

Table 7. Estimation results from EGARCH (1, 1) model

Statistics	Parameters	Exchange rate	CPI
Mean Equation	ϕ (constant)	0.000003*	0.4664*
Variance Equation	ω (constant)	-2.9366*	1.5932*
	α (ARCH effect)	9.9988*	0.3062*
	β (GARCH effect)	0.8669*	0.1740*
	γ (Leverage effect)	-4.7315*	0.3117*
	$\alpha+\beta$	10.8657	0.4802
AIC		-12.236	2.4195
Log-likelihood		1273.413	-243.421
	ARCH-LM Test		
ARCH-LM test statistics		0.1893	0.9025
Prob. Chi-square [3]		0.6635	0.3421

*Indicates significant at 1% level.

The estimates in Table 7 show that both the coefficients and the parameters of the EGARCH model are significant at 1% significance level. The presence of ARCH and GARCH effect are all significant indicating the conditional variance of the current returns of exchange rate and CPI depends on the past variance. The negative value of the leverage effect of the exchange rate implies that negative shock has high conditional variance as opposed to positive shock of the same sign and the positive leverage in the CPI also implies negative leverage have low conditional variance for positive shock for negative shock of the same sign. The persistent coefficient of the exchange rate is greater than one (1) implies that large changes in returns of exchange rate are followed by huge changes and small changes typically follow other small changes, which will therefore, confirm that volatility clustering is observed in exchange rate of Ghana. The persistent coefficient of the CPI data is less than 1. The ARCH-LM test shows that there is no ARCH effect exists in the model hence the null hypothesis cannot be rejected. This shows that the variance model is correctly specified.

The results in Table 8 show the output of GJRGARCH (1, 1).The results shows significance effect in the parameter estimates for both exchange rate and CPI of Ghana except the constant term for the conditional variance model for exchange rate which is not significant. The ARCH and GARCH effect of the model in both data is significant at 1% indicating the presence of ARCH and GARCH effect in the two data sets. The model shows persistent coefficient greater than one in CPI and less than one in exchange rate, which then indicates that, shocks to the conditional variance are highly persistent in the CPI of Ghana. As a result, big changes in returns of consumer price index have a tendency to be followed by large changes and little changes are prone to be followed by little changes, which will intend, confirm that volatility clustering is observed in Ghana's CPI. The leverage effect is also significant in both data, negative and positive shocks have significant effects on the exchange rate and CPI of Ghana. The p-value of the ARCH-LM test greater than 0.8 in the two data of the GJRGARCH (1, 1) model shows the correct details of the conditional variance equation.

Table 8. Estimation results from GJRGARCH (1, 1) model

Statistics	Parameters	Exchange rate	CPI
Mean Equation	ϕ (constant)	0.00011*	0.3395*
Variance Equation	ω (constant)	0.00000	5.4570*
	α (ARCH effect)	0.3729*	1.00000*
	β (GARCH effect)	0.1118*	0.51448*
	γ (Leverage effect)	0.7066*	-0.73467*
	$\alpha + \beta$	0.4847	1.51448
AIC		-11.767	2.4741
Log-likelihood		1224.842	-249.067
ARCH-LM Test			
ARCH-LM test statistics		0.01926	0.0492
Prob.Chi-square [3]		0.8896	0.8245

*Indicates significant at 1% level

The results in Table 9 show the model estimates to the power GARCH in model which rather than modeling variance , models the standard deviation as in other GARCH models. This model also estimates the power rather than imposing it upon the model as other GARCH models do [15] The power estimates of this model are significant at 1% level of significance. The leverage effect of the PGARCH model is positive and also significant indicating higher volatility occurs when there is a positive shock and negative shock in the exchange rate of Ghana. This leverage is negative in CPI which is the reverse of what is observed in exchange rate. The PGARCH model is correctly specified since the ARCH-LM test shoe the acceptance the null hypothesis with a p-value greater than 0.8 for both data.

Table 9. Estimation results from PGARCH (1, 1) model

	Parameters	Exchange rate	CPI
Mean Equation	ϕ (constant)	-0.00018*	0.44685*
Variance Equation	ω (constant)	0.04990*	0.00957*
	α (ARCH effect)	1.00000*	0.00000
	β (GARCH effect)	0.19068*	0.99072*
	γ (Leverage effect)	0.86909*	0.99999*
	δ (Power parameter)	0.21203*	0.01000*
	$\alpha + \beta$	1.19068	0.99072
AIC		-8.7356	5.9256
Log-likelihood		911.139	-607.2952
ARCH-LM Test			
ARCH-LM test statistics		0.09195	0.03418
Prob. Chi-square [3]		0.9202	0.8533

The PGARCH model also gives a persistent coefficient of the exchange rate is greater than one (1) implying small changes in returns of exchange rate is followed by small changes and large changes tend to be followed by large changes, which will therefore, confirm that volatility clustering is observed in exchange rate of Ghana. Also, the persistent coefficient in the CPI data is almost 1 signifying the existence of volatility in Ghana's CPI data.

Models Comparison

The goodness of fit test used in the study is log-likelihood and AIC, since the AIC value is penalized by the number of parameters contained within the model, analysis for the model selection was based on the log-likelihood. From the models estimates of each model used in the analysis it is clear that higher value log-likelihood is observed in EGARCH (1, 1) for both exchange rate and CPI of Ghana.

4. Conclusion

A lot of works have been done on modeling volatility of stock markets in Ghana and other countries at large but, little has been done on the comparison of the modeling methods especially using Consumer price index and exchange rate. Modeling methods of volatility have been classified symmetric and asymmetric. Symmetric models deal with the symmetric nature of the volatility in the data whiles asymmetric models captures both the symmetric and leverage (asymmetric) effects in the data. Among the models used in this study, the ARCH and GARCH effect were all significant at 1% for the data on CPI and exchange rate. The asymmetric models also confirmed the presence of leverage effects by producing significant estimates.

The regression model of exchange rate and CPI shows that CPI has a positive significance influence on exchange rate in both model fits of the data. The comparison test results with the log-likelihood values were used in the analysis and it shows that EGARCH models produced the highest log-likelihood value compare with the other asymmetric models in both data. Hence, this study concludes that exponential GARCH (EGARCH) is the best model for modeling consumer price index volatility and exchange rate volatility of Ghana.

References

[1] Rastogi S, Don J., and Nithya V (2018) *Volatility Estimation using GARCH Family of Models: Comparison with Option Pricing*. Pacific Business Review International Volume 10 Issue 8.

[2] Javed Z.H and Farooq M.,(2009) *Economic Growth and Exchange Rate Volatility in Case of Pakistan*. Pak. j. life soc. sci. (2009), 7(2): 112-118.

[3] Alagidede, P., and Ibrahim, M., (2016), 'On the causes and effect of exchange rate volatility on economic growth' Evidence from Ghana.

[4] Segnon M., Lau C.K, and Gupta R.W (2017). "*Are multifractal processes suited to forecasting electricity price volatility? Evidence from Australian intraday data*," CQE Working Papers 6117, Center for Quantitative Economics (CQE), University of Muenster.

[5] Jeenanunta,C., Chaysiri, and L. Thong.(2018) *Stock Price Prediction With Long Short - Term Memory Recurrent Neural Network*. 2018 Int. Conf. Embed. Syst. Intell. Technol. Int. Conf. Inf. Commun. Technol. Embed. Syst., pp. 1–7. Khon Kaen, Thailand 7-9 May 2018.

[6] Dewi, K, Adikara, P.P and S. Adinugroho. Prediksi Indeks Harga Konsumen(IHK) KelompokPerumahan , (2018) Air , Listrik , Gas Dan Bahan Bakar Menggunakan Metode Support Vector 3856–3862, 2018.

[7] Budiastuti, S. M. S. Nugroho, and M. Hariadi (2018) *Predicting daily consumer price index using support vector regression method*. QiR 2017 - 2017 15th Int. Conf. Qual. Res. Int. Symp. Electr. Comput. Eng. Nusa Dua, Indonesia 24-27 July 2017.

[8] Gao, Y. Chai, and Y. Liu. (2018). *Applying Long Short Term Momory Neural Networks.*

[9] Osei-Assibey, E. (2018). Consumer price index targeting under weak macroeconomic fundamentals: Does Ghana need a monetary policy re-direction? IEA Roundtable Discussion. Retrieved February 16, 2018, from www. Myjoyonline.com.

[10] Frimpong, J.M. and Oteng-Abayie, E.F. (2006) Bounds Testing Approach: An Examination of Foreign Direct Investment, Trade, and Growth Relationships. MPRA Paper No. 352. http://mpra.ub.uni-muenchen.de/352/10.

[11] Bollerslev, T. (1986) Generalized Autoregressive Conditional Heteroskedasticity. Journal of Econometrics, 31, 307-327.

[12] Engle, R.F. (1982) Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation. Econometrica, 50, 987-1007.

[13] Glosten, R.L, Ravi .J, and Runkle D. E. (1993). *On the Relation between the Expected Value and the Volatility of the Nominal Excess Return on Stocks*, The Journal of Finance V Vol. Xiviii, No. 5 V December 1993.

[14] Ding, Z., Engle, R. and Granger, C. (1993) *Long Memory Properties of Stock Market Returns and a New Model*. Journal of Empirical Finance, 1, 83-106.

[15] Ocran, M. and Biekets, N. (2007) Forecasting Volatility in Sub-Saharan Africa's Commodity Markets. Investment Management and Financial Innovations, 4, 91-102.