# Monetary union and inflation Dynamics: The case of the West Africa Monetary Zone (WAMZ)

***Abstract***

*The literature on the dynamics of inflation appears to have shifted from the question of the root cause of shocks to inflation, to whether the monetary union has a bearing in the measure of the degree or the persistence of the effect of the shocks. Using the case of WAMZ economy, the study explores a univariate conventional and GARCH-based unit root tests to determine the extent to which monetary union matters for the persistence of effects of shocks to inflation. Findings from the study suggest the effects of shocks to inflation have been transitory and not persistence. This is revealed in the case WAMZ since the introduction of monetary union, and particularly when control for conditional time-varying and monetary policy shocks. It is also observed that monetary policy shock has the potential to neutralise the persistence of shocks to inflation at least in the long-run and following the introduction of monetary union, particularly when the time-varying property of the persistence in captured. It is in this light, among others, that the study recommends that for continued monetary support for those WAMZ member countries that still exhibit a higher proclivity for higher inflation persistence even after the introduction of monetary union will be needed. However, monetary authorities in such WAMZ country would be less costly and be able to avoid excessive interfering targets if they take cognisance of the time-varying property of the variable of interest.*

**Keywords**: Inflation Dynamics; Synchronization; Monetary Policy; Shocks; Multivariate GARCH Model.

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## 1. Introduction

The adoption of common monetary policy has over the years formed part of the process of economic integration. Following the formation of the European Monetary Union (EMU), a few regions around the world have expressed their interest in forming a similar union. This process has to do with member countries given up their independent monetary policies to pave the way for a common central bank that will be responsible for the conduct of monetary policy for the member states. Although, potential economic cost from transforming to a monetary union has been measuring to include seigniorage lost from printing money, however, the gain derivable from it in terms of low inflation is often the core reason for the increasing preference for a monetary union over the independent individual monetary policies. In the Western region part of Africa for example, the antecedents of a monetary union dated to 1987 when heads of state of the Economic Community of West African States (ECOWAS) adopted the monetary cooperation programme to accelerate the process of integration. The lack of progress in the spirit of Lome Summit of 1999 led the heads of state and government of the English-speaking countries of the ECOWAS, namely, Gambia, Ghana, Guinea, Nigeria and Sierra Leone to sign a treaty to form a second monetary union to be referred as "West African Monetary Zone (WAMZ)".

Following the examples of EMU and WAEMU, the WAMZ countries have set various criteria for macroeconomic convergence. Thus, entry into the union was made conditional on satisfying these convergence criteria[1], prominent among which is the attainment of single-digit inflation. More so, the WAMZ ultimate objective to establish a West African Central Bank and a single currency (the Eco) was mainly pre-conditioned on the attainment of single-digit inflation. Hence, it is generally expected that each of the member states in the union routing for a common currency will, as a matter of principle, pursue ex-ante independent monetary policies not only capable of narrowing inflation differentials across the member countries but also to foster convergence around a single inflation digit. However, the observation since the commencement of WAMZ in 2000 is that these primary convergence criteria (single digit inflation) have been the most difficult to fulfil. As shown in Table 1.1 below, average annual inflation in the WAMZ member countries has consistently hovered around double-digit figure both from the perspective of individual WAMZ member countries and of WAMZ as a group. Also, the WAMZ group's annual average inflation rate hovered

[1] Other convergence criteria include fiscal deficit/GDP ratio of less than 4%; central bank financing of deficit to be less than 10% and gross external reserves of about three months of import cover.

around 10% to 12% since the introduction of monetary union among the member countries with the indications of great variance in the rate of inflation across the member countries (see Table 1.1). The Gambia and Sierra Leone, on the one hand, have been maintaining on average, a single digit inflation rates since the commencement of WAMZ, the reverse seems the case for other WAMZ member countries. For example, the least average inflation rates since the commencement hovered around 10% to 12% in the case of Nigeria, 11% to 14% in the case of Ghana and Guineas except for the period between 2015 and 2017 in the case of the latter.

**Table: 1.1: Annual Average Inflationary Trends in the WAMZ Member States**

| | **Pre-WAMZ Period** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Member States** | **1965-69** | **1970-74** | **1975-79** | **1980-84** | **1985-89** | **1990-94** | **1995-99** |
| Ghana | 9.29 | 11.69 | 65.98 | 70.28 | 26.25 | 23.04 | 32.19 |
| Gambia | 2.41 | 5.18 | 14.07 | 11.27 | 23.67 | 7.69 | 3.16 |
| Guinea | NA | NA | NA | 32.20 | 35.20 | 1.30 | 4.40 |
| Nigeria | 3.95 | 10.26 | 21.35 | 15.90 | 25.88 | 35.83 | 25.45 |
| Sierra-Leone | 3.70 | 6.14 | 15.51 | 39.65 | 86.25 | 65.11 | 26.74 |
| ***WAMZ Group*** | 4.8375 | 8.3175 | 29.2275 | 33.86 | 39.45 | 26.594 | 18.388 |
| **WAMZ Period** | | | | | | | |
| | **2000-04** | **2005-09** | **2010-14** | **2015-17** | | | |
| Ghana | 22.44 | 14.51 | 11.14 | 17.31 | | | |
| Gambia | 9.04 | 4.25 | 5.15 | 7.01 | | | |
| Guinea | 11.80 | 20.60 | 14.73 | 8.14 | | | |
| Nigeria | 13.54 | 10.92 | 10.66 | 12.36 | | | |
| Sierra-Leone | 3.95 | 1.33 | 8.04 | 8.79 | | | |
| ***WAMZ Group*** | 12.154 | 10.322 | 9.944 | 10.722 | | | |

**Source: WAMI and IFS Database**

The above-stylized facts help to reflect the differential in inflation among the WAMZ member countries. It also reflects the potential of inflation adjusting back to its long-run steady-state or equilibrium level after a shock is likely to differ across these WAMZ member countries. Notwithstanding, the choice and design of monetary policy in the pursuance of low inflation are often pre-determined on the assumption that inflation series are mean-reverting.

The perception that the pro monetary union often stressed that such potential of inflation reverting to its mean values says within a year or two will likely ease the attainment of the convergence criteria of single digit inflation among monetary union member countries. If there are differences in the rate at which inflation reverts to its equilibrium path following a shock, policymakers in a monetary union are likely to be confronted with the challenge to design a monetary policy for diverse and conflicting economic environments. The more the likelihood of differential or asymmetric of shocks to inflation across the individual member states in a monetary union, the more likely the varying degrees of persistence in inflation. Hence, the greater would be the risk to the stability of monetary union.

The extensive literature on the dynamics and persistence of inflation (see for example, Nelson and Schwart, 1997; Barsky, 1987, Hassler and Wolters, 1995; Lee, 2005; Amano, 2007; Cuestas and Harrison, 2010; Hassler and Meller, 2014; Antonakakis et al., 2016; Caranella and Miller, 2017), have given little or no attention to issues on inflation persistence, dispersion and convergence from the perspective of monetary union. The only few exceptions, in this regard, are Edwards, 2006; Meller and Nautz, 2009; and Coleman, 2010, have rather focused mainly on the case of the European Monetary Union (EMU). The limited studies on inflation persistence and monetary union in the context of developing economies is the motivation to use the case of WAMZ. This is in a bid to advance the literature on the inflationary dynamics of a group of countries that appear to be determined to form a monetary union.

By focusing on "the West African Monetary Zone (WAMZ)", this study will be contributing to the literature in following folds: first, it set out to query whether inflation rates would react similarly to varying independent monetary policy shocks across the individual member countries in WAMZ. This is pertinent to the evaluation of the potential of the proposed West Africa Central Bank in the pursuance of the target single-digit inflation. However, understanding the level of inflation persistence across the individual member states in WAMZ matter for the design of a successful common monetary policy strategy, assuming constant persistence across business cycle phases. Thus, accounting for the time varying feature of the inflation may lead to biases in the estimate of inflation persistence and consequently misguide policy decisions. To bridge this gap, we extend the literature to capture the sensitivity of the degree of the persistence to the potential time-varying property

of inflation in WAMZ, particularly, in the context of monetary union in the Western region of Africa.

In the world over, the ultimate objective of any monetary policy is to keep prices of goods and services at rates that would not be detrimental to the economic system. The attainment of price stability matters for the wellbeing of every economy either developed or developing. It is necessary to observe the potential consequences of its non-attainment, prominent among which is inflation persistence. For instance, a continued rise in the general price level tends to undermine people's confidence in the central bank's policies. This could cause inflation expectations to differ from the central bank's objectives, as inflation expectations become sensitive to shocks that hit the economy. Thus, the higher the degree of persistence of an upward inflationary trend, the more the public is likely to view the central banks as not credible in their mandate to maintain price stability, as the public would expect high inflation in the future and make price and wage decision accordingly. Although, the public may yet perceive the central bank's mandate to maintain price stability as credible with their expectations of future inflation in line with the central bank's objective if there is an incentive for them to view the resulting increase inflation as temporary rather than permanent. In the absence of such incentive, the resulting potential deviation of the inflation rate from a specific target, the speed of reaction to correcting measures, and the output cost associated with the implementation of a disinflation policy will be more challenging in the context of monetary union.

The intellectual puzzles of WAMZ include: first, the potential of persistence inflation differentials within the WAMZ might mean that inflation is not always and everywhere a monetary phenomenon. To this end, the proposed single monetary policy may not be sufficient in fighting the rising general price level within the WAMZ region. Secondly, if the observed inflation differentials in WAMZ also manifest in the rate at which inflation returns to its mean level following a shock, the policymakers in the WAMZ are likely to be confronted with the challenge to design a monetary policy in the realm of diverse or conflicting economic environments. This raises concern about the potential of the proposed West African Central Bank to conduct an effective monetary policy in a monetary union that is characterised by the different inflation rate. This study finds it indispensable to examine the dynamics of inflation in the WAMZ from the perspective of how inflation rates will react similarly to different monetary policy shocks across the member countries in the union. This

will provide useful insight into the potential challenges that dispersion and varying degree of inflation persistence pose to the attainment of the convergence criteria of single digit inflation in WAMZ.

The study examines monetary union using the case of WAMZ matter for the degree of inflation persistence. To achieve this broad objective, the study specifically hopes to determine whether the historically observed inflation differentials in WAMZ also manifest in the rate at which inflation returns to its mean level for the period before and after the introduction of monetary union in WAMZ. Also, it will determine the extent to which independent monetary policy shocks across the individual member countries in WAMZ matter for the varying degree of inflation persistence in the zone. Lastly, it determines whether the degree of inflation persistence in WAMZ could be attributed to the time-varying property of inflation rates in the zone.

Although, we acknowledged that Alagidede et al. (2012) have also used the case WAMZ in their examination of the implications of persistent inflation shocks on monetary union, however, shocks to inflation in the context of their study are measured mainly via the past inflation value in the context of white noise autoregressive model (see also, Cogley and Sargent, 2005; and Levin and Piger 2004). However, other specific effects exist that have shown to matter for explaining the dynamic of inflation and inflation persistence. This study explores a more robust and explicit multivariate approach to estimating inflation persistence to identify the extent to which shocks due to monetary policy other than past inflation value matter for the degree of persistence in WAMZ inflation. Secondly, the bulk of the extant studies on the persistence of inflation have continued to assume that the degree of persistence is constant over time. However, assuming constant persistent despite the potential for the persistence to vary over time, for instance, across business cycles, may lead to misguided policy decisions. We extend the conventional univariate autoregressive unit root test approaches to estimating inflation persistence including a "generalised autoregressive conditional heteroskedastic (GARCH) based unit root tests" (Narayan and Liu, 2015) to account for probable time-varying property of the persistence. Following this introductory section, the rest of the paper is structured as follows: section two dwells on existing theory and empirical literature. Section 3 discusses the methodology and model specification. Section 4 presents and discusses the empirical results while section 5 concludes and provides policy implications.

## 2. Review of Empirical Literature

Understanding the dynamics of inflation is crucial to the implementation of any monetary-related policy such as inflation targeting and other monetary policy rules. Arize and Malindretos (2012) employ the ESTAR-type unit root tests based on symmetric adjustment (Kapetanios et al., 2003) and asymmetric adjustment (Sollis, 2009) for thirty-four African countries, and their results provide robust evidence in favour of the nonstationarity of CPI inflation for 34 countries. Zhou (2013) uses the stationarity test approach of Kapetanios et al. (2003) to examine the inflation rates of 12 European countries and finds that the majority of the inflation rates of the selected countries are stationary processes during the floating exchange rate periods. In the case of Chang et al. (2013), they adopt the flexible Fourier stationarity test proposed by Becker, Enders, and Lee (2006) to investigate the mean reversion of inflation in 22 OECD countries over the period from 1961 to 2011. Their empirical results show that inflation exhibits a mean-reversion process in all 22 OECD countries based on the flexible Fourier stationarity test.

Bolat et al. (2017) investigate the dynamic behaviour and seasonal property (with regime shift) of inflation in the Middle East and North Africa (MENA) countries using quantile regression approach developed by Roger Koenker and Zhijie Xiao (2004). Their empirical results show that the inflation rates are not mean-reverting, and they show the asymmetries in their dynamic adjustment. They also find out that a seasonal unit root does not exist in the inflation rate for any country thus implying that shocks do not have lasting effects on the inflation rate.

Machado and Portugal (2014) estimate inflation persistence in Brazil in a multivariate framework of unobserved components, accounting for the following sources affecting inflation persistence: deviations of expectations from the actual policy target; the persistence of the factors driving inflation; and the usual intrinsic measure of persistence, evaluated through lagged inflation terms. The study employs a Bayesian analysis approach to simplify the estimation of a great number of unknown variables. The findings indicate that expectations-based persistence matters considerably for inflation persistence in Brazil.

Phiri (2016) investigate inflation persistence using annual CPI inflation collected between 1994 and 2014 for 46 African countries. The study groups the countries into panels according to whether they are inflation targets or not and conducts estimations for pre and post inflation

targeting periods. Empirically, it finds that inflation persistence was much higher for inflation targets in periods before adopting their inflation targeting regimes and inflation persistence dropped by 40 per cent for these countries after adopting the policy frameworks. For non-inflation targets, inflation persistence has increased by almost 290 per cent between the two periods.

Lovcha and Perez-Laborda (2017) argue that structural VAR studies on the effects of monetary policy actions do not usually take into consideration the observed persistence of inflation and many of the other variables included in the models. To this end, their study account for this issue by analysing the effects of the monetary policy shock in a structural fractionally integrated VAR. Their findings reveal that overwhelming evidence of long memory with the traditional framework is decisively rejected by the data. Also, allowing for long memory has strong implications for the analysis of the responses of the variables to non-systematic policy actions. Typical VAR specifications lead to a misleading assessment of the importance of the monetary policy shock. Lastly, the long memory properties of inflation remain stable across the usual sample splits in the literature, consistent with the view that long memory is an intrinsic property of inflation data arising in the construction of the price indexes.

Canarella and Miller (2017) investigate the dynamics of inflation persistence for a sample of advanced (Canada, Sweden, and the United Kingdom) and newly industrialised and emerging market (Chile, Israel, and Mexico) economies that adopted inflation targeting (IT) before the year 2000. The study provides empirical evidence on two yet unanswered questions using fractional integration and cointegration techniques, First, it investigates whether each of these six countries shares a common persistence with two non-IT countries, Germany, the largest economy of the Euro Area, and the United States, the world's largest economy, that arguably represent the main core of the global economy. Second, it examines whether inflation in each of the six IT countries and Germany and the United States are driven by a common stochastic trend. The evidence on these issues as reported in the paper is mixed.

On the one hand, the study finds that the inflationary processes in Germany, the United States, and the three advanced economies are fractionally integrated, stationary, mean reverting, and share common inflation persistence. On the other hand, the inflationary processes in the three emerging market economies are fractionally integrated, mean reverting, non-stationary, and do not share a common persistence with Germany and the United States.

It also finds that in the post-IT period, Sweden is fractionally cointegrated at the global level, that is, with both Germany and the United States, whereas Canada is fractionally cointegrated at the regional level, that is, only with the United States.

In some emerging economies in the world, the degree of inflation persistence captured by long memory[2] differs between the official price index and online price index (Antonakakis et al., 2016). On inflation persistence differential, Cunado et al. (2016) examine the inflation persistence using both online and official price indexes in Argentina, Brazil, China, Japan, Germany, South Africa, the UK, and the US, using fractional integration technique. The main results suggest that the degree of persistence, estimated by the long-memory parameter, is smaller when using online price indexes (believed to be a more realistic measure of inflation), mainly in the cases of Argentina, Brazil, China, and the UK. Presenting a new measure of U.S. inflation persistence from the point of view of a professional forecaster often referred as perceived inflation persistence, (which is built via the implied autocorrelation function that follows from the estimates obtained using a forecaster-specific state-space model), Jain (2017, 2014) finds that perceived inflation persistence changed over time and that forecasters are more likely to view unexpected shocks to inflation as transitory, particularly since the mid-1990s. When compared to the autocorrelation function for actual inflation, the study finds that forecasters react less to shocks than the actual inflation data would suggest, and that is because they engaged in forecast smoothing.

Alagidede et al. (2014) used the case of Ghana to examine the crucial issue of inflation persistence in Ghana to better inform the welfare and policy implications associated with it. Specifically, the study investigates the existence of persistence at both aggregate (national) and regional levels. The study, which included investigation of persistence across thirteen sectors spanning across both core and headline inflation persistence, employs fractional integration methods to show that there are asymmetries in the degrees of inflation persistence both regionally and sectorally.

### 2.1. Summary of the Review and Contribution to Literature

It must be pointed out at this juncture that, despite the growing issue of inflation persistence, dispersion and convergence in the context of monetary union, only a minor attention has been

[2] A time series exhibit a long memory when there is significant dependence between observations that are separated by a long period of time (Caranella and Miller (2017))

devoted to it in the literature with the majority of the extant studies tend to focus on the case of European Monetary Union (EMU). Meller and Nautz (2009) for example use the case of EMU as a natural experiment to investigate whether more effective monetary policy reduces the persistence of inflation. The study confirms that inflation dynamics differed considerably across Euro area countries before the start of EMU, considering the fractional integration of inflation. Since 1999, however, the results obtained from panel estimation indicate that the degree of long-run inflation persistence has converged. In line with theoretical predictions, the study finds that the persistence of inflation has significantly decreased in the Euro area and that that may be probably due to the effectiveness of the monetary policy of the European Central Bank. In the case of monetary union in the Caribbean, Cuestas and Dobson (2011) analyse the inflation rates for twelve countries using various time series methods. Their empirical results show that the inflation rates are mean reverting processes and that there is evidence of a convergence club in inflation rates within the area.

To the best of our knowledge, Alagidede et al. (2010) seem to be the only notable study to have explored the case of WAMZ in an attempt to determine the extent to which the dynamic of inflation in the individual member countries of a monetary union is (dis) similar. However, while acknowledging the contribution of the paper to stimulate debate on the long-term sustainability of monetary union in the context of WAMZ, particularly by examining the dynamics of inflation within the member countries from the perspective of divergence and persistence in inflation rate, it must be yet pointed out that not only is the understanding of the level of inflation dis(similarity) as well as the degree of inflation persistence that is important for the sustainability of the union, but also the question of whether the persistence varies over time. It is against this background that our study aims to extend the literature on inflation persistence for the WAMZ member countries by exploring a generalised conditional heteroskedastic –based (GARCH) modelling approach that is consistent with a time-varying property of inflation. The novelty here lies on whether the similarity or similarity in the extent to which inflation revert to an equilibrium state after a shock and as well as whether the hypothesis of varying degree of inflation persistence depends on the time-varying properties of inflation in WAMZ.

## 3. The Model

### 3.1 Theoretical Framework

Using the case of West Africa Monetary Zone (WAMZ), we explore the backwards-looking Phillip curve approach to modelling inflation to investigate whether inflation in WAMZ follows an autoregressive stationarity process as shown below:

$$\pi = \alpha + \sum_{j=1}^{k} \beta_j \pi_{t-j} + \varepsilon_t \qquad (3.1)$$

where $\pi$ denotes inflation at time *t* and $\varepsilon$ is the residual series uncorrelated. To measure persistence, equation (3.1) can be re-parameterised as follows:

$$\pi = \alpha + \sum_{j=1}^{k-1} \delta_j \Delta\pi_{t-j} + \rho\pi_{t-1}\varepsilon_t \qquad (3.2)$$

where $\rho = \sum_{j=1}^{k} \beta_j$ is the persistence parameter, while $\delta$ parameters are the transformation of the AR coefficients in equation (3.1), $\delta_{j=1} = -\beta_k$.

In the context of equation (3.1), inflation persistence can be defined as the speed with which inflation converges to equilibrium after a shock in the disturbance term. For robustness purpose, we will augment the above univariate approach to estimating inflation persistence with a multivariate approach that will enable us to account for other determinants of inflation dynamics. This is important as the exclusion of important factors, which drive inflation, may bias results by exaggerating the impact of inflation persistence. Thus, the multivariate version of the inflation persistence framework in equation (3.1) can be represented below:

$$\pi = \alpha + \sum_{j=1}^{k} \beta_j \pi_{t-j} + \sum_{n=0}^{N} \lambda_n X_{t-n} + \varepsilon_t \qquad (3.3)$$

where $\lambda$ is a vector of coefficients on explanatory variables (lagged *n* times), and *X* is a matrix of explanatory variables, which in the contest of this study will be represented as monetary policy shocks in each of the WAMZ member states.

#### 3.1.1 The Univariate Method

The simplest univariate method to assess inflation persistence to determine whether a shock to inflation is permanent or transitory has been the unit root testing approach. For robustness and completeness purpose, we consider a few time-series and panel-based unit root test models to assess the persistence of shocks on the inflation rates of WAMZ economies.

## 3.2 Variable Description and Data Source

The natural logarithm of monthly Consumer Price Indices (CPI) of each of the WAMZ member states is used to measure for inflation while the short-term interest rate of the respective member countries will be utilised as a measure for their respective monetary policy shocks. Using a monthly data frequency, all the variables of interest will be sourced from the Central Bank database of the respective WAMZ member countries, the data scope will be portioned into two to include the period before the introduction of monetary union ranging from 1980 to 1999, and period after the introduction of the monetary union ranging from 2000 to 2017.

### 3.2.1. Estimation Techniques

The procedure used most often in estimating the parameters in a GARCH modelling framework involves the method of quasi-maximum likelihood (QMLE) function. The QMLE is used to estimate the model parameters, and it involves maximising the likelihood function given as (see Ling and McAleer, 2003):

$$L_n(\lambda) = \frac{1}{n}\sum_{t=1}^{n} l_t(\lambda),\ l_t(\lambda) = \frac{1}{2}\ln\left|D_t \Gamma D_t\right| - \frac{1}{2}\varepsilon_t'\left(D_t \Gamma D_t\right)^{-1}\varepsilon_t, \qquad (3.21)$$

where $L_n(\lambda)$ takes the form of the Gaussian log-likelihood; $\lambda$ denotes the vector of parameters to be estimated and $D_t \Gamma D_t = \varepsilon_t \varepsilon_t' = D_t \eta_t \eta_t' D_t$.

This method requires an assumption about the conditional distribution of the error terms. There are three assumptions commonly employed in the empirical work that adopts the GARCH modelling process: the normal distribution, student's t-distribution, and the generalised error distribution (GED). For this study, one of the attractions to the QMLE is the fact that $\eta_t$ is assumed non-normal which is a prominent feature of long memory time series including those under consideration in this paper.

## 4. Empirical Results and Discussions

### 4.2. Preliminary Analysis

#### 4.2.1. Descriptive and Summary Statistics

First, we find that Gambia whose average interest rates at 27.33 per cent seem relatively higher, particularly when compared to that of Ghana, Guinea and Nigeria, is also the country with the least year-on-year average monthly inflation rates. This though seems consistent with the theoretical assertion of higher interest rate, lower inflation rate nexus; the reverse is rather the case of Guinea, Nigeria and Sierra Leone.

**Table 4.1: Country-by-Country Summary Statistics (Full-Sample Periods)**

| | **Inflation Rates** | | | | |
|---|---|---|---|---|---|
| **Statistics** | **Gambia** | **Ghana** | **Guinea** | **Nigeria** | **Sierra Leone** |
| ***Mean*** | 8.57 | 21.99 | 24.52 | 20.22 | 32.17 |
| ***Std. Dev.*** | 11.23 | 13.16 | 30.91 | 19.16 | 39.07 |
| ***Skewness*** | 3.65 | 1.52 | 1.09 | 1.57 | 1.70 |
| ***Kurtosis*** | 18.08 | 5.64 | 3.17 | 4.68 | 4.88 |
| ***Jarque-Bera*** | 4071. (0.00) | 235.2 (0.00) | 69.41 (0.00) | 183.73 (0.00) | 219.42 (0.00) |
| **Statistics** | **Interest Rates** | | | | |
| | **Gambia** | **Ghana** | **Guinea** | **Nigeria** | **Sierra Leone** |
| ***Mean*** | 27.33 | 24.86 | 15.46 | 19.25 | 28.50 |
| ***Std. Dev.*** | 3.02 | 9.65 | 7.70 | 4.23 | 11.80 |
| ***Skewness*** | 1.70 | 0.75 | -0.38 | 0.86 | 1.98 |
| ***Kurtosis*** | 6.02 | 2.65 | 1.55 | 5.63 | 5.99 |
| ***Jarque-Bera*** | 299.19 (0.00) | 34.17 (0.00) | 38.83 (0.00) | 142.5 (0.00) | 356.1 (0.00) |
| ***No. Observations*** | 348 | 348 | 348 | 348 | 348 |

**Note: the values in parenthesis are the probability values for the Jarque-Bera Statistics**

Secondly, the standard deviations values at 11.23 and 13.16 reveal Gambia and Ghana as the countries whose inflation rates are the least volatile when compared to that of others. This may not be unconnected to the fact that monetary policy in these countries is equally among the least volatile, with Nigeria and Ghana the only countries with the more stable monetary policy given their respective lower interest rates standard deviation values. Thirdly, coefficients of the skewness are positive for the inflation series in all the WAMZ member countries, thus implying the flatness of inflation to the right as against the normal distribution. More so, the non-zero value of the skewness statistic for the interest rate series

also implies the interest rate data, which measure for monetary policy in the context of this study are not normally distributed. Either it is positive for virtually all the countries or it is negative for Guinea. In the case of the kurtosis, the coefficients of excess kurtosis seem evident for inflation series in virtually all the WAMZ member countries. This evidence of leptokurtic which implies that the empirical distributions of the WAMZ inflation samples under consideration have fat tails also hold for the interest rates except for the case of Ghana and Guinea. Confirming the non-zero status of the skewness and the mainly platykurtic nature of the series is the Jarque-Bera normality test whose null of normality was consistently rejected.

A look at the mean statistics shows that the monthly average inflation in the pre-WAMZ period was as high as 40 to 50 per cent for Guinea and Sierra Leone, 28 to 29 per cent for Ghana and Nigeria and 11 per cent for Gambia. However, the quest to fulfil the criteria of single-digit inflation, which is one of the main pre-requisites for joining the WAMZ monetary union, might be responsible for the relative lower inflation rates in the WAMZ member countries since the introduction of monetary union in the zone. For instance, the mean statistics reported for the WAMZ periods in Table 4.3 shows that the monthly average inflation is single-digit for Gambia, Guinea and Sierra Leone. Although the average monthly inflation yet remains double-digit for Ghana and Nigeria even after the introduction of WAMZ, the rates are smaller when compared to the rates of inflation for the periods before the introduction of WAMZ in the year 2000.

Consequently, the standard deviation values of the inflation series are relatively lower for the periods after the introduction of WAMZ, thus suggesting that since the introduction of the monetary union inflation has become less volatile in each of the WAMZ member countries. On the potential of monetary policy shock for the moderation of inflation in the WAMZ economies, the interest rates have been relatively lower and less volatile since the introduction of monetary union compared to the pre-WAMZ periods. Concerning the statistical distribution of the variables, all the series of interests are positively skewed, but interest rate for the case of Sierra Leone's aftermath of the introduction of WAMZ is not. For the statistic of kurtosis, the results are mainly leptokurtic for the inflation series, particularly after the introduction of WAMZ, but mixed for the pre-WAMZ periods. Taking these indications of non-zero skewness and excess kurtosis into consideration, the Jarque-Bera (JB) test for the normality in the distribution of the series, consistently suggests the rejection of the

null of normality for the case inflation across both the period before and after the introduction of monetary union in WAMZ.

**Table 4.2: Country-by-Country Summary Statistics (Pre-WAMZ Periods)**

| Statistics | Inflation Rates | | | | |
|---|---|---|---|---|---|
| | **Gambia** | **Ghana** | **Guinea** | **Nigeria** | **Sierra Leone** |
| ***Mean*** | 11.16 | 28.47 | 47.81 | 29.28 | 58.25 |
| ***Std. Dev.*** | 15.10 | 14.49 | 30.06 | 23.97 | 42.60 |
| ***Skewness*** | 2.62 | 1.14 | 0.14 | 0.57 | 0.90 |
| ***Kurtosis*** | 9.54 | 4.29 | 2.59 | 2.18 | 2.45 |
| ***Jarque-Bera*** | 490.99 (0.00) | 48.29 (0.00) | 1.73 (0.00) | 13.93 (0.00) | 24.56 (0.00) |
| **Statistics** | **Interest Rates** | | | | |
| | **Gambia** | **Ghana** | **Guinea** | **Nigeria** | **Sierra Leone** |
| ***Mean*** | 25.96 | 31.64 | 20.19 | 19.97 | 34.88 |
| ***Std. Dev.*** | 3.03 | 8.75 | 3.54 | 5.26 | 14.33 |
| ***Skewness*** | 2.75 | 0.34 | 0.20 | 0.47 | 0.97 |
| ***Kurtosis*** | 9.86 | 1.82 | 2.27 | 4.28 | 2.70 |
| ***Jarque-Bera*** | 540.61 (0.00) | 13.05 (0.42) | 4.89 (0.08) | 17.57 (0.00) | 27.09 (0.00) |
| ***No. Observations*** | 168 | 168 | 168 | 168 | 168 |

**Note: the values in parenthesis are the probability values for the Jarque-Bera Statistics**

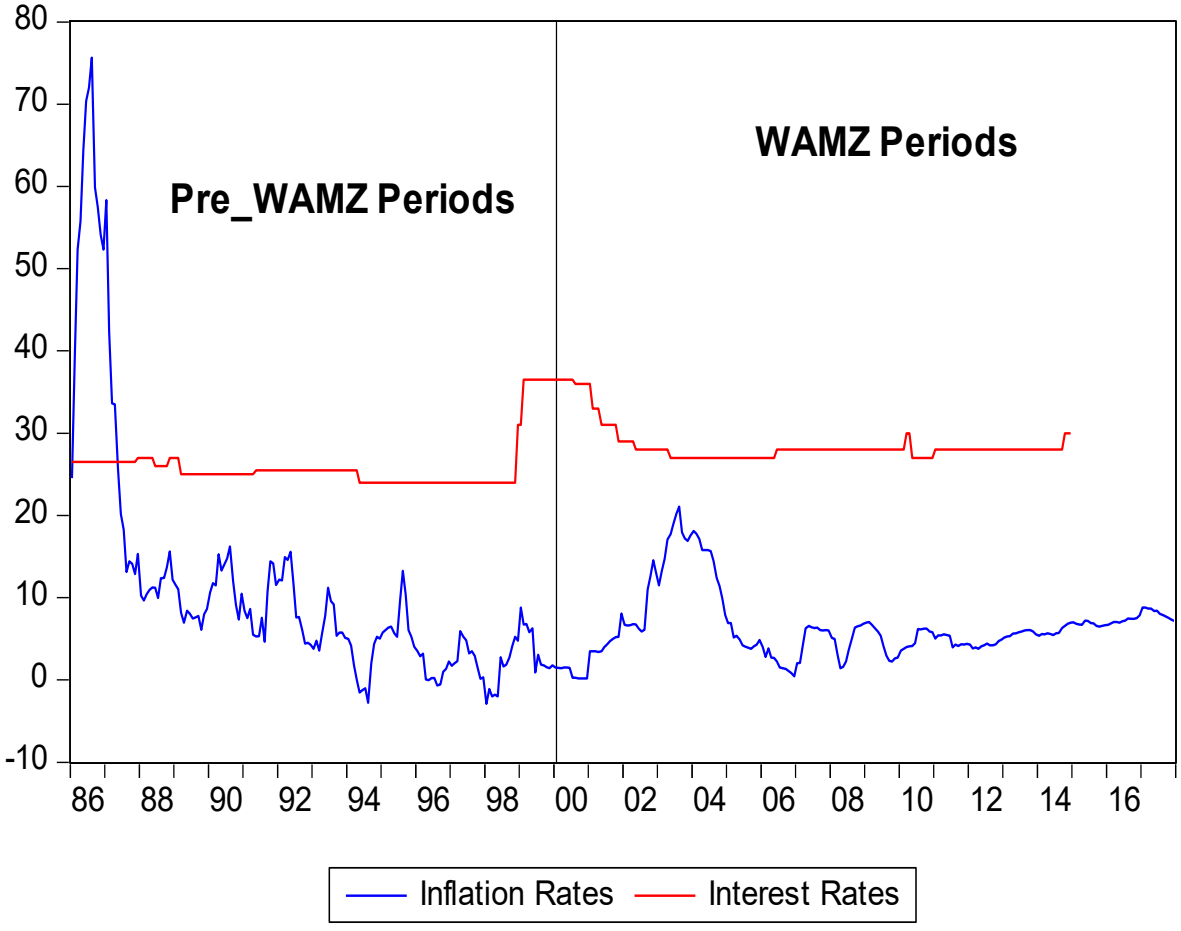
**Table 4.3: Country-by-Country Summary Statistics (WAMZ Periods)**

| Statistics | Inflation Rates | | | | |
|---|---|---|---|---|---|
| | **Gambia** | **Ghana** | **Guinea** | **Nigeria** | **Sierra Leone** |
| ***Mean*** | 6.16 | 15.95 | 2.79 | 11.77 | 7.83 |
| ***Std. Dev.*** | 4.45 | 7.97 | 5.01 | 5.21 | 5.72 |
| ***Skewness*** | 1.56 | 1.53 | 0.66 | 0.39 | -0.32 |
| ***Kurtosis*** | 4.93 | 4.96 | 4.19 | 3.78 | 2.64 |
| ***Jarque-Bera*** | 100.67 (0.00) | 98.94 (0.00) | 23.71 (0.00) | 9.16 (0.01) | 3.99 (0.14) |
| **Statistics** | **Interest Rates** | | | | |
| | **Gambia** | **Ghana** | **Guinea** | **Nigeria** | **Sierra Leone** |
| ***Mean*** | 28.62 | 18.54 | 11.05 | 18.58 | 22.55 |
| ***Std. Dev.*** | 2.39 | 5.07 | 7.92 | 2.83 | 2.10 |
| ***Skewness*** | 2.46 | 0.63 | 0.62 | 1.01 | 0.21 |
| ***Kurtosis*** | 8.02 | 1.97 | 1.47 | 3.77 | 1.91 |
| ***Jarque-Bera*** | 370.27 (0.00) | 20.08 (0.00) | 29.20 (0.00) | 34.88 (0.00) | 10.15 (0.01) |
| ***No. Observations*** | 180 | 180 | 180 | 180 | 180 |

**Note: the values in parenthesis are the probability values for the Jarque-Bera Statistics**

A critical inspection of the Figure shows that there has not been any evidence of co-movement between the country's inflation and the interest rate at least for the period under consideration. Partially, due to the relative stability of inflation in Gambia, monetary policy (interest rate) in the country appears to have been moving within a fixed bound in both the periods before and after the introduction of WAMZ. However, after 1976 where inflation in Gambia seems to have risen to its historical peak for the period under consideration, it has since been trending below 10 per cent, particularly after the introduction of WAMZ in 2000, and except for month of July 2003 where the inflation is as high as 20 per cent, but immediately reverted back to its traditional path.

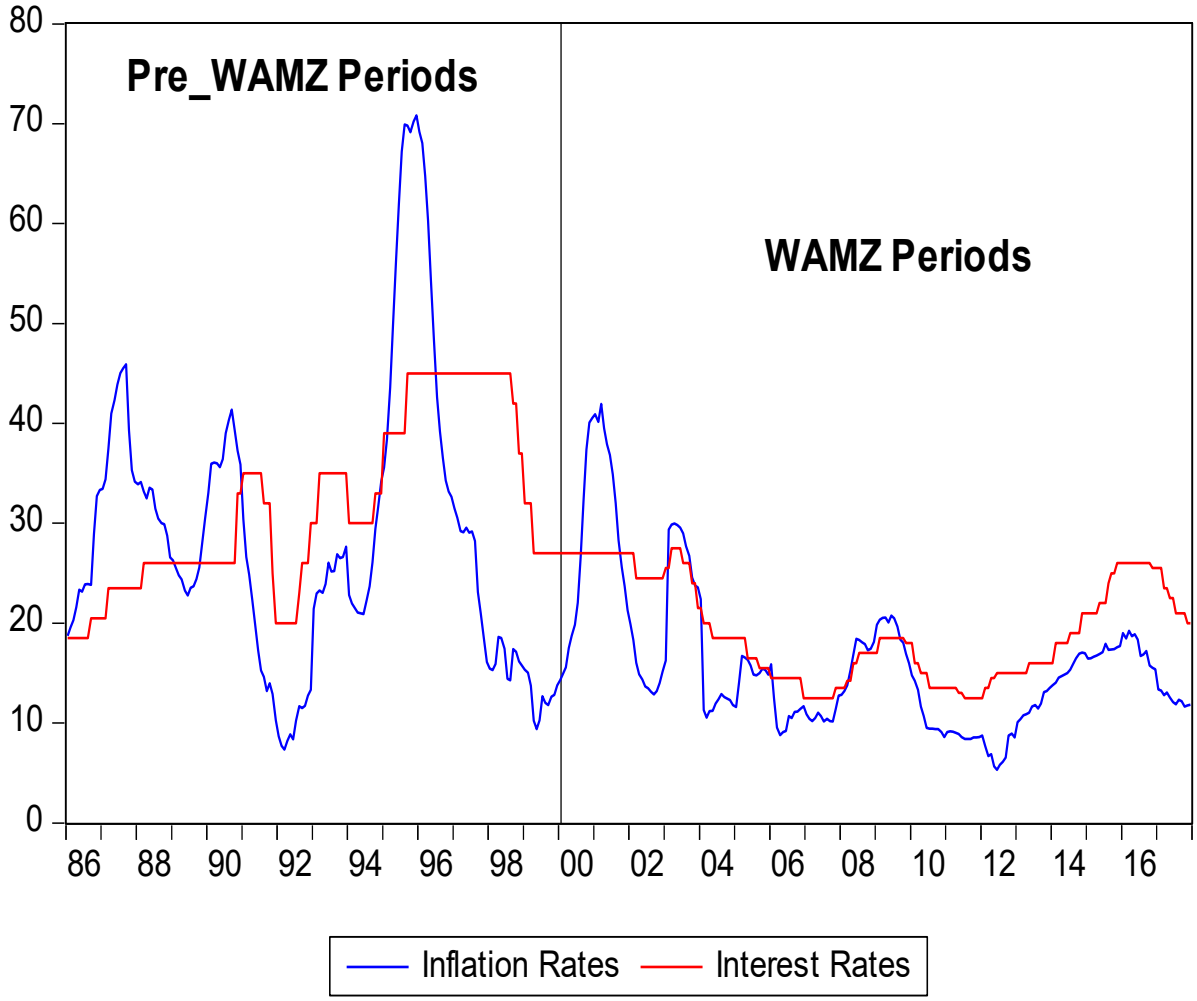
**Figure 1: Gambian Monthly Inflation and Interest Rates (1986M1-2017M12)**




Unlike the case of the Gambia where, as illustrated in Figure 1, we find no indication of co-movement between inflation and interest rates, Figure 2, on the other hand, shows that there have been co-movements between inflation and interest rate in Ghana. This by implication suggests that monetary policy (interest rate) in Ghana has the potential as a tool for moderating inflation in Ghana. However, the indication of the co-movement between

inflation and interest rates appears to be more pronounced in the periods after the introduction of WAMZ. This is an indication that the role of monetary policy for mitigating upward inflationary trend is likely to be more effective when pursued from the perspective of a monetary union such as WAMZ. For instance, a look at Figure 2 below shows that, the few instances such as March 2006 and June 2012 that sees inflation falling to single-digit of 6 per cent and 5 per cent, respectively, were after the introduction of WAMZ.

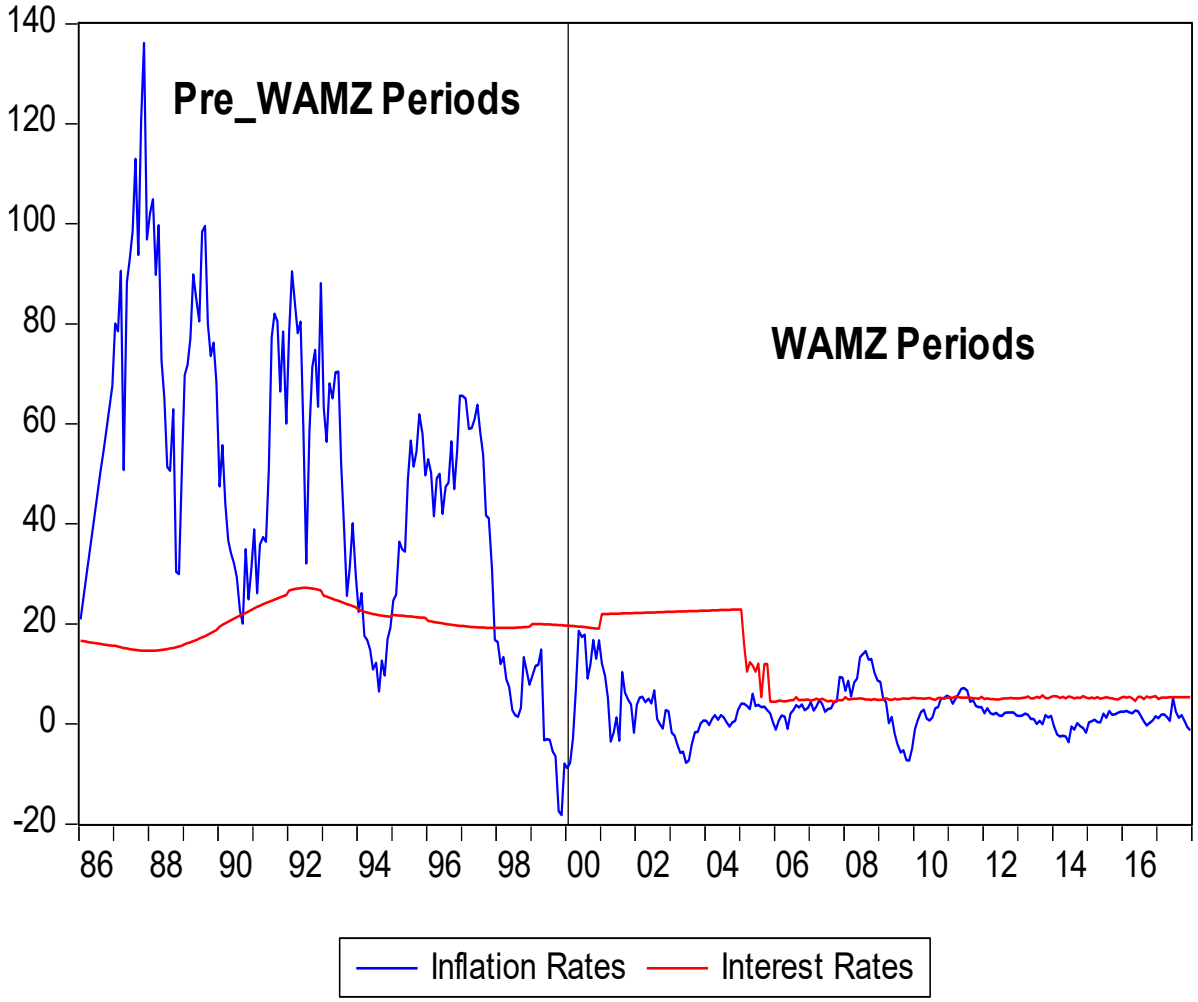
**Figure 2: Ghanian Monthly Inflation and Interest Rates (1986M1-2017M12)**




Plotted in Figure 3 is the visual representation of Guinea inflation and interest rates for the period before and after the introduction of WAMZ. However, a look at the Figure tends to suggest that there has not been any evidence of historical co-movement between the country's inflation and interest rates. For instance, while the period before the introduction of WAMZ appears to be characterised with the upward inflationary trend, the monetary policy (interest rate) on the other is rather fixed even after the introduction of monetary union (WAMZ). What this portends, therefore, is that the relatively lower level of inflation as

depicted in the Figure following the introduction of WAMZ, may not necessarily be because of monetary policy shocks (interest rate), but other macroeconomic fundamentals.

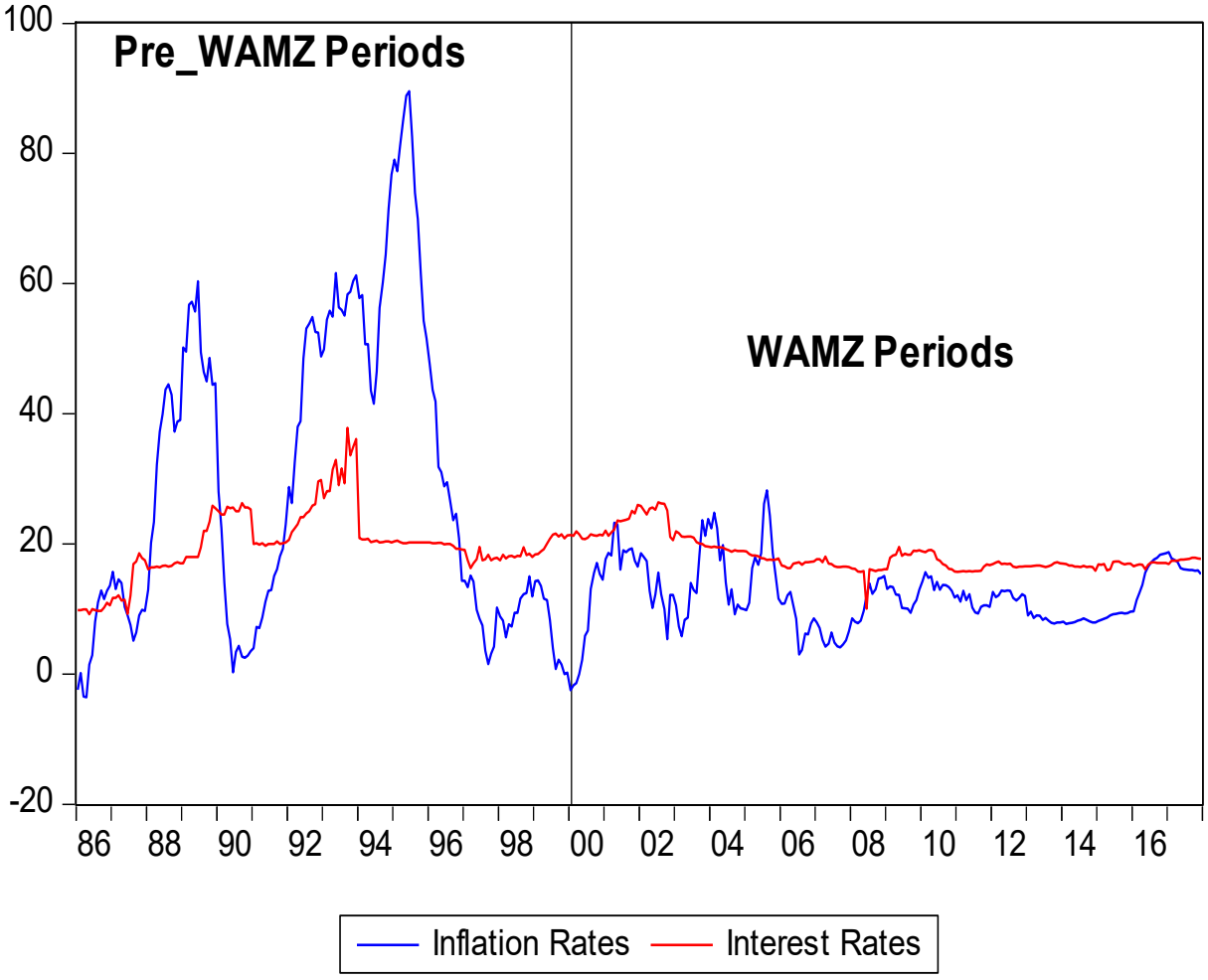
**Figure 3: Guinean Monthly Inflation and Interest Rates (1986M1-2017M12)**




In the case of Nigeria (see Figure 4), the co-movement between inflation and interest rates appears to be more pronounced in the periods after the introduction of WAMZ. That is, while there are several instances in the Figure 4 both in the periods before and after the introduction of WAMZ, upon which some of the historical movements in the Nigerian inflation rate can be attributed to shocks due to monetary policy (interest rates), it must be pointed out in clear term that quite a few such co-movement are mainly evident in the WAMZ periods. More importantly, both inflation and monetary policy (interest rates) in Nigeria appears relatively more stable since the introduction of WAMZ when compared to the period before WAMZ. More so, a look at Figure 4 below suggests that both the inflation

and interest rate in Nigeria have been moving within fixed bound, particularly since the introduction of WAMZ. This though, the recent upward trend in the country's inflation starting from the last quarter of 2015 is rather attributable to the unprecedented decline in the international price of crude oil that lasted between the last quarter of 2015 and early 2017.

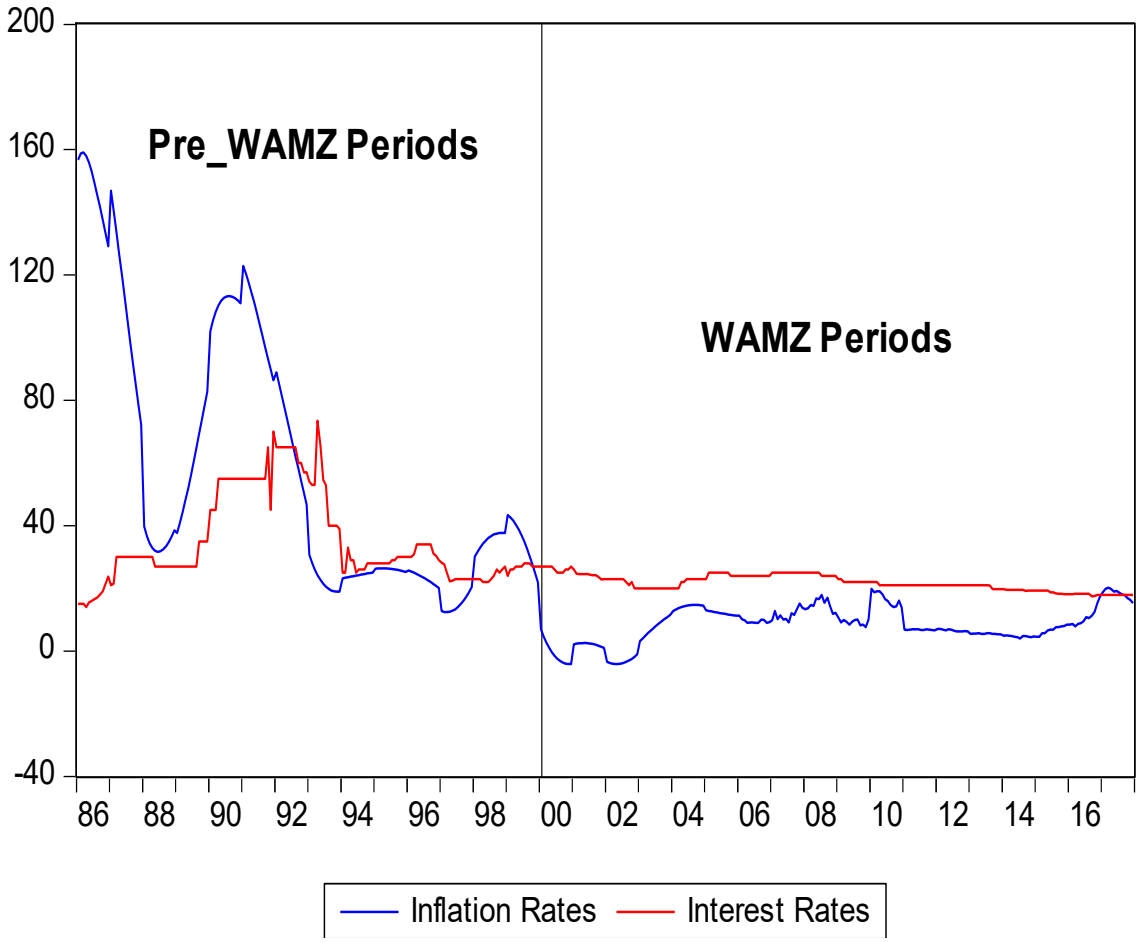
**Figure 4: Nigerian Monthly Inflation and Interest Rates (1986M1-2017M12)**




Except for the periods between 1985 and 1987, where inflation and monetary policy variable (interest rate) appears to be moving in the opposite direction as depicted in Figure 5, in the case of Sierra Leone. The assertions that inflation is a monetary phenomenon seem relatively more evident in the case of Sierra Leone given the level of consistency in the evidence of the historical co-movements between the country's inflation and interest rates. Since late 1988, both the inflation and monetary policy in Sierra Leone have been moving in the same direction. However, while either can cause reaction from the other, we choose to perceive the monetary policy variable (interest rate) as responding to the dynamics of the inflation in efforts to moderate and stabilise prices in the economy. Thus, the pre-WAMZ periods

characterised by high level of inflation have also seen monetary policy variable (interest rate) in Sierra Leone trending in an upward direction over the same period. Consequently, a relative lower inflation rate as experienced in the country since the introduction of WAMZ have also seen monetary policy in the country moving within fixed bound.

**Figure 5: Sierra Leone Monthly Inflation and Interest Rates (1986M1-2017M12)**




### 4.3. Empirical Results and Discussions

### 4.4. Empirical Results from the Conventional Unit Root Tests

We explored some conventional unit root tests to ascertain the order of integration in the variable of interest (inflation), as a basic approach to determine the degree of inflation persistence in the WAMZ economy for the period before and after the introduction of monetary union. Starting with country-by-country (time-series) unit test-based approach, we considered a number of prominent time-series –based unit root tests that includes, the Augmented Dickey-Fuller (ADF) test, its GLS version, Phillps-Perron (PP) unit root test, Ng-

Perron (NP) unit root test and Phillips-Perron and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test. Thus, presented in Table 4.4 is the summary of the unit root test results as obtained from each of these stationarity tests and across the periods before and after the introduction of monetary union in the WAMZ economies.

**Table 4.4(A): Augmented Dickey-Fuller (ADF) Unit Root Test Results**

| WAMZ Countries | Pre-WAMZ Period (1986-1999) | | | WAMZ Period (2000-2017) | | |
|---|---|---|---|---|---|---|
| | ***Level*** | ***First Difference*** | ***I(d)*** | ***Level*** | ***First Difference*** | ***I(d)*** |
| Gambia | -1.4952[a] | -11.0063[a]*** | I(1) | -2.2335[a] | -10.6914[a]*** | I(1) |
| Ghana | -2.3849[b] | -5.5674[b]*** | I(1) | -2.8696[a]** | - | I(0) |
| Guinea | -3.5362[b]** | - | I(0) | -4.6295[b]*** | - | I(0) |
| Nigeria | -2.2868[a] | -5.3248[b]*** | I(1) | -3.7022[b]*** | - | I(0) |
| Sierra Leone | -2.7500[b] | -5.4384[b]*** | I(1) | -1.5263[a] | -13.1894[a]*** | I(1) |
| **Table 4.4(B): Phillips-Perron (PP) Unit Root Test Results** | | | | | | |
| Gambia | -2.7105[b] | -11.0063[a]*** | I(1) | -2.1679[a] | -10.7609[a]*** | I(1) |
| Ghana | -2.1627[b] | -5.4234[b]*** | I(1) | -2.6990[a]* | - | I(0) |
| Guinea | -3.5473[b]** | - | I(0) | -4.9785[b]*** | - | I(0) |
| Nigeria | -1.8784[b] | -9.6775[b]*** | I(1) | -3.9646[a]*** | - | I(0) |
| Sierra Leone | -2.2071[a] | -9.6800[a]*** | I(1) | -2.3902[b] | -13.2864[a]*** | I(1) |
| **Table 4.4(C): Ng-Perron (NP) Unit Root Test Results** | | | | | | |
| Gambia | -1.8368[a] | -1.0007[b] | I(1) | -1.3927[a] | -6.9757[b]*** | I(1) |
| Ghana | -2.2305[b] | -4.7027[b]*** | I(1) | -2.9405[a]*** | - | I(0) |
| Guinea | -1.8739[b]* | - | I(0) | -2.4447[b] | -13.0969[b]*** | I(1) |
| Nigeria | -1.5496[a] | -4.3278[b]*** | I(1) | -1.8261[b] | -7.2591[b]*** | I(1) |
| Sierra Leone | -2.0846[b] | -3.1646[a]*** | I(1) | -1.8182[b] | -4.0799[b]*** | I(1) |
| **Table 4.4(D): Phillips-Perron and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit Root Test** | | | | | | |
| Gambia | 11.1065[a] | 6.6435[b]* | I(1) | 6.6920[a] | 0.2513[a]*** | I(1) |
| Ghana | -4.7027[a] | 0.6057[a]*** | I(1) | 1.4173[a]*** | - | I(0) |
| Guinea | 3.6910[b]* | - | I(0) | 5.4954[a] | 0.0266[b]*** | I(1) |
| Nigeria | 5.5094[a] | 2.4283[b]*** | I(1) | 13.5486[a] | 0.2613[b]*** | I(1) |
| Sierra Leone | 12.5157[a] | 0.8105[a]*** | I(1) | 5.9332[b] | 1.3874[b]*** | I(1) |
| **Table 4.4(E): Dickey-Fuller GLS (DF-GLS) Unit Root Test** | | | | | | |
| Gambia | -1.8710[b] | -1.0936[b] | I(1) | -1.8149[b] | -10.7032[b]*** | I(1) |
| Ghana | -2.2168[b] | -5.5751[b]*** | I(1) | -2.8411[a]*** | - | I(0) |
| Guinea | -1.9144[b]* | - | I(0) | -1.8821[a]* | - | I(0) |
| Nigeria | -1.7716[b] | -5.3021[b]*** | I(1) | -1.8689[a] | -12.9047[b]*** | I(1) |
| Sierra Leone | -1.9941[b] | -3.8511[b]*** | I(1) | -1.8432[b] | -4.6444[b]*** | I(1) |

Note: a Indicates a model with constant but without deterministic trend; b is the model with the constant and deterministic trend as exogenous lags are selected based on Schwarz info criteria. *, **, *** imply that the series is stationary at 1%, 5% and 10% respectively. The null hypothesis for ADF, PP, NP, and DF-GLS is that an observable time series is not stationary (i.e. has unit root) while that of KPSS tests for the null hypothesis is that the series is stationary.

**Table 4.5(A): Panel unit root test results (All WAMZ member countries)**

| Test Method | Pre-WAMZ Periods | | | WAMZ Period | | |
|---|---|---|---|---|---|---|
| | ***Level*** | ***First Diff.*** | ***I(d)*** | ***Level*** | ***First Diff.*** | ***I(d)*** |
| ***Null Hypothesis: unit root with common process*** | | | | | | |
| *Levin, Lin & Chu t** | -0.6323 | -9.8017*** | I(1) | -0.9845 | -16.2189*** | I(1) |
| *Breitung t-stat.* | 0.0992 | 0.5395*** | I(1) | -2.2648** | - | I(0) |
| *Harris-Tzavalis rho* | 0.9700* | - | I(0) | 0.9454*** | - | I(0) |
| ***Null Hypothesis: unit root with the individual unit root process*** | | | | | | |
| *Im, Pesaran & Shin W Stat* | -0.3020 | -16.2908*** | I(1) | -2.7360*** | - | I(0) |
| *ADF Fisher Chi-square* | -4.6827*** | - | I(0) | -5.0501*** | - | I(0) |
| ***Null Hypothesis: no unit root with the common unit root process*** | | | | | | |
| *Hadri Z-stat.* | 99.0039*** | 0.5520 | I(1) | 48.1274*** | -1.1523 | I(1) |

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

Each of the panel unit root tests under considerations was further re-estimated with the gradual omission of each of the WAMZ member countries but one at a time. Starting with the Gambian economy, the panel unit root test results in Table 4.5(B) share little or no significant difference with those presented in Table 4.4(A) despite the omission of Gambia in the WAMZ group. This by implication suggests that lessen Gambia from the group of WAMZ has little or no bearing on the extent to which the effects of shocks to inflation are permanent or transitory. The consistent and robustness of this finding seem evident in the following Tables, when Ghana, Guinea, Nigeria, and Sierra Leone are individually suppressed in the panel unit root tests. This suggests that none of the WAMZ member countries has the potential to constitute an outlier in the extent to which the effects of shocks to inflation are permanent (persistent) or transitory (temporary) in WAMZ.

**Table 4.5(B): Panel unit root test results (All WAMZ less Gambia)**

| Test Method | Pre-WAMZ Periods | | | WAMZ Period | | |
|---|---|---|---|---|---|---|
| | ***Level*** | ***First Diff.*** | ***I(d)*** | ***Level*** | ***First Diff.*** | ***I(d)*** |
| ***Null Hypothesis: unit root with common process*** | | | | | | |
| *Levin, Lin & Chu t** | -0.4013 | -8.2629*** | I(1) | -1.1998 | -14.7203*** | I(1) |
| *Breitung t-stat.* | 0.2764 | -12.1047*** | I(1) | -2.2241** | - | I(0) |
| *Harris-Tzavalis rho* | 0.9697* | - | I(0) | 0.9416*** | - | I(0) |
| ***Null Hypothesis: unit root with the individual unit root process*** | | | | | | |
| *Im, Pesaran & Shin W Stat* | -0.3484 | -14.0715*** | I(1) | -2.9320*** | - | I(0) |
| *ADF Fisher Chi-square* | -2.5995*** | - | I(0) | -4.9756*** | - | I(0) |
| ***Null Hypothesis: no unit root with the common unit root process*** | | | | | | |
| *Hadri Z-stat.* | 87.8969*** | 0.6018 | I(1) | 46.3360*** | -1.0773 | I(1) |

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

**Table 4.5(C): Panel unit root test results (All WAMZ less Ghana)**

| | Pre-WAMZ Periods | | | WAMZ Period | | |
|---|---|---|---|---|---|---|
| **Test Method** | ***Level*** | ***First Diff.*** | ***I(d)*** | ***Level*** | ***First Diff.*** | ***I(d)*** |
| ***Null Hypothesis: unit root with common process*** | | | | | | |
| *Levin, Lin & Chu t** | -0.6670 | -10.0575*** | I(1) | -0.9815 | -15.6453*** | I(1) |
| *Breitung t-stat.* | 0.3431 | -6.0938*** | I(1) | -1.8383** | - | I(0) |
| *Harris-Tzavalis rho* | 0.9689*** | - | I(0) | 0.9287*** | - | I(0) |
| ***Null Hypothesis: unit root with the individual unit root process*** | | | | | | |
| *Im, Pesaran & Shin W Stat* | 0.2377 | -16.0362*** | I(1) | -3.0078*** | - | I(0) |
| *ADF Fisher Chi-square* | -4.0801*** | - | I(0) | -4.4568*** | - | I(0) |
| ***Null Hypothesis: no unit root with the common unit root process*** | | | | | | |
| *Hadri Z-stat.* | 93.1726*** | 0.4150 | I(1) | 26.4749*** | -1.0585 | I(1) |

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

**Table 4.5(D): Panel unit root test results (All WAMZ less Guinea)**

| | Pre-WAMZ Periods | | | WAMZ Period | | |
|---|---|---|---|---|---|---|
| **Test Method** | ***Level*** | ***First Diff.*** | ***I(d)*** | ***Level*** | ***First Diff.*** | ***I(d)*** |
| ***Null Hypothesis: unit root with common process*** | | | | | | |
| *Levin, Lin & Chu t** | -0.7100 | -7.4008*** | I(1) | -0.6292 | -14.2592*** | I(1) |
| *Breitung t-stat.* | 0.3299 | -5.8754*** | I(1) | -1.8868** | - | I(0) |
| *Harris-Tzavalis rho* | 0.9814 | 0.3689*** | I(1) | 0.9613*** | - | I(0) |
| ***Null Hypothesis: unit root with the individual unit root process*** | | | | | | |
| *Im, Pesaran & Shin W Stat* | 0.0878 | -13.2261*** | I(1) | -1.4376* | - | I(0) |
| *ADF Fisher Chi-square* | -4.8225*** | - | I(0) | -4.1959*** | - | I(0) |
| ***Null Hypothesis: no unit root with the common unit root process*** | | | | | | |
| *Hadri Z-stat.* | 91.5693*** | 3.6586 | I(1) | 48.1420*** | -0.8587 | I(1) |

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

**Table 4.5(E): Panel unit root test results (All WAMZ less Nigeria)**

| | Pre-WAMZ Periods | | | WAMZ Period | | |
|---|---|---|---|---|---|---|
| **Test Method** | ***Level*** | ***First Diff.*** | ***I(d)*** | ***Level*** | ***First Diff.*** | ***I(d)*** |
| ***Null Hypothesis: unit root with common process*** | | | | | | |
| *Levin, Lin & Chu t** | -0.9333 | -9.2567*** | I(1) | -0.5296 | -13.6478*** | I(1) |
| *Breitung t-stat.* | 0.3605 | -5.9700*** | I(1) | -2.3276** | - | I(0) |
| *Harris-Tzavalis rho* | 0.9673** | - | I(0) | 0.9543*** | - | I(0) |
| ***Null Hypothesis: unit root with the individual unit root process*** | | | | | | |
| *Im, Pesaran & Shin W Stat* | -0.5570 | -14.6815*** | I(1) | -1.8019** | - | I(0) |
| *ADF Fisher Chi-square* | -4.8978*** | - | I(0) | -3.8753** | - | I(0) |
| ***Null Hypothesis: no unit root with the common unit root process*** | | | | | | |
| *Hadri Z-stat.* | 99.8438*** | 0.0419 | I(1) | 49.9770*** | -1.0830 | I(1) |

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

**Table 4.5(F): Panel unit root test results (All WAMZ less Sierra Leone)**

| Test Method | Pre-WAMZ Periods | | | WAMZ Period | | |
|---|---|---|---|---|---|---|
| | ***Level*** | ***First Diff.*** | ***I(d)*** | ***Level*** | ***First Diff.*** | ***I(d)*** |
| ***Null Hypothesis: unit root with common process*** | | | | | | |
| *Levin, Lin & Chu t** | -0.0477 | -9.1939*** | I(1) | -1.1632 | -14.3862*** | I(1) |
| *Breitung t-stat.* | -1.6402** | - | I(0) | -1.9290* | - | I(0) |
| *Harris-Tzavalis rho* | 0.9602*** | - | I(0) | 0.9367*** | - | I(0) |
| ***Null Hypothesis: unit root with the individual unit root process*** | | | | | | |
| *Im, Pesaran & Shin W Stat* | 0.1809 | -14.8392*** | I(1) | -3.0564*** | - | I(0) |
| *ADF Fisher Chi-square* | -4.5416*** | - | I(0) | -5.0812*** | - | I(0) |
| ***Null Hypothesis: no unit root with the common unit root process*** | | | | | | |
| *Hadri Z-stat.* | 58.2096*** | -0.0955 | I(1) | 39.9638*** | -1.0299 | I(1) |

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% respectively.

**Table 4.6(A): Conditional Heteroscedasticity Test (ARCH LM)**

| WAMZ Countries | Pre-WAMZ Periods | | | WAMZ Periods | | |
|---|---|---|---|---|---|---|
| | $k=2$ | $k=4$ | $k=6$ | $k=2$ | $k=4$ | $k=6$ |
| Gambia | 732.6293*** | 421.0747*** | 411.0742*** | 1422.456*** | 714.1903*** | 478.2286*** |
| Ghana | 5284.199*** | 2602.809*** | 1691.723*** | 2376.543*** | 1250.497*** | 822.2122*** |
| Guinea | 131.0779*** | 79.0132*** | 59.7154*** | 136.7653*** | 76.4545*** | 75.2343*** |
| Nigeria | 1028.720*** | 539.9023*** | 361.3036*** | 184.5158*** | 74.1911*** | 47.7484*** |
| Sierra Leone | 2566.620*** | 1022.263*** | 510.0703*** | 762.999*** | 403.4141*** | 264.1019*** |

**Table 4.6(B): Serial Autocorrelation (Q-stat.)**

| WAMZ Countries | Pre-WAMZ Periods | | | WAMZ Periods | | |
|---|---|---|---|---|---|---|
| | $k=2$ | $k=4$ | $k=6$ | $k=2$ | $k=4$ | $k=6$ |
| Gambia | 310.01*** | 553.98*** | 722.37*** | 402.55*** | 740.19*** | 1015.2*** |
| Ghana | 320.06*** | 585.35*** | 781.02*** | 397.76*** | 708.10*** | 918.00*** |
| Guinea | 267.06*** | 467.03*** | 600.42*** | 264.34*** | 362.17*** | 410.37*** |
| Nigeria | 316.41*** | 582.18*** | 790.44*** | 312.48*** | 482.27*** | 554.27*** |
| Sierra Leone | 317.08*** | 595.08*** | 828.61*** | 422.94*** | 780.25*** | 1067.7*** |

The reported values for the serial correlation are the Ljung-Box Q-statistics and ARCH-LM test F-statistics for the conditional heteroscedasticity test. We consider three different lag lengths (k) of 2, 4 and 6 for robustness purpose. The null hypothesis for the autocorrelation test is that there is no serial correlation, while the null for the ARCH-LM test is that there is no conditional heteroscedasticity. *** indicates significance at 1%.

**Table 4.7(A): Bai-Perron Multiple Structural Breaks for Pre-WAMZ Period**

| WAMZ Countries | $T_1$ | | $T_2$ | | NSB |
|---|---|---|---|---|---|
| | $\sup F_T(\ell \quad \ell)$ | Break Date | $\sup F_T(\ell \quad \ell)$ | Break Date | |
| Gambia | Not applicable | | Not applicable | | 0 |
| Ghana | 21.17 | 1994M02 | 15.70 | 1996M03 | 2 |
| Guinea | Not applicable | | Not applicable | | 0 |
| Nigeria | 15.98 | 1995M07 | Not applicable | | 1 |
| Sierra Leone | 17.42 | 1988M03 | 16.76 | 1991M02 | 2 |

**Table 4.7(B): Bai-Perron Multiple Structural Breaks for WAMZ Period**

| WAMZ Countries | $T_1$ | | $T_2$ | | NSB |
|---|---|---|---|---|---|
| | $\sup F_T(\ell \quad \ell)$ | Break Date | $\sup F_T(\ell \quad \ell)$ | Break Date | |
| Gambia | 16.28 | 2003M09 | Not applicable | | 1 |
| Ghana | Not applicable | | Not applicable | | 0 |
| Guinea | 17.77 | 2003M01 | Not applicable | | 1 |
| Nigeria | Not applicable | | Not applicable | | 0 |
| Sierra Leone | 14.33 | 2003M01 | 13.93 | 2011M01 | 2 |

Note: NSB denotes the number of significant structural breaks. The $\sup F_T(\ell \quad \ell)$ test statistics for the breaks are reported in parentheses. The critical values for $\sup F_T(\ell \quad \ell)$ at 10% level of significance as obtained from the Bai and Perron (2003) paper are 7.04and 8.51 respectively for $\ell$

Thus, contrary to the results of the non-GARCH –based unit root tests both from the perspective of time-series and panel data, where we fail to reject the null hypothesis of unit root particularly in the periods before WAMZ, indication in Table 4.8 shows that we can reject the null hypothesis of unit root when we account for time-varying and structural breaks. We found that except where some of these statistical features do not hold or seem applicable as suggested by the ARCH and Bai-Perron break tests, the non-rejection of a unit root for inflation using the conventional unit root tests might be due to the presence of

heteroscedasticity, time trend, and structural breaks. It may be argued that the unit root test for inflation in WAMZ is better modeled with GARCH process. That is, it may be necessary to pre-test the existence of these statistical features when determining whether the effects of shocks to inflation is permanent (persistent) or transitory (temporary).

**Table 4.8: GARCH –Based Unit Root Test Results**

| WAMZ Countries | Pre-WAMZ Periods | | | WAMZ Period | | |
|---|---|---|---|---|---|---|
| | Cook (2008) | NL (2013) | NL (2015) | Cook (2008) | NL (2013) | NL (2015) |
| Gambia | -4.4482** | Not Applicable | Not Applicable | -7.1943** | -6.4028** | -6.6645** |
| Ghana | -1.9726** | -4.79647** | -3.9020** | -2.0998** | Not Applicable | Not Applicable |
| Guinea | -2.3664** | Not Applicable | Not Applicable | -3.6359** | -3.6710** | -3.5552** |
| Nigeria | -1.3303 | -2.3079** | -3.3495** | -1.5595 | Not Applicable | Not Applicable |
| Sierra Leone | 3.4017** | -4.7439** | -2.6562** | -12.5669*** | -2.7457** | -3.7564** |

Note: ** denotes 5% level of statistical significance. The critical value for the GARCH-based unit root test at the 5% level is computed as 2.87. Since our observations are quite close to those used in NL (2015), we find the average of the computed critical values for 5% level of statistical significance as reported in Table 4.8 for the period before and after the introduction of WAMZ.

### 4.9. Empirical Results from Autoregressive (AR) Model for Inflation Persistence

Table 4.9(A) highlights the results of the AR model for a different number of lags and across the periods before and after the introduction of monetary union in the WAMZ. Although, our finding shows no evidence of perfect persistence, however, the estimated AR coefficients are mostly close to one (1) thus suggesting a high degree of persistence in the inflation of WAMZ member countries. More so, the degree of the persistent is relatively lower for the higher autoregressive process such as 3 & 4 and mainly in the periods after the introduction of monetary union. This portends that the degree of persistence of the effects of shocks to inflation is higher for shocks in the immediate past period say the last one or two months compared to effects of shocks in the last three or four months past periods. Further collaborating our earlier finding is the indication of the relatively lower degree of persistence of shocks to inflation in each of the WAMZ member countries since the introduction of monetary union as against the periods before.

**Table 4.9(A): Country-by-Country Degree of Inflation Persistence Results**

| WAMZ Countries | Pre-WAMZ Periods | | | |
|---|---|---|---|---|
| | *AR(1)* | *AR(2)* | *AR(4)* | *AR(6)* |
| Gambia | 0.9745***[0.0170] | 0.9332***[0.0256] | 0.8121***[0.0372] | 0.6620***[0.0413] |
| Ghana | 0.9890***[0.0123] | 0.9612***[0.0226] | 0.8700***[0.0403] | 0.7418***[0.0551] |
| Guinea | 0.9337***[0.0295] | 0.8935***[0.0386] | 0.7993***[0.0531] | 0.6688***[0.0660] |
| Nigeria | 0.9851***[0.0129] | 0.9611***[0.0213] | 0.8785***[0.0367] | 0.7795***[0.0489] |
| Sierra Leone | 0.9802***[0.0082] | 0.9547***[0.0135] | 0.8896***[0.0230] | 0.8106***[0.0314] |
| **WAMZ Periods** | | | | |
| Gambia | 0.9759***[0.0138] | 0.9394***[0.0222] | 0.8520***[0.0343] | 0.7624***[0.0427] |
| Ghana | 0.9756***[0.0152] | 0.9317***[0.0251] | 0.8063***[0.0411] | 0.6484***[0.0530] |
| Guinea | 0.8488***[0.0345] | 0.7026***[0.0465] | 0.4005***[0.0610] | 0.2940***[0.0601] |
| Nigeria | 0.9018***[0.0265] | 0.7872***[0.0386] | 0.5682***[0.0511] | 0.3442***[0.0593] |
| Sierra Leone | 0.9758***[0.0158] | 0.9448***[0.0237] | 0.8651***[0.0361] | 0.7757***[0.0451] |

This table reports the persistence test results which is conducted by regressing a first-order autoregressive process for example: $\pi_t = \alpha + \rho\pi_{t-1} + \upsilon_t$ using the OLS estimator. The first order autocorrelation coefficient $(\rho)$ captures the persistence effect and is reported in Table 4.9 for each of the WAMZ countries, and across the periods before and after the introduction of WAMZ. The null is that there is the presence of persistence effect if $\rho$ is statistically significant and the closer the value to one the higher the degree of persistence.

The result of the half-life adjusted process in Table 4.9(B) for each of the WAMZ member countries indicates Guinea as the country with the higher estimated speed of convergence aftermath of a shock to inflation irrespective of the lag of AR process or sample period. For instance, a shock to inflation following an AR(1) before the introduction of WAMZ may take as much as 62, 46, 34 and 26 months to fizzle out in Ghana, Nigeria, and Sierra Leone, but ten months in the case of Guinea. Although the return of inflation to its equilibrium appears to be faster for each of the WAMZ member countries when shocks to their respective inflation are captured via higher order of AR process, the speed of the reversibility is yet relatively the faster for the Guinea economy.

**Table 4.9(B): Country-by-Country Half-Life (HL) Results**

| WAMZ Countries | Pre-WAMZ Periods | | | |
|---|---|---|---|---|
| | *AR(1)* | *AR(2)* | *AR(4)* | *AR(6)* |
| Gambia | 26.8 | 10.0 | 3.3 | 1.7 |
| Ghana | 62.7 | 17.5 | 5.0 | 2.3 |
| Guinea | 10.1 | 6.2 | 3.1 | 1.7 |
| Nigeria | 46.2 | 17.5 | 5.4 | 2.8 |
| Sierra Leone | 34.7 | 15.0 | 5.9 | 3.3 |
| **WAMZ Periods** | | | | |
| Gambia | 28.4 | 11.1 | 4.3 | 2.6 |
| Ghana | 28.1 | 9.8 | 3.2 | 1.6 |
| Guinea | 4.2 | 2.0 | 0.8 | 0.6 |
| Nigeria | 6.7 | 2.9 | 1.2 | 0.6 |
| Sierra Leone | 28.3 | 12.2 | 4.8 | 2.7 |

Note: The Half-Life (HL) is computed as $\mathrm{Ln}(0.5)/\mathrm{Ln}(\rho)$

The half-life statistics are relatively lower since the introduction of the monetary union except for the Ghana economy, where the reverse appears to be the case. This may not be unconnected to the desire of each of the WANZ member countries to achieve single digit inflation, which has been the main criterion for joining the union. However, as we have some different estimated AR coefficients for the inflation of each of the WAMZ member countries across different lag orders and periods before and after the introduction of monetary union, it thus becomes a matter of necessity to pool the value as a representative of the whole group.

**Table 4.10(A): Panel Data Results for Degree of Inflation Persistence**

| WAMZ Group | Pre-WAMZ Period | | | |
|---|---|---|---|---|
| | ***AR(1)*** | ***AR(2)*** | ***AR(4)*** | ***AR(6)*** |
| Full-Panel | 0.9746***[0.0065] | 0.9498***[0.0092] | 0.8873***[0.0137] | 0.8113***[0.0177] |
| Less Gambia | 0.9708***[0.0078] | 0.9428***[0.0110] | 0.8716***[0.0164] | 0.7838***[0.0212] |
| Less Ghana | 0.9740***[0.0074] | 0.9494***[0.0103] | 0.8883***[0.0152] | 0.8143***[0.0195] |
| Less Guinea | 0.9821***[0.0044] | 0.9590***[0.0072] | 0.8987***[0.0122] | 0.8278***[0.0164] |
| Less Nigeria | 0.9734***[0.0074] | 0.9487***[0.0103] | 0.8892***[0.0150] | 0.8163***[0.0192] |
| Less Sierra Leone | 0.9705***[0.0097] | 0.9458***[0.0133] | 0.8803***[0.0194] | 0.7966***[0.0245] |
| **WAMZ Periods** | | | | |
| Full-Panel | 0.9672***[0.0073] | 0.9273***[0.0109] | 0.8374***[0.0162] | 0.7572***[0.0195] |
| Less Gambia | 0.9652***[0.0084] | 0.9232***[0.0125] | 0.8295***[0.0186] | 0.7473***[0.0223] |
| Less Ghana | 0.9536***[0.0099] | 0.9018***[0.0143] | 0.7939***[0.0206] | 0.7141***[0.0239] |
| Less Guinea | 0.9716***[0.0076] | 0.9325***[0.0117] | 0.8394***[0.0178] | 0.7329***[0.0225] |
| Less Nigeria | 0.9723***[0.0076] | 0.9383***[0.0113] | 0.8574***[0.0178] | 0.7886***[0.0206] |
| Less Sierra Leone | 0.9659***[0.0082] | 0.9246***[0.0123] | 0.8333***[0.0178] | 0.7548***[0.0218] |

This table reports the panel persistence test results conducted by regressing a first-order autoregressive process for example: $\pi_{it} = \alpha_i + \rho\pi_{it-1} + \upsilon_{it}$ using OLS estimator. The first order autocorrelation coefficient $(\rho)$ captures the persistence effect and is reported in Table 4.9(B) for each of the various categorised WAMZ panel groups, and across the periods before and after the introduction of WAMZ. The null is that there is the presence of persistence effect if $\rho$ is statistically significant and the closer the value to one the higher the degree of persistence.

Table 10(A) shows that similar to the results obtained from the country-by-country analysis of the degree of persistence of the effects of shocks to inflation, the estimated AR coefficients are equally close to one(1) even after pooling the member countries as a group. This which suggests a high degree of persistence in the inflation of WAMZ seems to be consistent and robust to the various panel groups under consideration, irrespective of the period before and after WAMZ and as well as across the different lag numbers considered. On whether lessen each of the member countries from the group of WAMZ had any bearing on the degree of the persistence of effects of the shocks to inflation when we pooled the countries as a group, the half-life statistic in Table 10(B) seems to suggest it does. Before the introduction of WAMZ for example, the HL results show that the tendency of inflation to return to its equilibrium state after a shock to it may

require a lower number of period (i.e. the number of months), when the Gambia and Sierra Leone are omitted from the group of WAMZ, respectively. This suggests that the portion of the effects of shocks to inflation traceable to these countries may take longer periods to fizzle out. Thus, making them the potential accelerator of inflation persistence relative to other member countries.

On the contrary, lessen Guinea from the group of WAMZ tends to elongate the number months it might require for inflation to revert to its equilibrium, therefore, portraying Guinea potential neutraliser of inflation persistence in the group. Re-affirming the consistency of this finding is HL results aftermath of the introduction of monetary union, which yet shows that lessen Guinea tends to increase the periods it will take inflation in WAMZ to revert to equilibrium after a shock to it. For example, while it may take 20 months for inflation in the WAMZ era to return to its equilibrium when Guinea is part of the group, it may take as much as 24 months to recover from the same shocks if Guinea is not part of the Group. This again proves that Guinea has the potential to neutralise persistence in inflation and while the same can also be true of Nigeria, it must be pointed out that it was only after the introduction of WAMZ thus making Guinea the most consistent in that regard.

**Table 4.10(B): Panel Data Half-Life (HL) Results**

| WAMZ Group | Pre-WAMZ Period | | | |
|---|---|---|---|---|
| | ***AR(1)*** | ***AR(2)*** | ***AR(4)*** | ***AR(6)*** |
| Full-Panel | 26.9 | 13.5 | 5.8 | 3.3 |
| Less Gambia | 23.4 | 11.8 | 5.0 | 2.8 |
| Less Ghana | 26.3 | 13.3 | 5.9 | 3.4 |
| Less Guinea | 38.4 | 16.6 | 6.5 | 3.7 |
| Less Nigeria | 25.7 | 13.2 | 5.9 | 3.4 |
| Less Sierra Leone | 23.1 | 12.4 | 5.4 | 3.0 |
| **WAMZ Periods** | | | | |
| Full-Panel | 20.8 | 9.2 | 3.9 | 2.5 |
| Less Gambia | 19.6 | 8.7 | 3.7 | 2.4 |
| Less Ghana | 14.6 | 6.7 | 3.0 | 2.1 |
| Less Guinea | 24.1 | 9.9 | 4.0 | 2.2 |
| Less Nigeria | 24.7 | 10.9 | 4.5 | 2.9 |
| Less Sierra Leone | 20.0 | 8.8 | 3.8 | 2.5 |

Note: The Half-Life (HL) is computed as $\mathrm{Ln}(0.5)/\mathrm{Ln}(\rho)$

## 4.10. Empirical Results from VARMA-DCC-GARCH Model

Tables 4.11(A&B) reports the estimated coefficients as obtained from the VARMA-DCC-GARCH model. The significance of the DCC coefficient as evident in both the period before and after the introduction of WAMZ tends to stress our hypothesis, that assuming constant persistence in the estimate of shocks to inflation is likely to cause bias on the estimate. Hence, the justification for our choice of estimation technique. Starting with the periods before the introduction of monetary union, the empirical results in Table 4.11(A) show that when monetary policy shocks are captured, the degree of the persistent of the effects of the shocks are likely to be higher at least in the short run except for the case of Gambia. In the long run, the degree of the persistence of the effects of both the inflation own shocks and monetary policy shocks are relatively lower and substantially less than Ghana, Nigeria and Sierra Leone.

**Table 4.11(A): VARMA-DCC-GARCH Results for Pre-WAMZ Periods**

| Variables | Gambia | Ghana | Guinea | Nigeria | Sierra Leone |
|---|---|---|---|---|---|
| | | | | | |
| $c_1$ | 1.5381(0.0890)* | 1.2231(0.6237)* | 12.2461(0.0197)* | -0.3011(0.0146)* | 0.1641(0.0006)* |
| $\alpha_{11}$ | 0.2304(0.0133)* | 1.0417(0.0045)* | 0.2361(0.0003)* | 1.1240(0.0319)* | 3.2430(0.0473)* |
| $\alpha_{12}$ | 0.2364(0.2364)* | -0.0108(0.0040)* | -3.6673(0.0115)* | 0.3894(0.0417)* | -0.0506(0.0037)* |
| $\beta_{11}$ | 0.5039(0.0100)* | 0.0761(0.0041)* | 0.8574(0.0002)* | 0.3063(0.0156)* | -0.0011(0.0001) |
| $\beta_{12}$ | -2.2341(0.0938)* | 0.0267(0.4103)* | 1.4156(0.0014)* | -0.1094(0.0323)* | 0.0109(0.0001) |
| Short-Run Persistence $\alpha_{11}+\alpha_{12}$ | **0.4668** | **1.0309** | **-3.4312** | **1.5134** | **3.1924** |
| Long-Run Persistence $\beta_{11}+\beta_{12}$ | **-1.7302** | **0.1028** | **2.273** | **0.1969** | **0.0098** |
| DCC | 0.3508(0.0222)* | 0.7462*(0.0008) | 0.1577(0.0359)* | 0.0282(0.0001)* | 0.6905(0.0001)* |

Note: a denote statistical significance at 5% while figures in parentheses represent standard errors.

However, unlike the periods before the introduction of monetary union, the empirical estimates reported in Table 4.11(B) show that the degree of persistence of the effects of shocks to inflation has been relatively low since the introduction of WAMZ. With the exception of Sierra Leone where the degree of inflation persistence is as high as 1.2 and 8.6 in both the short and long run situations, the degree of the persistence of the effects of shocks to inflation has been substantially less than one (1) for the rest of the WAMZ member countries both in the short and long run situations. This by implications tends to suggest that

the role of monetary policy for moderating the effect of shocks to inflation seem to be more effective since the introduction of monetary union as against the periods before WAMZ.

**Table 4.11(B): VARMA-DCC-GARCH Results for WAMZ Periods**

| Variables | Gambia | Ghana | Guinea | Nigeria | Sierra Leone |
|---|---|---|---|---|---|
| $c_1$ | 0.6450(0.0212)* | 0.4422(0.0001)* | 6.4292(0.0092)* | 0.0401(0.0000)* | -0.0514(0.0040)* |
| $\alpha_{11}$ | 0.5666(0.2397)* | 0.9207(0.0001)* | 0.6970(0.0074)* | 0.1313(0.0000)* | 1.4824(0.0107)* |
| $\alpha_{12}$ | -0.0846(0.0209)* | -1.1602(0.0001)* | 0.0083(0.1671) | 0.0410(0.0001)* | -0.2644(1.6269) |
| $\beta_{11}$ | -0.0503(0.0293) | 0.0018(0.0000)* | -0.1039(0.0011)* | 0.8795(0.0000)* | -0.0352(0.0001)* |
| $\beta_{12}$ | -0.0415(0.0182)* | -0.2852(0.0008)* | -0.0324(1.9349) | -0.5924(0.0001) | -8.6114(0.0159)* |
| Short-Run Persistence $\alpha_{11}+\alpha_{12}$ | **0.482** | **-0.2395** | **0.7053** | **0.1723** | **1.218** |
| Long-Run Persistence $\beta_{11}+\beta_{12}$ | **-0.0918** | **-0.2834** | **-0.1363** | **0.2871** | **-8.6466** |
| DCC | 0.7729(0.0000)* | 0.6467(0.0000)* | 0.2520(0.0064)* | 0.0396(0.0000)* | 0.2129(0.0009) |

Note: a denote statistical significance at 5% while figures in parentheses represent standard errors.

## 5. Conclusion and Recommendations

### 5.1 Conclusion

Empirically, the degree of persistence tends to decline with the introduction of monetary union in WAMZ, but the rate of the declines seems relative more evident when we control for conditional time-varying, and monetary policy shocks thus making the multivariate GARCH –based model for analysing inflation persistent. The paper infers that the level of inflation persistence is important in economic analyses, but also question whether the persistence varies over time for the role of monetary policy shocks in a monetary union framework. More importantly, a shock to inflation is likely to have different implications for each WMAZ member countries given the differences in the length of the half-life of shocks. The monetary policy in each country yet has the potential for neutralising the persistence of effects shocks to inflation at least in the long-run.

### 5.2 Policy Recommendations

Premised on our finding of a potential link between monetary policy and the degree of inflation persistence, it recommends continued monetary support for those WAMZ member countries that yet exhibit a higher proclivity for higher inflation persistence even after the introduction of monetary union. However, monetary authorities of these WAMZ countries should less costly implement disinflation policies and be able to avoid excessive interfering targets if they take cognisance of the time-varying property of the variable of interest and the source of a structural shift in their analysis of the degree persistence of shocks to inflation. Since inflation in WAMZ is found as stationary around a broken trend, any disinflation monetary policy that is informed by evidence based on models that ignore breaks and conditional time-varying in the trend path of inflation in WAMZ may not be able to avoid the wasted costs of interference. This among others constitutes an important way to respond to policy questions such as how monetary policy should be set optimally when the structure of an economy exhibits inflation persistence and unit root hysteresis which is important source of convergence dis-functioning.

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