# A Comparative Analysis of Exchange Rate Volatility in the West African Monetary Zone

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*This study employs measures of variability and three GARCH models to comparatively explore the behaviour of exchange rate volatility of the currencies in the West African Monetary Zone (WAMZ) for the period 1960M01-2011M12. The study selects a sub-sample period of 2000M1 to 2011M12 to investigate whether central bank intervention decreases volatility of the local currencies per US$. Our findings reveal that the Ghanaian cedi is the most volatile currency in the Zone. Also, we found that leverage effect does exist for Gambian dalasi, while it does not exist for Nigerian naira; but inconclusive for other countries. The impact of central bank intervention on exchange rate volatility is also found to be inconclusive for Ghana, Guinea, and Liberia. However, the impact of central bank intervention on foreign exchange decreases the level of volatility persistence in Gambia and Nigeria, while it increases the level of volatility persistence in Sierra Leone for the period under consideration.*

**Keywords**: Exchange rate, Volatility, GARCH, West African Monetary Zone

**JEL Classification**: C10, F31

## 1.0 Introduction

Exchange rates and their rates of change in the course of time have been more volatile than relative price levels and rates of inflation. They are often as reported in the literature to be inconsistent with equilibrium. Attempts to manage exchange rate volatility and its overshooting tendencies started after the failure of the Bretton Woods System in 1971 (Stockman, 1978).

The exchange rate policy regimes employed by nations that make up the West African Monetary Zone (WAMZ) spans from fixed to peg to managed float and to independent floating. The adoption of the floating exchange rate regime in the WAMZ dates back to the 1980s (Sekkat and Varoudakis, 1998). Unlike the fixed exchange rate regime which is rigid, the adoption of floating exchange rate-or flexible exchange rate-allows the free movement of supply and demand of currency in the foreign exchange market i.e. scarcity or surplus does not build up for too long (Jhingan, 2003).

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The outcome of the policy to move towards a more flexible exchange rate mechanism in the Non- Communauté Financière Africaine (CFA), however, led to the rising real exchange rate volatility through the 1980s. This experience is obviously not in the best interest of countries in the zone since they are largely import dependent. The country whose exchange rate volatility persists would be vulnerable to macroeconomic problems like instability in domestic prices of fully imported goods and goods with high level of import content. Consequently, the Central Banks of the WAMZ countries have had to intervene from time to time (Sekkat and Varoudakis, 1998).

Attempts to address at least some of these macroeconomic issues caused the region to envision a full-blown monetary union. The WAMZ, being the second monetary zone in West Africa, was formed in year 2000 with five countries (Gambia, Ghana, Guinea, Nigeria and Sierra Leone) while Liberia joined in 2010 (Sekkat and Varoudakis, 1998). After the 2003 failure, the zone projected to introduce its common currency by 2015. The common currency, named 'eco', is projected to reduce volatility among WAMZ countries due to anticipated drop in transaction costs; overridden price uncertainty caused by differences in official exchange rate. These may thus pave way for a stable inflation rate, and enhanced efficiency in allocating capital for intra-regional trade (Yuen, 2000).

Studies in the area of modelling exchange rate volatility are replete in the literature for advanced economies but in the WAMZ our review of literature revealed that only few studies have been done in recent time and only Nigeria out of all member countries of the WAMZ is covered. This study attempts to fill this gap.

Olowe (2009), on Nigeria, presented results separately for the period before and after deregulation using different versions of Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model on monthly data over the period January 1970 to December 2007. The results showed that volatility is persistent in the Nigerian foreign exchange rate. The study therefore, rejected the hypothesis of leverage effect from all its asymmetry models. Adeoye and Atanda (2011) with Autoregressive Conditional Heteroscedasticity (ARCH) and GARCH models also discovered that there is presence and persistency of volatility shocks in the nominal and real exchange rates for Naira vis-à-vis U.S dollar monthly time series between 1986 and 2008. Their coefficient of

variation measure, under the real exchange rate, was the only measure that suggested overshooting volatility shocks.

Bala and Asemota (2013) on the other hand examined exchange rate volatility for three major currencies in the Nigerian foreign exchange market with variants of GARCH models using monthly exchange rate return series from 1985 to 2011 for Naira/US dollar return and from 2004 to 2011 for Naira/British Pounds and Naira/Euro returns. They identified USD as the most volatile and BPS as the least volatile. They found significant evidence that all the asymmetric models they adopted rejected the existence of a leverage effect except for models of GARCH with volatility breaks.

This study unlike the studies on Nigeria, explores volatility behaviour of exchange rate of the currencies in the WAMZ, models exchange rate volatility of the currencies, compare them and determine which of the currencies has the highest level of volatility over the period 1960 to 2011 using three variants of GARCH models. The rest of the paper is structured as follows; section 2 is on conceptual issues, section 3 discusses the methodology. Section 4 is on discussion of results, section 5 is on the summary of the paper and section 6 concludes the paper.

## 2.0 Conceptual Issues

The unexpected movement in exchange rate is termed exchange rate volatility (Ozturk, 2006). It is associated with currency depreciation or appreciation and may have no trend to it (Marston et al, 1988). Exchange rates are extremely volatile in the short run because they are very responsive to monetary policy, central bank intervention policy, changes in expectations, etc. and are influenced by relative commodity prices in the long run (Samuelson and Nordhaus, 2001). Volatility could also arise from overshooting behaviour which is when the current spot rate does not equal a measure of the long-run equilibrium obtainable from a long-run model. This behaviour could arise when the financial market is not operating as expected (Jones and Kenen, 1990). However, these normative issues are not within the objective of this study.

To measure volatility, range, variance and its square root are traditionally used. A higher range and standard deviation depicts higher level of volatility (see: Ross, Westerfield and Jordan, 1998; Bleaney and Francisco; 2008). However, since the debut of the ARCH and GARCH by Engel (1982) and

Bollerslev (1986), measuring volatility has taken a huge dimension from using range and standard deviation.

That said, exchange rate volatility has been modelled in the last thirty years using parametric (variants of GARCH modelling) and non-parametric estimators like realized volatility, bi-power and truncated power variation, etc. (Erdemlioglu, Laurent and Neely, 2012). Thus, theory has not provided a definitive guidance as to which measure of volatility is most suitable (Adeoye and Atanda, 2011).

To achieve our objective, this study applied the traditional measures and parametric estimator using GARCH model with exponential GARCH (EGARCH) model, and Glosten, Jogannathan, and Rankle (1992) GARCH (GJR-GARCH) model so as to explore leverage effects on the volatility of the variable of study.

## 3.0 Methodology

### 3.1 Sources of Data

Monthly data series of official exchange rate (local currency per US$) for the six WAMZ countries were obtained from the International Monetary Fund's (IMF) International Financial Statistics (IFS) CD-ROM. The countries' respective local currencies are: the Gambia –dalasi, Ghana –cedi, Guinea –franc, Liberia –Liberian dollar, Nigeria –naira, and Sierra Leone –Leone. The sample period covered by this study is from 1960M1 to 2011M12. To efficiently achieve the objective of this study a sub-sample period of 2000M1 to 2011M12 is selected to know whether central bank intervention decreases volatility of the local currencies per US$.

### 3.2 GARCH models

Our first model is the GARCH econometric technique widely used in the literature for estimating volatility of exchange rate behaviour (see: Doyle, 2001; Dukich et al, 2010; Vee et al, 2011).

$$y_{xt} = c_x + u_{xt} \quad (1)$$

From equation 1 where $y_{xt}$ is the relative change in exchange rate for country x at time t and $u_{xt}$ is the error term, we can obtain an ARCH model, shown in

equation 2, which allows conditional variance to change over time as a function of past errors.

$$u_{xt}^2 = \alpha_0 + \alpha_1 u_{xt-1}^2 + \alpha_2 u_{xt-2}^2 + \cdots + \alpha_p u_{xt-p}^2 \quad (2)$$

Bollerslev (1986) argues that a simple GARCH model provides a marginally better fit than an ARCH model with a relatively long lag. The GARCH process: equation 1 is the mean equation and equation 3 is the generalized variance specification i.e. the standard GARCH (p, q) specification. Of which ARCH (p + q) model is equivalent to GARCH (p, q).

$$\sigma^2_{xt} = \omega_x + \sum_{j=1}^{p} \alpha_j u^2_{xt-j} + \sum_{i=1}^{q} \beta_i \sigma^2_{xt-i} \quad (3)$$

Equation 3 has non-negative coefficients. The ARCH term ($\alpha_j$) is the lag of the squared residual from the mean equation. It will tell if volatility reacts to market movements i.e. if volatility from previous period affects volatility in current period. The GARCH parameter ($\beta_i$) is the forecasted variance from the previous period. While $\omega_x$ is the constant term, $\sigma^2$ is the conditional variance. The sum of the ARCH and GARCH term will inform us if volatility shocks are persistent. If the sum ($\alpha_x+\beta_x$) is less than unity the shocks would die out slowly if not it would die out quickly (Bollerslev and Wooldridge, 1990).

$$\varpi_x = \frac{\omega_x}{1 - \alpha_x - \beta_x} \quad (4)$$

Equation 4, $\varpi_x$ is the unconditional variance which measures the long run volatility as long as $\alpha_x+\beta_x < 1$. There would be non-stationarity in variance if $\alpha_x+\beta_x > 1$ while $\alpha_x+\beta_x = 1$ is termed unit root in variance. If $\varpi_x$ is squared we obtain the unconditional standard deviation. The result of this would identify which of the WAMZ countries has the highest level of volatility in its exchange rate. The second model is the GJR-GARCH model, in equation 5, introduced by Glosten, Jaganathan, and Runkle (1993).

$$\sigma^2_{xt} = \omega_x + \sum_{j=1}^{p} \alpha_j u^2_{xt-j} + \sum_{k=1}^{r} \gamma_k u^2_{xt-k} I_{t-k} + \sum_{i=1}^{q} \beta_i \sigma^2_{xt-i} \quad (5)$$

Where $I_t=1$ if $u_t<0$ and 0 otherwise. In this model good news ($u_{t-1}>0$) and bad news ($u_{t-1}<0$) have different effects on the conditional variance. Good news has an impact of $\alpha_j$ and bad news has an impact of $\alpha_j+\gamma_k$. Bad news increases volatility if $\gamma_k>0$ and so we say that there is a leverage effect for the i-th order. Also, if $\gamma_k\neq0$, this means the news impact is asymmetric.

$$\log(\sigma^2_{xt}) = \omega_x + \sum_{j=1}^{p} \alpha_j \left| \frac{u_{xt-j}}{\alpha_{xt-j}} - E\left(\frac{u_{xt-j}}{\alpha_{xt-j}}\right) \right| + \sum_{k=1}^{r} \gamma_k \frac{u_{xt-j}}{\alpha_{xt-j}} + \sum_{i=1}^{q} \beta_i \log(\sigma^2_{xt-i}) \quad (6)$$

The third model is the exponential GARCH (EGARCH) as proposed by Nelson (1991). The left side of equation 6 is the log of the conditional variance. The model implies that the leverage effect is exponential. The news impact is asymmetric if $\gamma_k\neq0$. Leverage effect is present if $\gamma_k<0$.

### 3.2 Estimation Procedure

After obtaining the logarithmic of the data, we provide statistics on its measures of variability and proceed to estimate its stationarity by employing the Dickey and Fuller (1979) and Phillips and Perron (1988) unit root tests.

Heteroscedasticity (ARCH) test is made to find if there is ARCH effect which is the justification for us to run the GARCH models. Once this condition is fulfilled, we estimated our GARCH models. To know if there is any further ARCH effect present, we conducted another Heteroscedasticity (ARCH) test after estimating our GARCH models. The above procedure is repeated with volatility break. The presented results are selected based on the lower Akaike info and Schwarz information criteria.

## 4.0 Discussion of Findings

### 4.1 1960 to 2011

#### 4.1.1 Measures of Variability for 1960M01 to 2011M12

The range of each country's exchange rate on Table 1 reveals that Ghana has the highest range while Gambia has the lowest range. According to range, Ghana has the most variable official exchange rate while Gambia has the least variable official exchange rate. Sierra Leonean leone has the second most

variable official exchange rate, in the WAMZ region during the period 1960 and 2011, with Guinean franc, Nigerian naira, and Liberian dollar being at the third, fourth, and fifth position respectively.

Table 1: Measures of Variability (1960M01 to 2011M12)

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Range | 2.9984 | 19.2509 | 6.0357 | 4.2905 | 5.7283 | 8.7419 |
| Ranking | 6th | 1st | 3rd | 5th | 4th | 2nd |
| Variance | 1.0856 | 17.8591 | 4.7991 | 3.2045 | 4.9248 | 12.6686 |
| Standard Deviation | 1.0419 | 4.2260 | 2.1907 | 1.7901 | 2.2192 | 3.5593 |
| Ranking | 6th | 1st | 4th | 5th | 3rd | 2nd |

Table 1 also depicts the results of the variance and square root of the variance that is the standard deviation. This shows that Gambia's official exchange rates are clustered closely around its mean while Ghana's official exchange rates are spread from the mean. Thus, Ghanaian cedi is the most volatile and Gambian dalasi is the least volatile. Sierra Leonean leone and Liberian dollar remain as the second and fifth most variable official exchange rate while Nigerian naira and Guinean franc swap positions of third and fourth.

### 4.1.2 Pre Estimation tests for 1960M01 to 2011M12

The results of Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root test on Table 2 shows that the data on official exchange rate, for all the countries during the period 1960M01 to 2011M12, are integrated of order one at all levels of significance.

Table 2: Unit root test

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| ADF t-statistic | -19.49 | -25.03 | -25.45 | -29.01 | -23.72 | -20.06 |
| Remark | I(1)*** | I(1)*** | I(1)*** | I(1)*** | I(1)*** | I(1)*** |
| PP t-statistic | -19.47 | -25.03 | -25.45 | -29.07 | -23.78 | -20.31 |
| Remark | I(1)*** | I(1)*** | I(1)*** | I(1)*** | I(1)*** | I(1)*** |
| Critical Values | | | | | | |
| 1% | -3.44 | | | | | |
| 5% | -2.86 | | | | | |
| 10% | -2.56 | | | | | |

***Significant at 1%, 5%, and 10%

Table 3: Heteroscedasticity ARCH test without volatility breaks for 1960M01 to 2011M12

| ARCH test: | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| | 25777 | 1430.2 | 17487.3 | 5886.7 | 21550 | 48597.2 |
| F-Statistic | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |

Probability values are in parentheses

The results of the heteroscedasticity ARCH test in lag 5, on Table 3, indicate that the residuals of the respective countries' official exchange rate show the presence of ARCH effects.

Table 4: Chow Breakpoint test

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| F-statistic | 7902.7*** | 1649.9*** | 9603.4*** | 143023*** | 1959.7*** | 1793.6*** |
| Log likelihood | 2043.8*** | 1369.9*** | 2408.6*** | 3395.9*** | 1241.4*** | 1194*** |
| Wald Statistic | 15805.5 | 4949.9*** | 28810.3*** | 143023*** | 3919.4*** | 3587.3*** |
| | | 1978M04 | 1971M12 | | | |
| | 1986M01 | 1999M11 | 1986M01 | | 1981M04 | 1981M04 |
| Break Date(s) | 2001M02 | 1978M04 | 1999M12 | 1998M01 | 1999M01 | 1997M08 |

***Significant at all levels

Moving on, Table 4 shows the volatility break dates and the Chow test rejects the null hypotheses of no volatility break in the models. Table 5 indicates that the residuals of the respective countries' official exchange rate with volatility breaks show the presence of ARCH effects.

Table 5: Heteroscedasticity ARCH test with volatility breaks for 1960M01 to 2011M12

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| ARCH test: | | | | | | |
| | 28429 | 1173.6 | 22605.2 | 3.8699 | 31423 | 28266 |
| F-statistic | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |

Values of probability are in parentheses

### 4.1.3 Generalized Autoregressive Conditional Heteroscedasticity (GARCH) without volatility breaks

All the estimated results on Table 6 are GARCH (1, 1) models for all the countries. The constants under the variance equation are all significant at 1%

for all the currencies in WAMZ, except the Guinean franc (see row 5, Table 6). The constants satisfy the non-negative a priori as they are all greater than zero. This implies that their respective unconditional variance will grow linearly with time. The ARCH term (α) and GARCH term (β) for Gambia are significant. Adding the two terms to determine (α+β) the level of persistence implies that there is no stationarity in variance. Thus, when there are volatility shocks to the conditional variance of Gambian dalasi official exchange rate the variance would not revert back to the long run mean.

One can infer from Dornbusch (1976) that volatility in dalasi could be explained by overshooting dynamics. That is, the effect of volatility shocks on dalasi in the short run makes the buying and selling rates of dalasi in the foreign exchange market to move far beyond the Gambian Central Bank's buying and selling rates.

The α and β for Ghanaian cedi are significant but the α did not comply with the a priori expectation of non-negativity. The sum of both terms means there is high persistence and stationarity in variance. As such, Ghanaian cedi's conditional variance will experience a slow reversion to its long run average whenever it experiences volatility shocks.

Table 6: GARCH results for 1960M01 to 2011M012 without volatility breaks

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0024** | 0.0062 | 0.0004 | 0.0005 | 0.0061 | 0.0041 |
| Variance Equation | | | | | | |
| ω | 0.00003*** | 0.0004*** | 0.0058 | 0.0278*** | 0.0037*** | 0.00004*** |
| α(ARCH(-1)) | 0.2841*** | -0.0017*** | -0.0020*** | 0.1768** | 1.4447*** | 0.0398*** |
| β(GARCH(-1)) | 0.794*** | 0.9981*** | 0.5746 | -0.0114** | -0.0009 | 0.9595*** |
| α+β | 1.0781 | 0.9964 | 0.5726 | 0.1654 | 1.4438 | 0.9993 |
| $\varpi$ | -0.0004 | 0.1111 | 0.0136 | 0.0333 | -0.0083 | 0.0571 |
| $\sqrt{\varpi}$ | -0.02 | 0.3333 | 0.1165 | 0.1825 | -0.0911 | 0.239 |
| Ranking | 5th | 1st | 4th | 3rd | 6th | 2nd |
| Akaike Info Criterion | -4.3861 | 0.2091 | -1.5552 | -0.7345 | -2.5992 | -2.9761 |
| Schwarz Criterion | -4.3506 | 0.2375 | -1.5267 | -0.7061 | -2.5707 | -2.9477 |
| Diagnostic: ARCH Test | | | | | | |
| F-statistic | 0.1138 (0.98) | 0.0026(1.00) | 0.0038(1.00) | 0.0021(1.00) | 0.0021(1.00) | 0.0113(1.00) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

The ARCH term for Guinean franc is significant but did not comply with the a priori expectation while the GARCH term is not significant. The addition of the terms implies that variance is stationary and has low persistence. The two terms are significant for Liberian dollar, although the β did not comply with the non-negative a priori. The sum of the two terms gives a very low level of persistence which equates to quick reversion of Liberian dollar official exchange rate conditional variance towards the long run mean than that of Guinean franc.

The ARCH term for Nigerian naira, on Table 6, is significant while the GARCH term is not significant. Similar to Gambian dalasi, the sum of the terms is greater than one. As such, there is the presence of overshooting volatility shocks. The two terms are significant for Sierra Leone leone official exchange rate. Similar to Ghana, the sum of both terms is stationary and has a high persistence. Unconditional variance$(\varpi)$, also called long run average variance, was calculated for Table 6. It informs us on the magnitude to which tomorrow's variance does not depend on today's variance. Ghana's unconditional variance is the highest and Nigeria has the lowest unconditional variance of -0.0083.

The estimated results on Table 7 are TGARCH (1,1) models for all the countries. The leverage effects (γ) are significant and, since $\gamma \neq 0$, the news impact is asymmetric for all the countries. The ARCH and GARCH terms are significant for Gambian dalasi. Leverage effect exists for dalasi because γ has a significantly positive relationship with conditional variance ($\sigma^2$).

### 4.1.4 Threshold Generalized Autoregressive Conditional Heteroscedasticity (TGARCH) without volatility breaks

Good news has an effect of 0.1153 (i.e. α) on dalasi official exchange rate while bad news has an effect of 0.3971 (i.e. α+γ). Thus, bad news confers higher volatility than good news of the same order of magnitude (i.e. 0.3971>0.1153).

The α and β for Ghanaian cedi are not significant. Leverage effect does not exist for cedi. This implies that bad news does not confer higher volatility than good news as the effect of bad news is smaller than the effect of good news. ARCH and GARCH terms are significant for Guinean franc. Leverage effect

does exist for franc. Bad news has a very high effect of on franc while good news has a low effect on franc.

Table 7: TGARCH results for 1960M01 to 2011M012 without volatility breaks

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0011 | 0.0013 | 0.0012*** | 0.0033 | 0.0069 | 0.0039** |
| Variance Equation | | | | | | |
| $\omega$ | 0.00003*** | 0.0629 | 0.00002*** | 0.0134** | 0.0034*** | 0.0000 |
| $\alpha$(ARCH(-1)) | 0.1153*** | -0.0017 | 0.6077*** | -0.0023 | 2.3616*** | 0.0512*** |
| $\beta$(GARCH (-1)) | 0.8239*** | 0.5714 | 0.5568*** | 0.5775*** | 0.0675*** | 0.9427*** |
| $\alpha+\beta$ | 0.9392 | 0.5697 | 1.1645 | 0.5752 | 2.4291 | 0.9939 |
| $\gamma$ | 0.2818*** | -1.1796*** | 62.0661*** | 0.0928*** | -2.5934*** | 0.5685*** |
| $\alpha+\gamma$ | 0.3971 | -1.1813 | 62.6738 | 0.0905 | -0.2318 | 0.6197 |
| Akaike Info Criterion | -4.4183 | 0.9137 | -3.3895 | -0.7186 | -2.6336 | -3.0831 |
| Schwarz Criterion | -4.3756 | 0.9493 | -3.3539 | -0.6831 | -2.598 | -3.0475 |
| Diagnostic: | | | | | | |
| ARCH Test | | | | | | |
| F-statistic | 0.1006(0.99) | 0.0018(1.00) | 0.0244 (0.99) | 0.0061(1.00) | 0.0028(1.00) | 0.0201(0.99) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

The ARCH term is not significant while the GARCH term is significant for Liberian dollar (see column 5, Table 7). Leverage effect exists for dollar. The good news effect on Liberian dollar is -0.0023 and the bad news effect on Liberian dollar is 0.0905. The two terms are significant for Nigerian naira but leverage effect does not exist for naira. The effect of bad news is -0.2318 and it is smaller than the effect of good news which is 2.3616. The two terms are also significant for Sierra Leonean leone and leverage effect exists for leone (see column 7, Table 7). Thus, bad news confers higher volatility than good news of the same order of magnitude on leone (i.e. 0.6197>0.0512).

### 4.1.5 Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) without volatility breaks

The estimated results on Table 8 are EGARCH (1,1) models for all the countries. The leverage effects ($\gamma$) for Table 8 are also significant and the news impact is asymmetric for all the countries. There is no leverage effect for Gambian dalasi official exchange rate. However, dalasi is covariance stationary because the GARCH term is significant and is less than one.

Table 8: EGARCH results for 1960M01 to 2011M012 without volatility breaks

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0033** | 0.0143*** | 0.0000 | 0.0000 | 0.002*** | 0.0008*** |
| Variance Equation | | | | | | |
| $\omega$ | -6.0326*** | -3.449*** | -2.3394*** | -3.3809*** | -3.1116*** | -0.1743*** |
| α(ARCH (-1)) | 1.2556*** | 8.3677*** | 2.8642*** | -0.3505*** | -0.9237*** | -0.1417*** |
| β(GARCH(-1)) | 0.2579*** | 0.6245*** | 0.5867*** | 0.0607 | 0.4193*** | 0.9661*** |
| α+β | 1.5135 | 8.9922 | 3.4509 | -0.2898 | -0.5044 | 0.8244 |
| γ | 0.2386*** | -6.7783*** | -2.9872*** | -0.6723*** | 1.6786*** | 0.3185*** |
| Akaike Info Criterion | -4.2946 | -1.5059 | -2.1625 | -0.7776 | -2.673 | -3.3674 |
| Schwarz Criterion | -4.2519 | -1.4704 | -2.1270 | -0.7421 | -2.6374 | -3.3318 |
| Diagnostic: | | | | | | |
| ARCH Test | | | | | | |
| F-statistic | 0.3588(0.87) | 0.0057(1.00) | 0.0738 (0.99) | 0.0031(1.00) | 0.0027(1.00) | 0.0562(0.99) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

Leverage effect does exist for Ghanaian cedi, Guinean franc, and Liberian dollar because γ is negative. Cedi and franc are covariance stationary as their GARCH terms are significant and less than one while the GARCH term for Liberian dollar is not significant. Leverage effect does not exist for Nigerian naira and Sierra Leonean leone. Naira and leone are covariance stationary. Decision on the existence of leverage effect for Guinea, Liberia, and Nigeria is the same under EGARCH and TGARCH models while it is contradictory for other countries.

### 4.1.6 Generalized Autoregressive Conditional Heteroscedasticity (GARCH) with volatility breaks

All the estimated results on Table 9 are GARCH (1,1) models for all the countries. The constants under the variance equation are all significant at 1% for all the currencies in WAMZ, except the Liberian dollar. The constants satisfy the non-negative a priori as they are all greater than zero.

Gambia, Guinea, and Nigeria have a level of persistence that is higher than one. This implies that there is no stationarity in variance for the countries' currencies official exchange rate. Thus, there is the presence of overshooting volatility shocks.

Table 9: GARCH results for 1960M01 to 2011M012 with volatility breaks

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0013 | 0.0099** | 0.0022** | 0.0000 | 0.0010 | 0.0026** |
| Break | 0.0021 | 0.0559 | 0.0263 | 0.0302 | 0.0262 | 0.0317 |
| Variance Equation | | | | | | |
| $\omega$ | 0.00004*** | 0.0003*** | 0.0003*** | 0.0000 | 0.0001*** | 0.00001*** |
| α(ARCH(-1)) | 0.3035*** | 0.0126*** | 1.7555*** | 0.0539*** | 1.3152*** | 0.0343*** |
| β(GARCH(-1)) | 0.7915*** | 0.7923*** | 0.0261 | 0.3186*** | 0.030* | 0.9187*** |
| α+β | 1.095 | 0.8049 | 1.7816 | 0.3725 | 1.3452 | 0.953 |
| Break | -0.00003*** | 0.0787*** | 0.0181*** | 0.0348*** | 0.0178*** | 0.0008*** |
| Akaike Info Criterion | -4.4163 | -1.3289 | -2.615 | -16.7706 | -4.5902 | -3.8598 |
| Schwarz Criterion | -4.3665 | -1.2862 | -2.5723 | -16.7279 | -4.5403 | -3.810 |
| Diagnostic: ARCH Test | | | | | | |
| F-statistic | 0.160(0.97) | 0.3251(0.89) | 0.0069(1.00) | 0.0065(1.00) | 0.0365(0.99) | 0.0716(0.99) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

Table 10: TGARCH results for 1960M01 to 2011M012 with volatility breaks

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0006 | 0.0081*** | 0.0013 | -0.0077 | 0.0015 | 0.0022* |
| Break | 0.0019 | 0.0899*** | -0.0005 | 0.0084 | 0.0275 | 0.0347* |
| Variance Equation | | | | | | |
| $\omega$ | 0.00003*** | 0.0008*** | 0.0004*** | 0.0188* | 0.00001*** | 0.00001*** |
| α(ARCH(-1)) | 0.1302*** | 0.00005 | 0.7201*** | -0.0025*** | 1.6417*** | 0.005 |
| β(GARCH(-1)) | 0.815*** | -0.0007 | -0.0092*** | 0.576*** | 0.0417* | 0.9156*** |
| α+β | 0.9452 | -0.00065 | 0.7109 | 0.5735 | 1.6834 | 0.9206 |
| γ | 0.2957*** | 38.87*** | -0.0816 | 0.1431*** | -0.7778*** | 0.0889*** |
| α+γ | 0.4259 | 38.87005 | 0.6385 | 0.1406 | 0.8639 | 0.0939 |
| Break | 0.00003*** | 0.0064 | 0.0448*** | 0.0068 | 0.0175*** | 0.0011*** |
| Akaike Info Criterion | -4.4458 | -1.3895 | -3.5561 | -0.5878 | -4.5920 | -3.8828 |
| Schwarz Criterion | -4.3888 | -1.3397 | -3.5063 | -0.5381 | -4.5698 | -3.8258 |
| Diagnostic: ARCH Test | | | | | | |
| F-statistic | 0.1489(0.98) | 0.3689(0.87) | 0.0085(1.00) | 0.0062(1.00) | 0.0394(0.99) | 0.1298(0.98) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

Ghanaian cedi and Sierra Leonean leone have high persistence and stationarity in variance. As such, cedi and leone's conditional variance will experience a slow reversion to its long run average whenever it experiences volatility shocks. The level of persistence for Liberian dollar is the lowest on Table 9.

This equates to a quick reversion of dollar's conditional variance towards the long run mean whenever there are volatility shocks.

### 4.1.7 Threshold Generalized Autoregressive Conditional Heteroscedasticity (TGARCH) with volatility breaks

The estimated results on Table 10 are TGARCH (1,1) models for all the countries. The leverage effects (γ) are significant for all countries except for Guinea. Since $\gamma \neq 0$, the news impact is asymmetric for all the countries. Leverage effect exists for Gambia, Ghana, Liberia, and Sierra Leone.

This means that bad news confers higher volatility than good news of the same order of magnitude for their currencies. Leverage effect does not exist for Guinea and Nigeria which means that good news confers higher volatility than bad news.

Table 11: EGARCH results for 1960M01 to 2011M012 with volatility breaks

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0037*** | 0.0133*** | 0.0000 | 0.0045 | 0.0000 | -0.0007 |
| Break | -0.0163*** | 0.0448 | 0.009** | 0.1456 | 0.0285 | 0.044*** |
| Variance Equation | | | | | | |
| $\omega$ | -5.2087*** | -4.0069*** | -3.4641*** | -7.2223* | -5.6673*** | -0.1977*** |
| α(ARCH(-1)) | 1.2474*** | 0.8734*** | 1.9304*** | 0.2617 | 1.0653*** | 0.0418*** |
| β(GARCH(-1)) | 0.3917*** | 0.4104*** | 0.5692*** | 0.3915 | 0.3678*** | 0.9748*** |
| α+β | 1.6391 | 1.2838 | 2.4996 | 0.6532 | 1.4331 | 1.0166 |
| γ | 0.1103** | -1.2067*** | -1.4635*** | -0.0219 | -0.0695 | -0.1257*** |
| Break | 0.2453*** | 3.2801*** | 1.3786*** | 8.3073* | 3.0999*** | 0.0667*** |
| Akaike Info Criterion | -4.3172 | -1.3072 | -2.7781 | -5.6148 | -4.5383 | -4.0373 |
| Schwarz Criterion | -4.2602 | -1.2574 | -2.7282 | -5.5579 | -4.4813 | -3.9803 |
| Diagnostic: ARCH Test | | | | | | |
| F-statistic | 0.2252(0.95) | 0.0391(0.99) | 0.0082(1.00) | 0.0015(1.00) | 0.2851(0.92) | 0.4941(0.78) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

### 4.1.8 Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) with volatility breaks

The estimated results on Table 11 are EGARCH (1,1) models for all the countries. The leverage effects (γ) on Table 11 are significant for Gambia,

Ghana, Guinea, and Sierra Leone but not significant for Liberia and Nigeria. Since $\gamma \neq 0$, the news impact is asymmetric for all the countries. There is no leverage effect for Gambian dalasi official exchange rate and the currency is covariance stationary.

Leverage effect does exist for Ghanaian cedi, Guinean franc, and Sierra Leone leone because $\gamma$ is negative. Cedi, franc, and leone are covariance stationary as their GARCH terms are significant and less than one. Decision on the existence of leverage effect for Ghana, Nigeria and Sierra Leone is the same under EGARCH and TGARCH models while it is contradictory for other countries.

## 4.2 2000 to 2011

### 4.2.1 Measures of Variability for 2000M01 to 2011M12

The range of each country's official exchange rate on Table 12 shows that Ghana retains the highest range while Gambia has the lowest range. According to range, Ghana has the most variable official exchange rate while Nigeria has the least variable official exchange rate for the period 2000M01 to 2011M12. Liberian dollar, Guinean franc, Sierra Leonean leone, and Gambian dalasi have the second, third, fourth, and fifth most variable official exchange rate in the WAMZ region.

Table 12: Measures of Variability (2000M01 to 2011M12)

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Range | 0.9784 | 10.7186 | 1.5673 | 1.7648 | 0.4962 | 0.9813 |
| Ranking | 5th | 1st | 3rd | 2nd | 6th | 4th |
| Variance | 0.0703 | 6.2235 | 0.2348 | 0.0442 | 0.0147 | 0.0604 |
| Standard Deviation | 0.2653 | 2.4947 | 0.4846 | 0.2102 | 0.1211 | 0.2458 |
| Ranking | 3rd | 1st | 2nd | 5th | 6th | 4th |

Table 12 also depicts the results of the variance and square root of the variance. This shows that Nigeria's official exchange rates are clustered closely around the mean while Ghana's official exchange rates are spread from the mean. Thus, Ghanaian cedi remains the most volatile and Nigeria naira is the least volatile during 2000M01 to 2011M12. Guinean franc, Gambian dalasi, Sierra Leone leone, and Liberian dollar Sierra Leonean leone have the second, third, fourth, and fifth most variable official exchange rate.

### 4.2.2 Pre Estimation tests for 2000M01 to 2011M12

The results of ADF and PP unit root test on Table 13 shows that the data on official exchange rate, for all the countries during the period 2000M01 to 2011M12, are integrated of order one at all levels of significance except for Liberia which is integrated at level at all levels of significance.

Table 13: Unit root test

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| ADF t-statistic | -8.63 | -11.95 | -7.97 | -7.09 | -8.59 | -5.42 |
| Remark | I(1)*** | I(1)*** | I(1)*** | I(0)*** | I(1)*** | I(1)*** |
| PP t-statistic | -8.63 | -11.95 | -7.86 | -7.73 | -8.61 | -8.28 |
| Remark | I(1)*** | I(1)*** | I(1)*** | I(0)*** | I(1)*** | I(1)*** |
| Critical Values | | | | | | |
| 1% | -3.47 | | | | | |
| 5% | -2.88 | | | | | |
| 10% | -2.57 | | | | | |

***Significant at 1%, 5%, and 10%

The results of the heteroscedasticity ARCH test, on Table 14, indicate that the residuals of the respective countries' official exchange rate show the presence of ARCH effects.

Table 14: Heteroscedasticity ARCH test without volatility breaks for 2000M01 to 2011M12

| ARCH test | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| F-statistic | 1064 | 221.37 | 491.85 | 18.42 | 409.99 | 662.86 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |

Values of probability are in parentheses

Table 15: Chow Breakpoint test

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| F-statistic | 296.26*** | 133.17*** | 674.01*** | 56.44*** | 527.76*** | 562.90*** |
| Log likelihood | 287.2*** | 95.26*** | 394.15*** | 84.69*** | 361.49*** | 409.65*** |
| Wald Statistic | 888.8 | 133.17*** | 2022*** | 112.8*** | 1583*** | 2251.6*** |
| Break Date(s) | 2002M08 2009M03 | 2010M04 | 2003M06 2010M04 | 2002M01 2009M09 | 2002M06 2009M01 | 2002M06 2009M08 |

***Significant at all levels

Table 15 shows the volatility break dates and the Chow test rejects the null hypotheses of no volatility break in the models.

Table 16: Heteroscedasticity ARCH test with volatility breaks for 2000M01 to 2011M12

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| ARCH test: | | | | | | |
| F-statistic | 264.32 (0.00) | 533.2 (0.00) | 565.92 (0.00) | 18.42 (0.00) | 390.32 (0.00) | 542.67 (0.00) |

Values of probability are in parentheses

Table 16 indicates that the residuals of the respective countries' official exchange rate with volatility breaks show the presence of ARCH effects.

Table 17: GARCH results for 2000M01 to 2011M012 without volatility breaks

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0095** | -0.0085 | 0.0114*** | -0.0172 | 0.0027 | 0.0005 |
| Variance Equation | | | | | | |
| $\omega$ | 0.0002*** | 0.2805 | 0.0009*** | 0.0246 | 0.0002*** | 0.0000 |
| α(ARCH(-1)) | 0.3324*** | -0.0075*** | 0.7419*** | 0.2875 | 0.2141* | 0.4243*** |
| β(GARCH(-1)) | 0.5445*** | 0.5631 | 0.0476 | -0.0265 | -0.0473 | 0.6574 |
| α+β | 0.8769 | 0.5556 | 0.7895 | 0.261 | 0.1668 | 1.0817 |
| $\varpi$ | 0.0016 | 0.6311 | 0.0043 | 0.0333 | 0.0002 | 0 |
| $\sqrt{\varpi}$ | 0.04 | 0.7944 | 0.0656 | 0.1825 | 0.0141 | 0 |
| Ranking | 4th | 1st | 3rd | 2nd | 5th | 6th |
| Akaike Info Criterion | -4.3249 | 2.2886 | -3.5565 | -0.781 | -5.3746 | -5.7219 |
| Schwarz Criterion | -4.2213 | 2.3715 | -3.4736 | -0.6982 | -5.2917 | -5.6391 |
| Diagnostic: | | | | | | |
| ARCH Test | | | | | | |
| F-statistic | 0.2037(0.96) | 0.0058(1.00) | 0.0497(0.99) | 0.0163(0.99) | 0.0444(0.99) | 1.753(0.12) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

### 4.2.3 Generalized Autoregressive Conditional Heteroscedasticity (GARCH) without volatility breaks

All the estimated results on Table 17 are GARCH (1,1) models for all the countries. All the currencies have a level of persistence that is less than one except for Sierra Leone leone. Thus, Sierra Leone experienced overshooting volatility; Gambia and Guinea experienced high persistent volatility; and

Ghana, Liberia, and Nigeria experienced low persistent volatility during the period. This also implies that there is no stationarity in variance for Sierra Leone while there is stationarity in variance for other countries.

The long run average variance ($\varpi$) was calculated for Table 17. Ghana's long run average variance remains the highest with a value of 0.6311 and Sierra Leone has the lowest long run average variance of zero.

### 4.2.4 Threshold Generalized Autoregressive Conditional Heteroscedasticity (TGARCH) without volatility breaks

The estimated results on Table 18 are TGARCH (1,1) models for all the countries. The news impact is asymmetric for all the countries. Thus, leverage effect exists for Gambian dalasi but not for Sierra Leone leone official exchange rate. In other word, bad news confers higher volatility than good news of the same order of magnitude for dalasi while bad news confers lower volatility than good news for leone.

Table 18: TGARCH results for 2000M01 to 2011M012 without volatility breaks

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0072* | -0.0105 | 0.0114*** | -0.0174 | 0.0028 | 0.0007 |
| Variance Equation | | | | | | |
| $\omega$ | 0.0002*** | 0.2805 | 0.0009*** | 0.0104 | 0.0002*** | 0.0000 |
| α(ARCH(-1)) | 0.0229 | -0.0075*** | 0.5298** | -0.058 | 0.2907 | 0.4417*** |
| β(GARCH(-1)) | 0.582*** | 0.5632 | 0.0857 | 0.5531 | -0.0145 | 0.6978*** |
| α+β | 0.6049 | 0.5557 | 0.6155 | 0.4951 | 0.2762 | 1.1395 |
| γ | 0.5004*** | -0.7372 | 0.3684 | 0.1533 | -0.2223 | -0.3008*** |
| α+γ | 0.5233 | -0.7447 | 0.8982 | 0.0953 | 0.0684 | 0.1409 |
| Akaike Info Criterion | -4.3879 | 2.2883 | -3.5461 | -0.7983 | -5.3655 | -5.7384 |
| Schwarz Criterion | -4.2635 | 2.3919 | -3.4425 | -0.674 | -5.2619 | -5.64 |
| Diagnostic: ARCH Test | | | | | | |
| F-statistic | 0.1874(0.96) | 0.0058(1.00) | 0.0726(0.99) | 0.1342(0.98) | 0.0336(0.99) | 0.9669(0.44) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

### 4.2.5 Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) without volatility breaks

The estimated results on Table 19 are EGARCH (1,1) models for all the countries. Since $\gamma \neq 0$, the news impact is asymmetric for all the countries.

There is no leverage effect for Liberian dollar. The dollar is also not covariance stationary because its GARCH term is not significant. Leverage effect does not exist for Gambian dalasi and Guinean franc, either but they are covariance stationary as their GARCH terms are significant and less than one. Thus, decision on the existence of leverage effect is the same for all the countries under EGARCH and TGARCH models except for Guinea.

Table 19: EGARCH results for 2000M01 to 2011M012 without volatility breaks

| | **Gambia** | **Ghana** | **Guinea** | **Liberia** | **Nigeria** | **Sierra Leone** |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.007 | 0.0555*** | 0.013*** | -0.0079*** | 0.0031 | 0.0009*** |
| Variance Equation | | | | | | |
| $\omega$ | -1.9722*** | 0.0079 | -3.3489*** | -6.1546*** | -8.987*** | -0.6765*** |
| α(ARCH(-1)) | 0.5134*** | -0.5114*** | 0.7913*** | 3.5173*** | 0.2521 | 0.6258*** |
| β(GARCH(-1)) | 0.7745*** | 0.9307*** | 0.5591*** | -0.0124 | -0.0688 | 0.9825*** |
| α+β | 1.2879 | 0.4193 | 1.3504 | 3.5049 | 0.1833 | 1.6083 |
| γ | -0.2428** | 0.0531 | -0.2464** | 2.3802*** | 0.1786 | 0.0824 |
| Akaike Info Criterion | -4.3726 | -0.4681 | -3.5265 | -1.508 | -5.3764 | -5.706 |
| Schwarz Criterion | -4.2483 | -0.3438 | -3.4229 | -1.4044 | -5.293 | -5.602 |
| Diagnostic: ARCH Test | | | | | | |
| F-statistic | 0.2506(0.93) | 0.0031(1.00) | 0.0884(0.99) | 0.1045(0.99) | 0.0284(0.99) | 1.0304(0.40) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

### 4.2.6 Generalized Autoregressive Conditional Heteroscedasticity (GARCH) with volatility breaks

All the estimated results on Table 20 are GARCH (1,1) models for all the countries. The coefficients for volatility breaks under variance equation are significant for all the countries except for Nigeria and Sierra Leone. Gambia, Guinea, and Liberia have a level of persistence that is higher than one (i.e. α+β). This implies that there is no stationarity in variance for the countries' currencies official exchange rate. Thus, there is the presence of overshooting volatility shocks. Ghana has a high persistent volatility and stationarity in variance. As such, Ghanaian cedi's conditional variance will experience a slow reversion to its long run average whenever it experiences volatility shocks.

Table 20: GARCH results for 2000M01 to 2011M012 with volatility breaks

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0138*** | 0.0025 | 0.00009 | 0.003 | 0.0042 | 0.0025 |
| Break | -0.0156*** | 0.3631 | 0.0272*** | 0.0334 | -0.0014 | 0.0037 |
| Variance Equation | | | | | | |
| $\omega$ | 0.0002*** | 0.0000*** | 0.0000 | 0.00006 | 0.0003 | 0.0006 |
| α(ARCH(-1)) | 0.2089*** | 0.2353*** | 1.2895*** | 1.3453*** | 0.15 | 0.15 |
| β(GARCH(-1)) | 0.8022*** | 0.732*** | 0.3286*** | 0.1433** | 0.60 | 0.60 |
| α+β | 1.0111 | 0.9673 | 1.6181 | 1.4886 | 0.75 | 0.75 |
| Break | -0.0002*** | 1.521*** | 0.0003* | 0.0285*** | 0.0000 | 0.0000 |
| Akaike Info Criterion | -4.4741 | -5.2505 | -4.1618 | -1.6356 | -4.8344 | -4.0531 |
| Schwarz Criterion | -4.3498 | -5.1054 | -4.0375 | -1.5113 | -4.71 | -3.9287 |
| Diagnostic: ARCH Test | | | | | | |
| F-statistic | 0.1707(0.97) | 0.1855(0.96) | 0.62(0.68) | 0.0127(0.99) | 0.5988(0.70) | 5.3329(0.00) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

### 4.2.7 Threshold Generalized Autoregressive Conditional Heteroscedasticity (TGARCH) with volatility breaks

The estimated results on Table 21 are TGARCH (1,1) models for all the countries. Since $\gamma \neq 0$, the news impact is asymmetric for all the countries. Leverage effect exists for Gambia, Guinea, and Liberia. This means that bad news confers higher volatility than good news of the same order of magnitude for Gambia, Guinea, and Liberia. Leverage effect does not exist for Ghana.

### 4.2.8 Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) with volatility breaks

The estimated results on Table 22 are EGARCH (1,1) models for all the countries except for Nigeria that has EGARCH (2,2). The leverage effects ($\gamma$) are significant for all the countries except for Sierra Leone. Since $\gamma \neq 0$, the news impact is asymmetric for all the countries. There is no leverage effect for Ghana, Liberia, and Nigeria and they have covariance stationarity because their respective GARCH terms are significant and less than one.

Table 21: TGARCH results for 2000M01 to 2011M012 with volatility breaks

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0093*** | 0.0026* | 0.00005 | -0.0182** | 0.0042 | 0.0025 |
| Break | 0.0045 | 0.7095 | 0.0248*** | 0.013 | -0.0014 | 0.0037 |
| Variance Equation | | | | | | |
| $\omega$ | 0.0002*** | 0.0000*** | 0.0000 | 0.0013** | 0.0003 | 0.0006 |
| α(ARCH(-1)) | 0.1372 | 0.2879*** | 0.9713*** | 0.0665* | 0.15 | 0.15 |
| β(GARCH(-1)) | 0.0358 | 0.7709*** | 0.3104*** | 0.5271* | 0.60 | 0.60 |
| α+β | 0.173 | 1.0588 | 1.2817 | 0.5936 | 0.75 | 0.75 |
| γ | 1.4524*** | -0.4019*** | 0.9522** | 0.1836*** | 0.05 | 0.05 |
| α+γ | 1.5896 | -0.114 | 1.9235 | 0.2501 | 0.2 | 0.2 |
| Break | 0.0004*** | 1.2637*** | 0.0003** | 0.0137* | 0.0000 | 0.0000 |
| Akaike Info Criterion | -4.4115 | -5.3071 | -4.169 | -1.36 | -4.8137 | -4.0342 |
| Schwarz Criterion | -4.2665 | -5.1414 | -4.04 | -1.215 | -4.6686 | -3.8892 |
| Diagnostic: ARCH Test | | | | | | |
| F-statistic | 0.1901(0.96) | 0.1319(0.98) | 1.0355(0.39) | 0.1508(0.97) | 0.6017(0.69) | 4.8052(0.00) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

Table 22: EGARCH results for 2000M01 to 2011M012 with volatility breaks

| | Gambia | Ghana | Guinea | Liberia | Nigeria | Sierra Leone |
|---|---|---|---|---|---|---|
| Mean Equation | | | | | | |
| C | 0.0126*** | 0.0013*** | 0.0000 | 0.0023 | -0.0007 | 0.0058*** |
| Break | -0.0102*** | 0.0012 | 0.0154*** | 0.0365 | 0.0025** | 0.0051*** |
| Variance Equation | | | | | | |
| $\omega$ | -6.8202*** | -1.7067*** | -4.0659*** | -2.5684*** | -2.0089*** | -0.9386*** |
| α(ARCH(-1)) | 1.1254*** | 0.2844** | 1.6651*** | 1.0853*** | -0.0606 | 0.7676*** |
| β(GARCH(-1)) | 0.2481*** | 0.8709*** | 0.645*** | 0.770*** | 0.5172*** | 0.9547*** |
| α(ARCH(-2)) | | | | | -0.6056*** | |
| β(GARCH(-2)) | | | | | 0.1834*** | |
| α+β | 1.3735 | 1.1553 | 2.3101 | 1.8553 | 0.0344 | 1.7223 |
| γ | -0.5272*** | 0.4519*** | -0.4388*** | 0.3273** | 0.605*** | 0.08454 |
| Break | 1.0266*** | 2.3773*** | 1.0598*** | 1.4307*** | -0.3653*** | -0.1739 |
| Akaike Info Criterion | -4.387 | -5.3616 | -3.9515 | -1.7518 | -6.1287 | -5.7635 |
| Schwarz Criterion | -4.249 | -5.2165 | -3.8064 | -1.6067 | -5.9422 | -5.6185 |
| Diagnostic: ARCH Test | | | | | | |
| F-statistic | 0.2043(0.96) | 0.9334(0.46) | 0.0997(0.99) | 0.0139(0.99) | 0.4568(0.80) | 0.5932(0.70) |

***Significant 1%, **Significant at 5%, and *Significant at 10%

Leverage effect does exist for Gambia and Guinean. Gambia and Guinea also have covariance stationary as their GARCH terms are significant and less than one. Decision on the existence of leverage effect is the same for all the countries under EGARCH and TGARCH models except for Liberia.

### 4.3 Diagnostic test

The results of ARCH test (under each country on Tables 6 to 11 and Tables 17 to 21) have F-statistics that are not significant for all the countries except for Sierra Leone on Tables 20 and 21. This proves that there are no further ARCH effects in the specified GARCH, TGARCH, and EGARCH models.

## 5.0 Summary

Evidence on Tables 7 and 8, shows that there is inconsistency in identifying whether the official exchange rates per US$ for each currency experiences a leverage effect or not. Choosing between TGARCH and EGARCH, we selected the model that has the lower Akaike Information Criterion (AIC) and Schwarz Criterion (SC) to inform our judgment. The most appropriate models for 1960M01-2011M12 without breaks are TGARCH for Gambia and Guinea and EGARCH for Ghana, Liberia, Nigeria and Sierra Leone. Based on these selections, Gambian dalasi, Ghanaian cedi, Guinean franc, and Liberian dollar do have leverage effect. That is negative or bad news has more volatility impacts on the currencies official exchange rates than positive or good news of the same magnitude. Meanwhile, leverage effect does not exist for Nigerian naira and Sierra Leonean leone which implies the opposite.

The results from Tables 9, 10, and 11, models with breaks are generally better models compared to those without breaks, in terms of AIC and SC. The most appropriate models for 1960M01-2011M12 with breaks are GARCH for Liberia, TGARCH for Gambia, Ghana, Guinea and Nigeria and EGARCH for Sierra Leone. Thus, we found that Leverage effect does exist for Gambian dalasi, Ghanaian cedi, and Sierra Leonean leone while leverage effect does not exist for Liberian dollar and Nigerian naira.

Models with breaks, for the period 2000M01 to 2011M12, generally have better results than those without breaks for the same period. In terms of leverage effect, they (both) give contradictory results compared to the period 1960M01-2011M12 but they corroborate the existence of leverage effect for Gambia and nonexistence of leverage effect for Nigeria.

## 6.0 Conclusion

The empirical evidence analysed in this paper suggests that the WAMZ countries experience exchange rate volatility of different levels. Evidence on Tables 1, 6, 12, and 17, shows the ranking of the WAMZ countries according to which country has the highest level of official exchange rate volatility. This has not been consistent based on our results. However, one thing has been consistent: Ghana has the highest range, variance, and GARCH Unconditional variance among the WAMZ countries. Thus, there is a maximum likelihood that Ghanaian cedi is the most volatile of all the currencies in the WAMZ region. From our findings, it is conclusive that leverage effect exists for Gambian dalasi while it does not exist for Nigerian naira. Whether leverage effect exists or not for other currencies is inconclusive in this study. Our findings on non-existence of leverage effect for Nigerian naira is consistent with that of Olowe (2009) and Bala and Asemota (2013).

Also, there is inconsistency as to whether central bank intervention in the foreign exchange market decreased or increased the level of volatility persistence during the period of our study for Ghana, Guinea, and Liberia. However, central bank intervention in the foreign exchange market decreased the level of volatility persistence in Gambia and Nigeria while it increased the level of volatility persistence in Sierra Leone. The need for government of the WAMZ economies to duly manage exchange rate volatility is, thus, pertinent because of its risk import to international trade returns and cost of financial transactions i.e. domestic prices in all the countries as they are all import dependent. In a zone that is predominantly poor, improved stability in exchange rate movement, among others, is desirable to also promote foreign direct investment inflows. The economic source or determinants of exchange rate volatility in the WAMZ countries could be investigated in our further study.

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