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AN ANALYSES OF EXCHANGE RATE VOLATILITY: A CASE OF SANE COUNTRIES

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ABSTRACT

The sensitivity of exchange rate to an economy has made the study of its volatility essential and that motivated this study in SANE countries. Using GARCH models under different error distributions and monthly data spanning a period of 2016-2020, findings of our study show that exchange rate is volatile in each of the countries sampled. We also found that while some models in each country exhibit mean reversion, others show none mean reversion. The asymmetric parameters of the models show that exchange rate volatility in SANE countries exhibits both positive and negative shocks. Finally, our findings show that other error distributions perform better than the traditional Normal distribution. We therefore recommend that monetary authorities in each of the SANE countries should fine tune their policies on exchange rate to ensure stable and realistic exchange rate regimes which do not hurt the macroeconomic environment. We also suggest that in modelling exchange rate volatility, each country should explore several error distributions so as to avoid biased outcomes.

Contribution/Originality: This study contributes to the existing literature by analyzing exchange rate volatility in SANE countries. Evaluating different error distributions in order to assist in a proper modeling of exchange rate in each of the countries is another area we have contributed to literature. We affirm the authenticity and originality of the paper.

1. BACKGROUND TO THE STUDY

The collapse of Breton Woods system around the 1970s ushered in volatility in exchange rate around the world economy. This development brought in its wake, major changes, thus culminating in forcing countries to choose different forms of exchange arrangement (Marwa, 2016). A country's peculiar characteristics determine the preference for any particular exchange rate arrangement and this has its peculiar macroeconomic implications. In another vein, financial liberalization across countries has equally introduced fluctuations in exchange rate.

Barguellil, Ben-Salha, and Zmami (2018) contended that the introduction of policies on financial liberalization has led to fluctuations in exchange rate in most developing countries.

SANE is the acronym for four countries within Africa, namely: South Africa, Algeria, Nigeria and Egypt. It is modelled after Brazil, Russia, India, and China (BRICS) countries. Owing to the enormity of economic activities in SANE countries, volatility in exchange rate is more pronounced in these countries. As noted by Duru and Siyan (2016), SANE countries represent Africa's G4 which holds the key for Africa's growth poles in terms of unravelling its capacities for economic prosperity. The study contended that it is because of the economic importance of these countries that informed most economic indicators in the context of Africa to be decomposed into two main economic groupings: the SANE and the rest of others. Therefore, any shock arising from exchange rate volatility in this block could affect the economy of other African countries.

In this paper, our main interest is anchored on exchange rate sensitivity in an economy and how volatility in this variable can influence macroeconomic environment. With the concentration of economic activities in the SANE countries, we contend that exchange rate volatility could infiltrate into the economy of other African countries, thus leading to macroeconomic economic dislocations. When a currency is weak, this could lead to rising inflation. Instability in exchange rate is also capable of having ripple effect on the financial markets as investors, in order to stem the tide of this volatility, juggle between various asset classes. It is noteworthy to state that by observing the currency circles, monetary authorities and fiscal planners can plan ahead.

A cross-country investigation of exchange rate volatility has not been carried out in SANE countries. Therefore, by focusing on this bloc, we contribute to existing knowledge. We also broadened the frontier of knowledge on this area by investigating the appropriate models that best suit exchange rate volatility in each of the SANE countries. We are being guided by the fact that applying an inappropriate error distribution in a volatility model could lead to model mis-specification and hence a biased outcome. Therefore, by testing the various error distribution models, we are able to select the best fit models that will be appropriate to model exchange rate volatility in SANE countries.

2. EMPIRICAL LITERATURE

The sensitivity of exchange rate to the economy has led many studies centered on its volatility at both country-specific and cross-country level. In South Africa, Muteba and Dube (2014) examined the effect of exchange rate volatility on international trade. By using monthly data spanning a period of January 1995 to June 2011 and under the framework of Structural Vector Autoregressive (SVAR), findings of the paper showed that various industries, sectors and subsectors of the economy of the Republic of South Africa are impacted differently by the volatility of the Rand/Yuan and Rand/Dollar exchange rates, respectively. For Algeria, Mohammed, Bendob, Djediden, and Mebsout (2015) investigated the responses of producer and consumer price indexes to exchange rate. Applying the Vector Autoregressive (VAR) model with a quarterly data for the period 2002-2011, the outcome of the study indicates that the consumer price increases responded to foreign exchange appreciation against the Algerian Dinar.

Salisu (2011) carried out a study to analyze exchange rate volatility in Nigeria over a period of 1999 and 2011. By employing daily returns, the study applied the Generalized Autoregressive Conditional Heteroscadasticity (GARCH) models in the estimation. The empirical evidence indicates that exchange rate behaviour tends to fluctuate within the study period amid changing leverage effect and persistence of shocks. The study recommends that different GARCH model should be used in estimating exchange rate volatility in Nigeria. Also applying the GARCH method for Nigeria and adopting monthly data over a period of 1985:1 to 2011:7, Bala and Asemota (2013) investigated the volatile nature of exchange rate of Naira/US dollar and Naira/British pounds. Findings of the study show the presence of volatility in the currencies sampled and the asymmetric models does not accept the existence of a leverage effect.

Another study for Nigeria by Kalu (2016) employing the GARCH models, estimated the volatilities in different types of exchange rates in Nigeria over a period of January 1995–December 2014. The outcome of findings revealed that current volatility of exchange rates is influenced by volatilities in interbank and bureau de change exchange rates in the previous periods. Yakub, Sani, Obiezue, and Aliyu (2019) using monthly data and under the framework of the Auto Regressive Distributed Lag (ARDL) bounds testing approach, found that volatility in exchange rates impacted negatively on trade flows only in the short run. In another study for Nigeria, Kanu and Nwadiubu (2020) by applying the VAR model, revealed an inverse relationship between international trade and real exchange rate in current periods. In Egypt, Hosni and Rofael (2015) under the framework of the Vector Error Correction Model (VECM), showed that real exchange rate appears to be misaligned, undervalued and overvalued during 2001-2009, 2003-2007, 2001-2002 and 2008-2012, respectively.

In another study for Egypt, Marwa (2016) examined the influence of Central Bank of Egypt actions on exchange rate volatility. Under the framework of GARCH model, finding shows the presence of volatility clustering which are not persistent. In a study for developing countries that applied GMM framework, Barguellil et al. (2018) revealed that the type of exchange rate regime in place determines the effect of exchange rate volatility. By adopting a Panel Vector Autoregression (PVAR), Ozcelebi (2018) show that exchange rate volatility can be a secondary factor for the variations in immediate interest rates in OECD countries.

2.1. Exchange Rate Profile of South Africa

The World Bank 2018 estimated that with a GDP of USD 294.8 billion in 2016, South African remains the most advanced economy in Africa. The major economic activities that sustain her include mining and agriculture which constitute the bedrock of the country's foreign exchange earners. South Africa exports plenty of natural resources and also imports finished goods. Government debts are denominated in US dollars as such, the real value of this rises on the back of a weak local currency against major currencies. Since her economy is mainly dependent on mining and agriculture, the Rand which is her domestic currency is prone to fluctuate each time the global demand for these export commodities change. Social unrests in the country usually lead to falling exports as the disruptions occasioning that phenomenon lead to closure of mines. For instance in 2014, platinum production was reduced owing to strike embarked upon by the Association of Mineworkers and Construction Union.

Exchange rate policy in South Africa over the years has centered on maintaining a floating currency regime. As an open economy, the country's socio-political and economic environment leads to movements in her exchange rate regime. It has been observed that the Rand underwent speculative attacks from speculators after a brief period in 1998 on grounds of fears of the likely economic direction as the country was approaching post-apartheid. Ever since then currency performance depended on the state of affairs of the country's economic cum social environment. In Figure 1, it can be observed that beginning from 2006, exchange rate has been showing fluctuating trends.

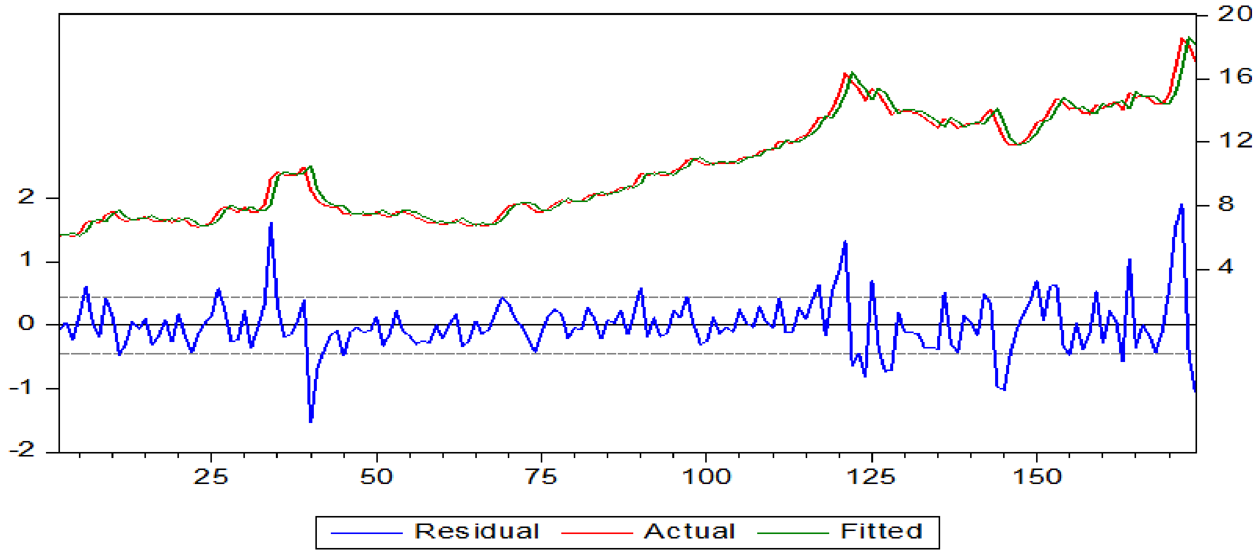

Figure-1. Trend of Exchange Rate Volatility in South Africa.

2.2. Exchange Rate Profile of Algeria

The oil sector is the dominant sector of Algeria's economy over the years, thus exposing the economy to dynamic nature of world oil prices. Since the oil sector contributes a large share of overall government revenues, fluctuations in oil prices affect fiscal policy performance. To worsen matters, changes in oil prices are exacerbated by the high burden of both domestic and foreign debt. For a long time, diversification of the economy to integrate other sectors has been the policy direction of the government. But despite successful stabilization in the past few years, progress in the structural areas has been slower.

The Algerian exchange rate policy since 1996 has always been that of a managed float after a long period of time. However, concerns have been raised that exchange rate policy in Algeria has been a failure. It has been noted that the black market provides close to 40% of business activities in Algeria during periods of widening gap between the domestic official exchange rate and other major currencies widens. Figure 2 reveals that Algeria's exchange rate has been fluctuating over the years.

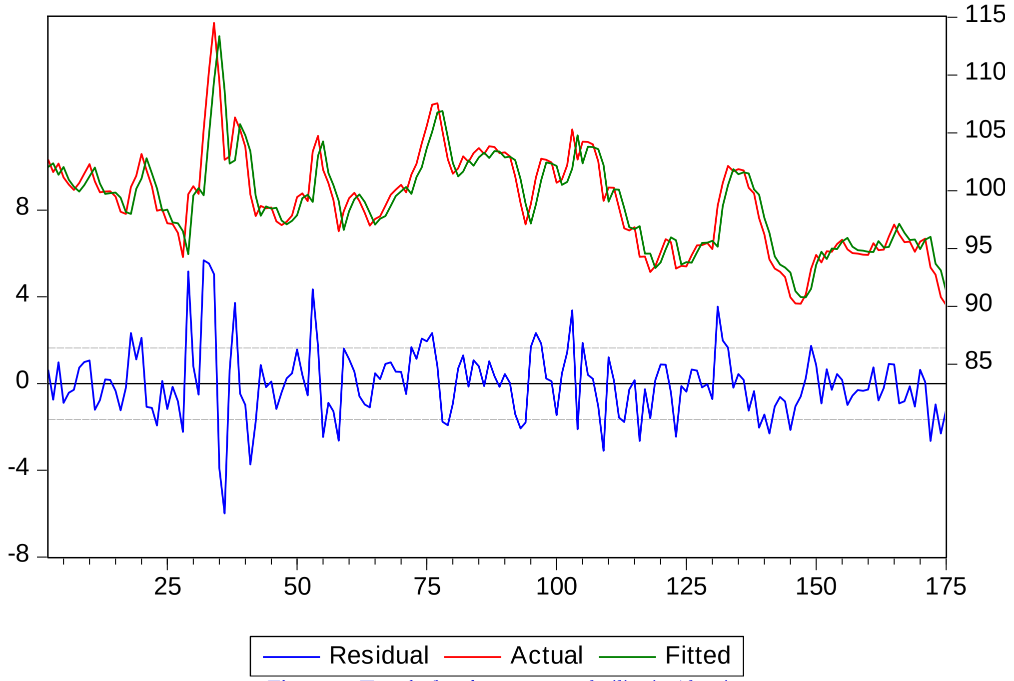

Figure-2. Trend of exchange rate volatility in Algeria.

2.3. Exchange Rate Profile of Nigeria

Exchange rate management in Nigeria is the responsibility of the Central Bank of Nigeria (CBN). The CBN ensures that variability in exchange rate is minimized in order to enhance monetary policy formulation and investment decisions. According to Osigwe (2015) Nigeria has moved from a regime of pegging to a regime of exchange rate flexibility following the introduction of structural adjustment policy (SAP) in 1986. The study noted that what obtains in reality is a managed float since in practice no exchange rate is pure float. In support of the above, Yakub et al. (2019) noted that several institutional frameworks have been put in place in order to stabilize the exchange rate in Nigeria.

These strategies include the introduction of the Second tier Foreign Exchange Market (SFEM), the Foreign Exchange Market (FEM) and the Autonomous Foreign Exchange Market (AFEM). Others include the Inter-bank Foreign Exchange Market (IFEM), Dutch Auction System (DAS), the Wholesale Dutch Auction System (WDAS) and the Retail Dutch Auction System (RDAS). Despite all the measures put in place so far, exchange rate volatility has always been a common feature of the Nigerian economy. Figure 3 shows volatility in the exchange rate of the Nigerian currency over the years.

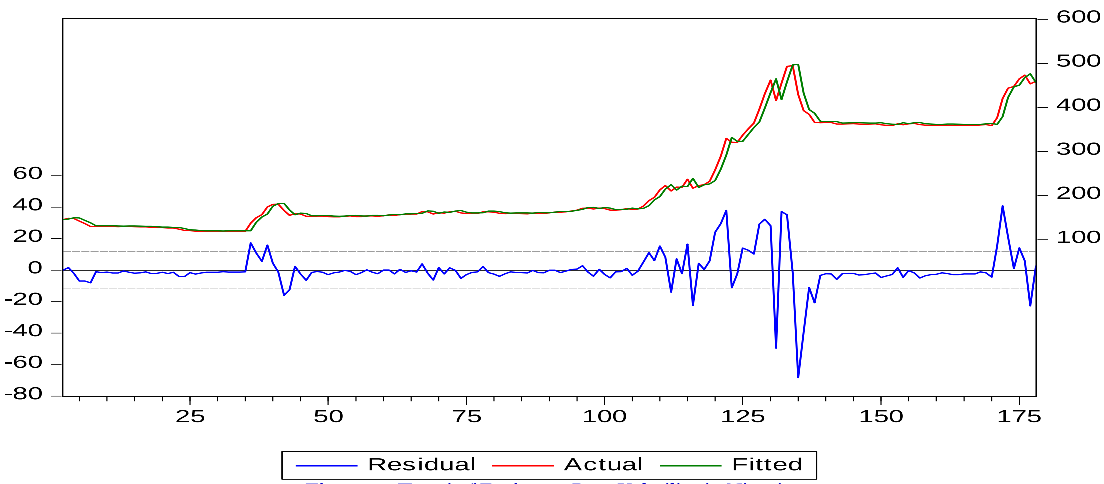

Figure-3. Trend of Exchange Rate Volatility in Nigeria.

2.4. Exchange Rate Profile of Egypt

Over the years, the Egyptian economy has undergone several stages of development which have led to several regimes of exchange rate. Since the nineties, macroeconomic policies in Egypt have rapidly been evolving as she applied a regime of exchange rate fixing. The shift to a regime of flexible exchange rate began in 2000. Notwithstanding this, by precisely January 2003, monetary authorities experimented on exchange rate floating. In 2004, this culminated in a transition to a unified flexible exchange rate. Following these developments, the Egyptian pounds underwent depreciation against the U.S Dollars between 200-2004.

By December 2004, the Central Bank of Egypt (CBE) introduced the interbank foreign exchange market. Owing to this, the Egyptian local currency appreciated within the period under review. Ghalwash (2010) observed that reserves rose steadily between 2005 and 2006 and the trend continued in 2010. A tight monetary policy approach applied by the CBE around 2005 to cushion the effect of the currency appreciation led to a declining inflation. The pound depreciated after 2012 owing to the introduction in that year, the Foreign Exchange Auctions which was meant to run side by side with the Dollar interbank system. As a result of constant differentials in the inflation rate with most of the country's trading partners as noted by Marwa (2016) there was a depreciation of the effective exchange rate by 11% from 2010 till October 2014. Figure 4 below depicts the trend in the Egyptian exchange rate over the years.

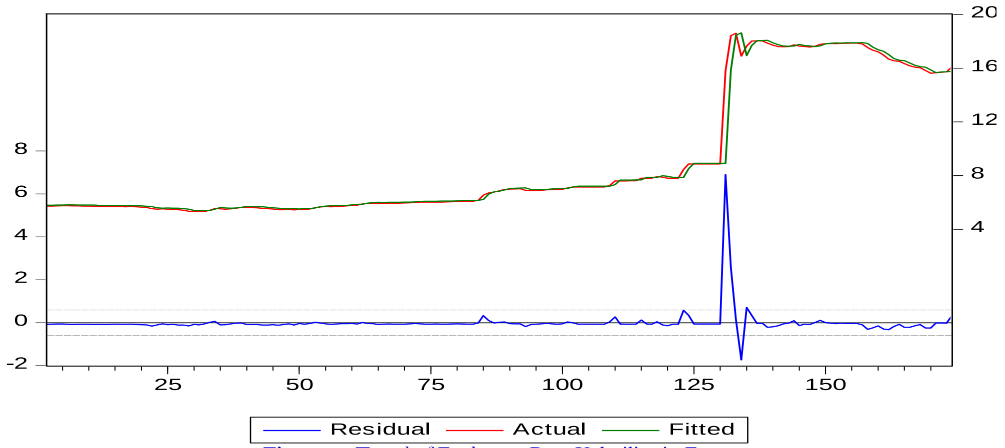

Figure-4. Trend of Exchange Rate Volatility in Egypt

2.5. Theoretical Matters

Different theories have been developed by scholars geared towards the determination and forecasting of exchange rate. The preponderance of these theories indicates the fundamental roles exchange rate play in the economy. Monetary models providing an exposition of exchange rate determination came into being in early 1970s after the fall of the fixed exchange rate system. A major ingredient of the theory is the postulation that the process of balancing aggregate demand and supply of money in any economy is a major determinant of exchange rate. In a nutshell, the model assumes that monetary factors exert influence on the determination of exchange rate. As observed by Lee, Azali, Yusop, and Yusoff (2007) monetary approach to exchange rate determination posits that there is a stable long run nominal demand for money which is positively related to nominal national income level but negatively related to interest rate.

The portfolio balance approach by McKinnon (1969) broadened the scope of the monetary approach by maintaining that apart from monetary factors, financial assets equally impact on the determination of exchange rate. Among the assets include both domestic and external bonds and money. Aima and Abbas (2015) noted that under this approach, equilibrium is established through exchange rate in the portfolio of the investor such as money, domestic and foreign bonds. With this, any change that arises in any one of the assets will induce the investor to re-establish in his portfolio, the desired balance. The study further observed that the process of rebalancing requires an adjustment that influences the asset demand and subsequently, exchange rate. For instance as observed by (Sharan, 2012(p.98)) as cited in Aima and Abbas (2015), if there is a rise in interest rate on foreign bonds, this will lead to an increase in the demand for the asset, thus raising the demand for foreign currency while depreciating the local currency.

3. METHODOLOGY

This study utilized the technique of the GARCH models and the choice of the models is informed by the advantages inherent in them in capturing volatility in the variables. The stages of estimating the volatility models which the paper employs include first a test for ARCH effects followed by estimating the GARCH models and then the robust tests.

The implication of a test for the existence of ARCH effect is to determine if the series are volatile. Any series that does not exhibit ARCH effect is not included in the GARCH models because as the name implies, GARCH models only handles volatile series. The steps involved in the estimation of ARCH effect include the following: First, a linear regression has to be conducted with respect to equation 1 below:

$$Z_t = \lambda_0 + \sigma_1 \lambda_{t-1} + \varepsilon_t; \quad (1)$$

where

$\varepsilon_t Z\ IID(0, \sigma^2)$.

Equation 1 above is a typical ARCH model, where λ indicates the rate of return of the series. The essence of running the above regression is to enable us obtain the residual and the next thing to do is to square the residual and then regress it on its own lags. This is displayed in Equation 2 as follows:

$$\hat{\varepsilon}_t^2 = \pi_0 + \pi_1 \hat{\varepsilon}_{t-1}^2 + v_t \quad (2)$$

From Equation 2 we obtain the R^2. The sample size multiplied by the coefficient of determination (TR^2) defines the test statistic which is distributed as a $\chi^2(q)$. The null hypothesis of no ARCH effect is tested against the alternative and if the null is rejected, it implies that there is a presence of ARCH effect in the series.

Having tested for ARCH effect, the next is to specify the ARCH model and this involves the modelling of the conditional mean equation as well as the conditional variance. The specifications are displayed in Equations 3 and 4 as follows:

$$Z_t = \lambda_0 + \sum_{i=1}^{p} \psi_i Z_{t-i} + \varepsilon_t \quad (3)$$

$$\sigma_t^2 = \gamma_0 + \sum_{i=1}^{p} \gamma_i \varepsilon_{t-1}^2 \quad (4)$$

Where

ε_{t-1}^2 is an ARCH term and $0 \leq \sum_{i=1}^{p} \gamma_1 < 1$ represents the stationary series. As $\sum_{i=1}^{p} \gamma_i \rightarrow 1$, it indicates that the series exhibit slow mean reverting, while as $\sum_{i=1}^{p} \gamma_i \rightarrow 0$, it indicates that the series show fast mean reverting.

The ARCH models have some limitations which led to their modification. Among the limitations include the decision on the proper lag length (q) which may be very large, thus making the model suffer over-paramatization. As a way of improving the limitations in the ARCH models, Bollerslev (1986) and Taylor (1986) respectively introduced the GARCH model. Equation 5 below shows the specification of the model:

$$\sigma_t^2 = \gamma_0 + \sum_{i-1}^{p} \gamma_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \pi_j \sigma_{t-j}^2 \quad (5)$$

Where $0 \leq \sum_{i-1}^{p} \rho_i + \sum_{j=1}^{q} \pi_j < 1$ connotes the mean reverting process. If $\sum_{i-1}^{p} \rho_i + \sum_{j=1}^{q} \pi_j \rightarrow 1$, the indication is that the model exhibits slow mean reverting while as $\sum_{i-1}^{p} \rho_i + \sum_{j=1}^{q} \pi_j \rightarrow 0$ it shows that the model is fast mean reverting.

In this study, we also considered the GARCH-in-Mean model. GARCH-in-Mean model allows the conditional mean to be a function of its own conditional variance. Engle, Lilien, and Robins (1987) noted that GARCH-in-Mean model is derived by introducing the conditional variance or standard deviation into the mean equation. The specification of the GARCH-in-Mean model is displayed in Equation 6 below as follows:

$$Z_t = \lambda_0 + \sum_{i=1}^{p} \psi Z_{t-i} + \varepsilon_t + \delta\sigma_t^2 \tag{6}$$

where

δ is the GARCH-M coefficient

We broadened the horizon of the study by including other models that account for good and bad news. This is informed by the limitations associated with the ARCH and GARCH models. One of such limitations is the inability of these models to indicate the leverage effects (asymmetry). These models assume a symmetric volatility response to positive and negative shocks. Consequently, GARCH model has been extended in diverse forms to accommodate these limitations. In this study, to account for leverage effect, we limited our study to the threshold GARCH (TGARCH) and the Exponential GARCH (EGARCH). Zakoian (1994) and Glosten, Jagannathan, and Runkle (1993) independently introduced the TGARCH. Asymmetries are captured in the TGARCH by including a multiplicative dummy variable in the variance equation. The essence is to investigate whether or not negative shocks is statistically significant. TGARCH model is specified in Equation 7 as follows:

$$\sigma_t^2 = \gamma_0 + \sum_{j=1}^{q} \gamma j \ \sigma_{t-j}^2 + \sum_{i=1}^{p} \pi_i \varsigma_{t-i} \varepsilon_{t-i}^2 + \sum_{k=1}^{p} \kappa \varepsilon_{t-1}^2 d_{t-1} \tag{7}$$

where

$\sigma_t^2 > 0$ accounts for good news, while $\sigma_t^2 < 0$ indicates bad news. γj indicates the impact of good news, $\gamma j + \pi_i$ shows the impact of bad news. When $\kappa_i > 0$, the volatility of bad news increases and this implies the existence of leverage effect in the *i*-th order. However, when $\kappa_i \neq 0$, there is asymmetry in news impact.

The EGARCH model introduced by Nelson (1991) is another version of the GARCH (p,q) model. As a way of modification, the lagged squared autoregressive component (ε_{t-i}^2) which appears in the standard GARCH model is substituted with a standard normal variable which may come from a generalized error distribution (GED). Equation 8 below shows the specification of the conditional variance of EGARCH (p,q) model:

$$l\log(\sigma_t^2) = \Pi_0 + \Pi_i \left| \sqrt{\frac{\varepsilon_{t-1}^2}{\sigma_{t-1}^2}} \right| + \varphi_i \sqrt{\frac{\varepsilon_{t-1}^2}{\sigma_{t-1}^2}} + \varpi_i \log(\sigma_{t-1}^2) \tag{8}$$

where

$\sigma_t^2 > 0$ and $\sigma_t^2 < 0$ indicate good news and bad news

$(1+\varpi_i)\left|\varepsilon_{t-i}^2\right|$ and (1-φ_i)$\left|\varepsilon_{t-i}^2\right|$ are total effects respectively. If $\varphi_i < 0$, the implication is that bad news exert higher impact on volatility. The *log* of the conditional variance is indicated in the left-hand side. By implication, the leverage effect is exponential and by no means quadratic. Consequently, forecasts of the conditional variance are guaranteed to be nonnegative.

3.1. Error Distributions

In order to assist in model selection, we employed three basic assumptions about the conditional distribution of the error term which are essential in ARCH models. These are: normal (Gaussian) distribution, Student's *t*-distribution and the Generalized Error Distribution (GED). The normal distribution is specified in Equation 9 below as follows:

$$L(\varpi_t) = -\frac{1}{2}\sum_{t-1}^{T}(\ln 2\lambda + \ln\sigma_t^2 + \frac{\varepsilon_t^2}{\sigma_t^2}) \qquad (9)$$

where

σ_t^2 is specified in each of the GARCH model.

The student's *t* distribution is specified in Equation 10 as follows:

$$L(\varpi_t = -\frac{1}{2}\log(\frac{\lambda(r)\gamma r/2^2}{\lambda(r+1)/2)^2}) - \frac{1}{2}\log\sigma_t^2 - \frac{r+1}{2}\log(1+\frac{y_t - x_t^1\varpi)^2}{\sigma_t^2(r-2)} \qquad (10)$$

As $v \rightarrow \infty$, the *t*-distribution approaches the normal.
r is the degree of freedom which controls the tail behaviour r > 2

For the Generalized Error Distribution (GED), the specification is shown in Equation 11 below:

$$L(\varpi_t) = -\frac{1}{2}\log(\frac{r1/v^3}{r(3/v)(v/2)^2} - \frac{1}{2}\log\sigma_t^2 - \frac{(r(3/v)(y_t - x_t^1\varpi)^2)^{v/2}}{\sigma_t^2\gamma(1/v)} \qquad (11)$$

where
r > 0 = the tail parameter . If r =2, it implies that the GED is a normal distribution However, if r < 2, it implies that it is fat-tailed. Skewness of the returns is accounted for by v. The higher the value of v, the greater the weight of tail. If v = 0, GED reverts to normal distribution

3.2. Data and their Sources

In this study, we employed monthly data over a period of January 2006 to June 2020. In each country, we considered exchange rate regime that exhibit volatility as indicated by the result of the ARCH effect. This is to enable us include only volatile variables in the GARCH models. Domestic currency per USA Dollars is used as a proxy for exchange rate. Exchange rate data for all the countries, except Nigeria were obtained from the International Monetary Fund (IMF) International Financial Statistics. Data for Nigeria was obtained from the Central Bank of Nigeria Statistical Bulletin. We employed Bureau De Change exchange rate for Nigeria in this study because this rate responds quickly with the market as most people rely on this source for transactions.

3.3. Results Presentation and Analysis

In every times series study, investigating the stationarity of the series is necessary in order to avoid estimating a spurious model. The tests are evaluated under the framework of the Augmented Dickey Fuller (ADF) and Phillip Perron (PP). At the 5% level, we tested the null hypothesis of no stationarity against the alternative. Results of finding are displayed in Tables 1 and 2 below and they include both at level and at first difference respectively. Evidence show that under both the ADF and the PP, none of the variables achieved stationarity at level. However, stationarity was achieved when they were differenced.

Table-1. Stationarity result at Level.

Variable	Country	ADF t-stat	PP t-stat.	ADF critical value at 5%	PP critical value at 5%	Order of integration
EXCHR	South Africa	-0.729709	-0.313673	-2.878212	-2.878113	,,
	Algeria	-3.383090	9.713784	-2.878113	-2.680856	,,
	Nigeria	-0.025748	0.038028	-2.877823	-2.877729	,,
	Egypt	-0.699431	-0.467417	-2.878212	-2.878113	,,

Note: asterisks (**) indicate the rejection of the null hypothesis at the 5% level.

Table-2. Stationarity result at first Difference

Variables	Country	ADF t-stat.	PP t-stat.	ADF critical value at 5%	PP critical value at 5%	Order of integration
ΔEXCHR	South Africa	-9.945769	-9.527844	-2.878212	-2.878212	I(1)
	Algeria	-9.713784	-9.924136	-2.878212	-2.878113	I(1)
	Nigeria	-9.560865	-9.575636	-2.877823	-2.877823	I(1)
	Egypt	-9.621236	-9.388324	-2.878212	-2.878212	I(1)

Note :asterisks (**) indicate the rejection of the null hypothesis at the 5% level.

3.4. Test for ARCH Effect

The next test we conducted to guide us in the study is a test to determine if the variables exhibit ARCH effect. Finding of the volatility of the series in Table 3 revealed that both the F-test and the Obs*R^2 tests show the existence of ARCH effect in the rate of growth of all the variables at the 5% level of significance for the first order autoregressive process. This implies that all the series used in the study are volatile and that is a condition for using them in the GARCH models. To corroborate the test, the plot of the residuals of the series displayed in Figures 1-4 above indicates that all the series experience fluctuations.

Table-3. Results of ARCH Effect.

Variable	Test	South Africa	Algeria	Nigeria	Egypt
EXCHR	F-Test	20.50763 (0.0000)	28.37559 (0.0000)	34.80893 (0.0000)	2.861049 (0.0926)
	Obs*R^2	18.51533 (0.0000)	24.62176 (0.0000)	29.33961 (0.0000)	2.846797 (0.0916)

Note: asterisks (**) indicate the rejection of the null hypothesis at the 5% level.

3.5. Model Selection

Having established the presence of ARCH effect in the series, we proceeded with the estimation of GARCH models with the three error distributions to assist in selecting the optimal models. In our model selection, we did not stick rigidly to only the Schwarz Information Criterion (SIC) as we also considered the performance of the models in providing significant results for the ARCH, GARCH and asymmetric coefficients. We therefore lay much stress on the performance of the models with regard to the last criterion unless otherwise none of the models considered exhibit significant results. This is because in GARCH models the significance of the coefficients matter for interpretation. Tables 4-7 below guided us in the model selection. Starting with South Africa as presented in Table 4 below, using the SIC, the normal distribution is selected under GARCH 11, while the student's t distribution is selected under GARCH M. Since the normal distribution with the least SIC provided insignificant GARCH coefficient, we rejected it under the TGARCH but instead went for the student's t distribution that has the next least SIC. Finally, the normal distribution with the least SIC was chosen under the EGARCH. For Algeria, we chose the student's t distribution in all the models as it provided the least SIC. For Nigeria, we selected the Generalized Error Distribution under GARCH 11, GARCH-M and TGARCH, while under EGARCH we selected the Normal distribution. We selected student's t distribution under GARCH 11, the Generalized Error Distribution under GARCH-M and the Normal distribution under the TGARCH and the EGARCH respectively for Egypt.

3.6. Estimation and Interpretation of Results of GARCH Models

The results of the model selection so far have shown that specifying the volatility models purely with Normal distribution cannot adequately capture volatility in exchange rate in SANE countries. Thus, the application of the Normal distribution could result in poor model specification because other error distributions could provide better fit models. For South Africa, the result as shown in Table 4 below reveals that the ARCH coefficients in all the models selected are statistically significant, thus lending credence to the presence of ARCH effects. Further, GARCH-M, TGARCH and EGARCH results of are not mean reverting. This is because the sum of the coefficients of the ARCH and GARCH are greater than unity.

Table-4. Results of Estimated Volatility of Exchange Rate for South Africa.

Models	Equations	Model Parameter	Normal Distribution			Student's *t* Distribution			Generalized Error Distribution		
			Coefficients	P-Value	SIC	Coefficients	P-Value	SIC	Coefficients	P-Value	SIC
GARCH (1, 1)	Mean	Intercept	-0.026667	0.7583	1.028176	0.007880	0.9296	1.029353	0.011426	0.8947	1.030979
		Exchr(-1)	1.005934	0.0000		1.003323	0.0000		1.001665	0.0000	
	Variance	ARCH	0.933942	0.0000		0.713451	0.0016		0.792480	0.0011	
		GARCH	0.039091	0.5813		0.070172	0.5517		0.053070	0.6137	
GARCH-M	Mean	Intercept	0.117253	0.2417	1.080080	0.226296	0.0621	1.015904	0.226824	0.0334	1.041588
		Exchr-1)	1.016786	0.0000		1.014191	0.0000		1.008092	0.0000	
	Variance	ARCH	0.363831	0.0033		0.184837	0.0281		0.222828	0.0252	
		GARCH	0.675381	0.0000		0.793572	0.0000		0.763366	0.0000	
		@SQRT(GARCH)	0.0014	0.0014		-0.889439	0.0083		-0.761265	0.0074	
TGARCH (1, 1)	Mean	Intercept	0.002200	0.9799	1.009170	0.092762	0.2753	1.036276	0.112031	0.1862	1.051353
		Exchr(-1)	1.005777	0.0000		0.996077	0.0000		0.992941	0.0000	
	Variance	ARCH	1.553315	0.0000		0.394000	0.0148		0.424404	0.0139	
		GARCH	0.090704	0.2752		0.764924	0.0000		0.752123	0.0000	
		Asymmetric	-1.199189	0.0022		-0.402267	0.0117		-0.454172	0.0078	
EGARCH (1, 1)	Mean	Intercept	-0.015379	0.8364	0.993736	-0.015232	0.8389	1.016323	-0.016241	0.8291	1.023314
		Exchr(-1)	1.007310	0.0000		1.007341	0.0000		1.007291	0.0000	
	Variance	ARCH	1.194811	0.0000		1.209056	0.0000		1.188014	0.0000	
		GARCH	0.456540	0.0001		0.461036	0.0000		0.449219	0.0001	
		Asymmetric	0.299174	0.0249		0.300254	0.0271		0.136877	0.0348	

Table-5. Results of estimated volatility of exchange rate for Algeria

Models	Equations	Model Parameter	Normal Distribution			Student's *t* Distribution			Generalized Error Distribution		
			Coefficients	P-Value	SIC	Coefficients	P-Value	SIC	Coefficients	P-Value	SIC
GARCH (1, 1)	Mean	Intercept	5.984873	0.0399	3.755143	5.288635	0.0429	3.742674	4.708639	0.0710	3.752219
		Exchr(-1)	0.939003	0.0000		0.945407	0.0000		0.951429	0.0000	
	Variance	ARCH	0.213899	0.0346		0.263604	0.0961		0.241710	0.0982	
		GARCH	0.608796	0.0001		0.579475	0.0021		0.578477	0.0037	
GARCH-M	Mean	Intercept	5.829366	0.0529	3.783335	5.173371	0.0523	3.771356	4.676079	0.0778	3.781360
		Exchr-1)	0.943317	0.0000		0.948671	0.0000		0.953667	0.0000	
	Variance	ARCH	0.205374	0.0405		0.251618	0.0915		0.231073	0.0962	
		GARCH	0.634152	0.0001		0.608805	0.0008		0.604184	0.0022	
		@SQRT(GARCH)	-0.191958	0.6289		-0.146655	0.6345		-0.132348	0.6902	
TGARCH (1, 1)	Mean	Intercept	5.852941	0.0559	3.781406	5.011653	0.0559	3.767409	4.523788	0.0865	3.778083
		Exchr(-1)	0.940430	0.0000		0.948276	0.0000		0.953380	0.0000	

	Variance	ARCH	0.232471	0.1395		0.292926	0.1711		0.267441	0.2212	
		GARCH	0.637216	0.0005		0.625230	0.0016		0.222674	0.0055	
		Asymmetric	-0.103458	0.4708		-0.168994	0.4180		0.203492	0.4908	
EGARCH (1, 1)	Mean	Intercept	5.897386	0.0452	3.808251	.439694	0.0334	3.790201	4.354840	0.1004	3.799642
		Exchr(-1)	0.940173	0.0000		0.943866	0.0000		0.955089	0.0000	
	Variance	ARCH	0.319835	0.0107		0.390200	0.0457		0.367067	0.0558	
		GARCH	0.849957	0.0000		0.837983	0.0000		0.830815	0.0000	
		Asymmetric	0.047189	0.4580		0.065549	0.4915		0.056131	0.5365	

Table-6. Results of estimated volatility of exchange rate for Nigeria.

Models	Equations	Model Parameter	Normal Distribution			Student's *t* Distribution			Generalized Error Distribution		
			Coefficients	P-Value	SIC	Coefficients	P-Value	SIC	Coefficients	P-Value	SIC
GARCH (1, 1)	Mean	Intercept	-0.144675	0.8644	6.338618	-0.082603	0.6894	5.614031	-0.094430	0.0000	5.597045
		Exchr(-1)	1.001917	0.0000		0.999959	0.0000		1.000758	0.0000	
	Variance	ARCH	0.914650	0.0000		646.8417	0.9915		1.862792	0.0544	
		GARCH	0.312917	0.0000		0.314048	0.0003		0.288723	0.0251	
GARCH-M	Mean	Intercept	0.899851	0.2645	6.340510	0.013169	0.9527	5.638137	-0.126938	0.0049	5.618400
		Exchr-1)	1.001203	0.0000		0.999939	0.0000		1.000383	0.0000	
	Variance	ARCH	0.928577	0.0000		588.1383	0.9947		1.081447	0.0441	
		GARCH	0.269054	0.0022		0.321212	0.0003		0.349692	0.0094	
		@SQRT(GARCH)	-0.239847	0.0332		-0.003341	0.9894		-0.005526	0.7982	
TGARCH (1, 1)	Mean	Intercept	1.137164	0.0002	6.243624	-0.070965	0.7007	5.488941	-0.192933	0.0003	5.662558
		Exchr(-1)	0.994750	0.0000		1.000018	0.0000		1.000540	0.0000	
	Variance	ARCH	0.781779	0.0000		1080.553	0.9911		0.404305	0.0202	
		GARCH	0.570652	0.0000		0.435598	0.0000		0.615935	0.0000	
		Asymmetric	-0.877032	0.0000		-1090.182	0.9911		-0.458477	0.0058	
EGARCH (1, 1)	Mean	Intercept	2.351153	0.0035	6.371503	-0.276247	0.0922	5.650982	-0.205699	0.0000	5.966779
		Exchr(-1)	0.992386	0.0000		1.000773	0.0000		1.000890	0.0000	
	Variance	ARCH	0.577851	0.0003		0.284421	0.1951		1.227874	0.0127	
		GARCH	0.807180	0.0000		0.886049	0.0000		-0.016251	0.9272	
		Asymmetric	0.387730	0.0001		0.960853	0.1165		0.479360	0.1686	

Table-7. Results of Estimated Volatility of Exchange Rate for Egypt.

Models	Equations	Model Parameter	Normal Distribution			Student's *t* Distribution			Generalized Error Distribution		
			Coefficients	P-Value	SIC	Coefficients	P-Value	SIC	Coefficients	P-Value	SIC
GARCH (1, 1)	Mean	Intercept	0.096277	0.8479	1.814828	0.001474	0.7232	-2.435646	0.044247	0.0000	1.827004I
		Exchr(-1)	0.994675	0.0000		0.999843	0.0000		0.994142	0.0000	
	Variance	ARCH	0.059260	0.5147		3.768356	0.0841		0.552786	0.7393	
		GARCH	0.442192	0.3614		-0.003097	0.0004		0.661429	0.4543	
GARCH-M	Mean	Intercept	-0.284407	0.7252	1.841296	-0.002743	0.4776	-2.401116	0.887965	0.0000	-1.397217
		Exchr-1)	0.993048	0.0000		1.000330	0.0000		0.985210	0.0000	
	Variance	ARCH	0.046272	0.5809		3.700978	0.1141		0.092025	0.0000	
		GARCH	0.486023	0.4179		-0.002424	0.0130		0.535538	0.0000	
		@SQRT(GARCH)	0.718788	0.6044		-0.003153	0.7933		1.686460	0.0000	
TGARCH (1, 1)	Mean	Intercept	-0.006879	0.6101		0.002627	0.6309	-2.397049	0.060205	0.0000	
		Exchr(-1)	1.003018	0.0000		1.000090	0.0000		0.991084	0.0000	-1.944914
	Variance	ARCH	0.066234	0.0000	1.552110	117.8421	0.9913		2.243491	0.2764	
		GARCH	0.903092	0.0000		0.365659	0.0000		0.683139	0.0000	
		Asymmetric	-1.034381	0.0000		546.7577	0.9913		6.062073	0.5769	
EGARCH (1, 1)	Mean	Intercept	0.075919	0.0000	-0.019636	0.003409	0.5610	-2.408196	0.043648	0.0000	-2.127023
		Exchr(-1)	0.987147	0.0000		0.999858	0.0000		0.994353	0.0000	
	Variance	ARCH	-0.262772	0.0000		1.024877	0.3049		0.331792	0.2281	
		GARCH	0.949365	0.0000		0.870842	0.00001		0.913734	0.0000	
		Asymmetric	0.247354	0.0000		-0.837680	0.3230		-0.193816	0.4666	

However, GARCH 11 is mean reverting, indicating that the impact of shocks on exchange rate volatility are not permanent. The asymmetric coefficient under TGARCH is significant and we found that under this, bad news impacts more on volatility than good news, indicating a leverage effect. In another dimension, while the asymmetric coefficient under EGARCH is significant, we found that good news impacts more on volatility than bad news (see Table 8 below). For Algeria as presented in Table 5, the result reveals that the ARCH coefficients in all the models selected, except TGARCH, are statistically significant which confirms the existence of ARCH effects. GARCH 11 and TGARCH results indicated that they are mean reverting, while the results of GARCH-M and EGARCH are not mean reverting since the sum of the coefficients of the ARCH and GARCH are greater than unity. The asymmetric coefficient under both TGARCH and TGARCH are not significant even when we found that under TGARCH model, bad news dominate good news while under EGARCH model, good news impacts more on volatility than good news (see Table 8). The result for Nigeria is presented in Table 6. The result reveals that the ARCH coefficients in all the models selected are statistically significant which indicate the existence of ARCH effects. Of all the models selected, results indicate that none of them exhibit mean reverting since the sum of the coefficients of the ARCH and GARCH are greater than unity. This implies that the effects of shocks on exchange rate are permanent. The asymmetric coefficients under TGARCH and EGARCH are significant. Under TGARCH, evidence showed that good news dominates bad news while under EGARCH; bad news impact more on volatility than good news (see Table 8 below). The result for Egypt is presented in Table 7. Evidence from the result reveals that the ARCH coefficients in all the models selected are statistically significant confirming the existence of ARCH effects. Findings revealed that in all the models selected, except EGARCH, non exhibited mean reverting as the sum of the coefficients of the ARCH and GARCH are greater than unity. This implies that the effects of shocks on the exchange rate are permanent. The asymmetric coefficients under TGARCH and EGARCH are significant. Evidence in Table 8 below shows that good news dominates bad news in the two models.

Table-8. News Impact.

	Asymmetric Models	
Exchange Rate Volatility for South Africa		
	TGARCH	**EGARCH**
Error Distribution	Normal Distribution	Normal Distribution
Good News Impact	0.394000	1.194811
Bad News Impact	-0.008267	0.299174
Exchange Rate Volatility for Algeria		
Error Distribution	Student's *t* Distribution	Student's *t* Distribution
Good News Impact	0.292926	0.390200
Bad News Impact	-0.168994	0.455749
Exchange Rate Volatility for Nigeria		
Error Distribution	Generalized Error Distribution	Normal Distribution
Good News Impact	0.404305	0.577851
Bad News Impact	-0.054172	0.965581
Exchange Rate Volatility for Egypt		
Error Distribution	Normal Distribution	Normal Distribution
Good News Impact	0.066234	-0.262772
Bad News Impact	-0.968147	-0.015418

3.7. Robustness Tests

After testing for the existence of ARCH effect in the models which informed applying the GARCH models, we also carried out the test to establish a non existence of further ARCH effects so that our results will be meaningful. Appendix 1 below displays the results of these tests in all the models. At the 5% level of significance, result is evaluated on the null hypothesis that that there is no remaining ARCH effect in the models. Evidence from the results indicates that the null hypothesis cannot be rejected at the chosen level of significance. The result implies that the volatility models we have adopted are good; implying the elimination of ARCH effect. In another vein, results of the serial correlation test are presented in Appendixes 2-5. Findings show that the probability values of the Qstatistics for all the lags considered are higher than 0.05. This clearly shows the absence of serial correlation in the residuals of the estimated models at the 5% significance level.

4. CONCLUSION AND RECOMMENDATIONS

In this study, we set out to investigate exchange rate volatility in SANE countries, using different error distributions. Evidence from our results so far has shown that exchange rate is volatile in each of the countries sampled as can be informed by the results of the ARCH effect test. We also found that while some models in each country exhibit mean reverting, others show none mean reverting. This implies that the effect of exchange rate volatility could be permanent as well as temporary in these countries. We investigated both symmetric and asymmetric models in this study. The results of the asymmetric models revealed the existence of leverage effects in some of the models. The asymmetric parameters of these models show that exchange rate volatility in SANE countries could exhibit both positive and negative shocks. Finally, our findings show that modelling exchange rate volatility in SANE countries solely on the basis of the Normal distribution could lead to biased results as evidence of findings show that other error distributions perform better. On grounds of the above results, we recommend that monetary authorities in each of the SANE countries should fine tune their policies on exchange rate to ensure a stable exchange rate regime that does not hurt the macroeconomic environment. In order to achieve this, a synergy should exist between the fiscal and monetary authorities. We also suggest that in modelling exchange rate volatility in the countries, each country should explore several error distributions so as to avoid biased outcomes inherent in using only the traditional Normal distribution.

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Appendix-1. ARCH LM test of estimated volatility.

Models	South Africa	Algeria	Nigeria	Egypt
	Error Distributions			
GARCH 11	Normal Distribution	Student's *t* Distribution	Generalized Error Distribution	Student's *t* Distribution
F-Test	0.185644 (0.6671)	0.027505 (0.8685)	0.002923 (0.9569)	0.006207 (0.9373)
nR^2	0.187623 (0.6649)	0.027822 (0.8675)	0.002957 (0.9566)	0.006279 (0.9368)
GARCH-M	Student's *t* Distribution	Student's *t* Distribution	Generalized Error Distribution	Generalized Error Distribution
F-Test	0.883833 (0.6553)	0.000104 (0.9919)	0.007500 (0.9311)	0.007182 (0.9326)
nR^2	33.06882 (0.6088)	0.000106 (0.9918)	0.007587 (0.9306)	0.007266 (0.9321)
TGARCH	Student's *t* Distribution	Student's *t* Distribution	Generalized Error Distribution	Normal Distribution
F-Test	0.266670 (0.6062)	0.002148 (0.9631)	0.002512 (0.9601)	0.009069 (0.9242)
nR^2	0.269385 (0.6037)	0.002173 (0.9628)	0.002541 (0.9598)	0.009176 (0.9237)
EGARCH	Normal Distribution	Student's *t* Distribution	Normal Distribution	Normal Distribution
F-Test	0.037313 (0.8471)	0.003151 (0.9553)	0.033553 (0.8549)	0.497670 (0.9135)
nR^2	0.037744 (0.8460)	0.003188 (0.9550)	0.033939 (0.8538)	6.244635 (0.9033)

Appendix-2. Serial Correlation Test Results of Selected Models for South Africa.

Lag	AC	PAC	Q-Stat	Prob*	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
	GARCH 11				GARCH -M				TGARCH				EGARCH			
1	0.155	0.155	4.2342	0.040	0.135	0.135	3.2187	0.073	0.049	0.049	0.4214	0.516	-0.014	-0.014	0.0365	0.848
2	-0.080	-0.107	5.3658	0.068	-0.075	-0.095	4.2015	0.122	-0.102	-0.104	2.2501	0.325	-0.067	-0.067	0.8360	0.658
3	0.013	0.045	5.3947	0.145	-0.047	-0.024	4.5996	0.204	-0.056	-0.046	2.7991	0.424	0.032	0.030	1.0194	0.797
4	-0.088	-0.111	6.7893	0.147	-0.018	-0.016	4.6607	0.324	-0.066	-0.072	3.5716	0.467	-0.005	-0.008	1.0232	0.906
5	0.031	0.075	6.9630	0.223	-0.017	-0.019	4.7157	0.452	-0.018	-0.022	3.6282	0.604	0.102	0.107	2.9148	0.713
6	0.023	-0.018	7.0573	0.316	0.078	0.082	5.8299	0.443	0.111	0.098	5.8568	0.439	0.169	0.173	8.0808	0.232
7	-0.026	-0.010	7.1812	0.410	0.033	0.006	6.0336	0.536	0.089	0.070	7.2938	0.399	0.044	0.070	8.4414	0.295
8	-0.004	-0.011	7.1843	0.517	0.121	0.131	8.7086	0.367	0.154	0.169	11.673	0.166	0.175	0.207	14.090	0.079
9	0.040	0.051	7.4805	0.587	-0.035	-0.066	8.9389	0.443	-0.053	-0.043	12.182	0.203	-0.051	-0.038	14.567	0.104
10	0.001	-0.017	7.4809	0.679	-0.069	-0.033	9.8360	0.455	-0.072	-0.016	13.145	0.216	-0.063	-0.052	15.304	0.121
11	0.066	0.078	8.2955	0.687	-0.052	-0.036	10.349	0.499	-0.004	0.015	13.149	0.284	0.250	0.210	27.016	0.005
12	-0.027	-0.062	8.4309	0.751	-0.014	-0.018	10.387	0.582	0.005	-0.001	13.153	0.358	-0.053	-0.101	27.547	0.006

Appendix-3. Serial Correlation Test Results of Selected Models for Algeria.

Lag	AC	PAC	Q-Stat	Prob*	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
	GARCH 11				GARCH -M				TGARCH				EGARCH			
1	-0.013	-0.013	0.0284	0.866	-0.001	-0.001	0.0001	0.992	-0.004	-0.004	0.0022	0.962	0.004	0.004	0.0033	0.954
2	-0.045	-0.045	0.3845	0.825	-0.043	-0.043	0.3223	0.851	-0.051	-0.051	0.4567	0.796	-0.035	-0.035	0.2255	0.893
3	0.079	0.078	1.4941	0.684	0.073	0.073	1.2692	0.736	0.084	0.084	1.7146	0.634	0.098	0.098	1.9393	0.585
4	0.018	0.018	1.5505	0.818	0.019	0.017	1.3338	0.856	0.019	0.017	1.7822	0.776	0.034	0.032	2.1441	0.709
5	-0.027	-0.020	1.6864	0.891	-0.026	-0.020	1.4598	0.918	-0.029	-0.021	1.9358	0.858	-0.022	-0.015	2.2299	0.817
6	-0.019	-0.025	1.7551	0.941	-0.021	-0.025	1.5390	0.957	-0.016	-0.021	1.9806	0.921	-0.023	-0.031	2.3299	0.887
7	0.009	0.004	1.7711	0.971	0.004	-0.001	1.5413	0.981	0.021	0.016	2.0632	0.956	0.014	0.007	2.3681	0.937
8	0.008	0.010	1.7824	0.987	0.006	0.007	1.5481	0.992	-0.002	0.001	2.0637	0.979	0.009	0.010	2.3838	0.967
9	0.004	0.009	1.7858	0.994	-0.001	0.004	1.5482	0.997	0.015	0.021	2.1058	0.990	0.024	0.031	2.4891	0.981
10	-0.027	-0.027	1.9215	0.997	-0.026	-0.026	1.6793	0.998	-0.017	-0.020	2.1597	0.995	-0.021	-0.022	2.5704	0.990
11	-0.036	-0.040	2.1706	0.998	-0.037	-0.039	1.9299	0.999	-0.009	-0.009	2.1758	0.998	-0.011	-0.013	2.5935	0.995
12	-0.011	-0.016	2.1926	0.999	-0.026	-0.030	2.0614	0.999	-0.015	-0.020	2.2189	0.999	-0.001	-0.009	2.5938	0.998

Appendix-4. Serial Correlation Test Results of Selected Models for Nigeria.

Lag	AC	PAC	Q-Stat	Prob*	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
	GARCH 11				GARCH -M				TGARCH				EGARCH			
1	-0.009	-0.009	0.0162	0.899	-0.002	-0.002	0.0008	0.977	0.056	0.056	0.5742	0.449	0.003	0.003	0.0015	0.969
2	-0.016	-0.016	0.0622	0.969	-0.020	-0.020	0.0707	0.965	-0.025	-0.028	0.6874	,0.709	-0.024	-0.024	0.1063	0.948
3	-0.007	-0.007	0.0702	0.995	-0.006	-0.006	0.0774	0.994	-0.017	-0.014	0.7377	0.864	-0.004	-0.004	0.1089	0.991
4	-0.016	-0.016	0.1175	0.998	-0.020	-0.020	0.1510	0.997	-0.031	-0.030	0.9139	0.923	-0.019	-0.019	0.1741	0.996
5	-0.016	-0.016	0.1642	0.999	-0.019	-0.020	0.2210	0.999	-0.032	-0.030	1.1061	0.954	-0.023	-0.023	0.2736	0.998
6	0.005	0.004	0.1686	1.000	0.005	0.004	0.2263	1.000	-0.014	-0.012	1.1419	0.980	0.021	0.020	0.3537	0.999
7	-0.014	-0.015	0.2048	1.000	-0.017	-0.018	0.2787	1.000	-0.014	-0.015	1.1787	0.991	0.018	0.017	0.4168	1.000
8	-0.014	-0.014	0.2400	1.000	-0.016	-0.016	0.3241	1.000	-0.017	-0.018	1.2309	0.996	-0.017	-0.016	0.4693	1.000
9	-0.015	-0.017	0.2840	1.000	-0.019	-0.020	0.3888	1.000	-0.024	-0.026	1.3431	0.998	-0.027	-0.027	0.6092	1.000
10	-0.010	-0.011	0.3031	1.000	-0.012	-0.014	0.4181	1.000	-0.012	-0.013	1.3709	0.999	0.006	0.006	0.6158	1.000
11	-0.014	-0.015	0.3397	1.000	-0.017	-0.019	0.4729	1.000	-0.023	-0.026	1.4758	1.000	-0.031	-0.031	0.8018	1.000
12	-0.012	-0.014	0.3678	1.000	-0.013	-0.015	0.5054	1.000	-0.007	-0.008	1.4864	1.000	0.004	0.004	0.8056	1.000

Appendix-5. Serial Correlation Test Results of Selected Models for Egypt.

Lag	AC	PAC	Q-Stat	Prob*	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
	GARCH 11				GARCH -M				TGARCH				EGARCH			
1	-0.006	-0.006	0.0064	0.936	-0.006	-0.006	0.0074	0.931	0.007	0.007	0.0094	0.923	0.178	0.178	5.5753	0.018
2	-0.006	-0.006	0.0130	0.994	-0.001	-0.001	0.0075	0.996	-0.008	-0.008	0.0197	0.990	-0.002	-0.034	5.5758	0.062
3	-0.004	-0.004	0.0152	1.000	0.023	0.023	0.1052	0.991	-0.000	-0.000	0.0197	0.999	0.051	0.059	6.0303	0.110
4	-0.006	-0.006	0.0219	1.000	-0.006	-0.005	0.1107	0.999	0.023	0.023	0.1156	0.998	0.063	0.045	6.7386	0.150
5	-0.006	-0.006	0.0288	1.000	-0.006	-0.006	0.1168	1.000	-0.003	-0.003	0.1173	1.000	0.020	0.003	6.8128	0.235
6	-0.006	-0.006	0.0358	1.000	-0.005	-0.006	0.1217	1.000	-0.008	-0.008	0.1289	1.000	-0.014	-0.019	6.8473	0.335
7	-0.006	-0.006	0.0429	1.000	-0.004	-0.004	0.1247	1.000	-0.005	-0.005	0.1329	1.000	-0.013	-0.012	6.8795	0.442
8	0.003	0.003	0.0444	1.000	0.003	0.003	0.1261	1.000	0.002	0.002	0.1340	1.000	-0.012	-0.013	6.9068	0.547
9	-0.006	-0.006	0.0518	1.000	-0.007	-0.007	0.1346	1.000	-0.007	-0.007	0.1422	1.000	-0.018	-0.015	6.9678	0.640
10	-0.006	-0.007	0.0593	1.000	-0.007	-0.007	0.1437	1.000	-0.008	-0.007	0.1527	1.000	-0.018	-0.010	7.0273	0.723
11	-0.006	-0.007	0.0668	1.000	-0.007	-0.007	0.1520	1.000	-0.008	-0.008	0.1640	1.000	-0.015	-0.008	7.0709	0.793
12	-0.006	-0.007	0.0745	1.000	-0.007	-0.007	0.1607	1.000	-0.008	-0.008	0.1758	1.000	-0.012	-0.006	7.1002	0.851