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, the study explores both the conventional and conditional time-varying unit root tests to understand the extent to which monetary union matters in the degree of inflation persistence. Empirically, we find the degree of inflation persistence to have been relatively lower since the advent of monetary union in WAMZ when compared to the period before. The significance of this finding is particularly evident when the time-varying property of the persistence is captured. It is also observed that a monetary policy shock has the potential to neutralise the persistence of shocks to inflation at least in the long run, particularly when the time-varying property of the inflation series is captured.

Keywords: Inflation, Synchronization, Monetary Policy, Shocks, Multivariate GARCH Model.

JEL Code: E31, E32, E44, E52, E58, E61.

1. Introduction

The primary objective of monetary policy anywhere in the world is to keep prices of goods and services at rates that would not be a detriment to the economic system. Thus, the pursuance, as well as the attainment of price stability, remains significant for the wellbeing of every economy either developed or developing. It is, therefore, a matter of necessity to be too observant of any potential hindrance to the attainment of the price stability, prominent among which is inflation persistence. For instance, the higher the degree of inflation persistence, the more the public is likely to view the central bank as not credible in their mandate to maintain price stability. That is, the public may only perceive the central bank's mandate to maintain price stability as credible when there is an incentive for them to view the resulting increase in inflation as temporary rather than permanent. In the absence of such an incentive, the output cost associated with the implementation of say, a disinflation policy is, however, likely to be more challenging, particularly in the context of a monetary union.

Entry into the monetary union, for example, have been conditioned on certain standard criteria, the prominent been the attainment of single-digit inflation. Following the example of European Monetary Union (EMU), the objective to set up the West African Monetary Union (WAMZ) and a common or single currency (the Eco) was to accelerate the actualization of monetary integration among the English-speaking countries in the Economic Community of West Africa (ECOWAS). It is expected that each member states in WAMZ will as a matter of principle commit to the goal of the single currency in order to narrow down the degree of divergence in the inflation of the member countries. What is, however, observable since the advent of the monetary union in WAMZ is the fact that the converge criteria of single-digit inflation appears to be far from met. As shown in Table 1, the average annual inflation rate in WAMZ has continued to linger around the double-digit figure both in the period before and after the introduction of the monetary union. Notable exceptions in this regard include the case of Gambia and Sierra Leone, where average inflation has been single-digit, particularly since the introduction of the monetary union.

Deducible from the depicted stylized facts in table 1 is the perpetual inflation differential among the WAMZ member countries, hence the probability of divergence in the degree of inflation persistence across the member countries. To put it differently, monetary authorities operating in the context of monetary union are likely to be confronted with the complex task of designing monetary policy for diverse or conflicting economic environments. The more the likelihood of differential or asymmetric in the monetary policy response to shocks to inflation in the individual member states in a monetary union, the more the probability of varying degrees of inflation persistence and the greater would be the risk to the stability of the monetary union. It is in this light, among others, that we consider the West Africa Monetary Zone (WAMZ), therefore, seems a natural experiment to investigate the extent to which monetary union accelerates or reduces the persistence of inflation.

Table: 1: Annual Average Inflationary Trends in the WAMZ Member States

Member States	**Pre-WAMZ Period**						
	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 extensive literature on the dynamics and persistence of inflation (see for example, Lee, 2005; Amano, 2007; Cuestas & Harrison, 2010; Hassler & Meller, 2014; Antonakakis et al., 2016; Caranella & 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 including Edwards, 2006; Meller & Nautz, 2009; and Coleman, 2010, have all focused on EMU as their case study. Thus, our choice of WAMZ as the case study for this study is to make an addition to the literature on inflation persistence, but from the perspective of a group of countries that appears to be determined to form a monetary union. Besides, limited studies on inflation persistence and monetary union, particularly in the context of developing economies further motivates this study. By focusing on “the West African Monetary Zone (WAMZ)”, this study would be essentially contributing to the literature in the following folds: First, the study sets out to find out whether inflation rates will 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 targeted single-digit inflation, particularly since the decision to form the monetary union is not pre-informed by any rigorous evidence-based research. Secondly, while understanding the level of inflation persistence across the individual members in WAMZ matters for successful monetary integration, assuming constant persistence across business cycle phases, particularly where their inherent feature of time-varying in the inflation series might bias the estimate of inflation persistence and consequently misguided 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.

Although, we acknowledge that Alagidede et al. (2012) have also used the case WAMZ to examine inflation persistence in the context of monetary union, however, their study and some of those before it (see for example, Levine & Piger, 2004; Cogley & Sargent, 2005) mainly follow the conventional approach to estimate inflation persistence via the white noise autoregressive (AR) model. It is instructive to understand the fact that there are other specific effects that have shown to matter for explaining the dynamic of inflation and inflation persistence. The third contribution of this study is, therefore, to explores a more robust and explicit multivariate approach to investigate the extent to which shocks due to monetary policy other than the past value of inflation value matters for the degree of inflation persistence. To achieve this, we extend the conventional univariate (AR) model to a multivariate approach to estimating inflation persistence in order to capture the role of monetary policy shocks in the addition to the time-varying property of the inflation variable using a Multivariate Generalized Autoregressive Conditional Heteroscedasticity (MGARCH) model.

In addition to this introductory section, the remaining of the paper is sectionalized as follows: Section two reviews the empirical findings of previous related studies. Section three presents the methodology. Section four present and discuss the results, while section five concludes the study and offers some recommendations.

2. Brief Literature Review

Notwithstanding the vastness of empirical literature on the persistence of inflation both from the perspectives of univariate and multivariate modelling approaches (see, for example, Arize & Malindretos, 2012; Zhou, 2013; Chang et al., 2013; Machado & Portuga, 2014; Phiri, 2016; Antonakakis et al., 2016; Bolat et al., 2017; Lovcha & Perez-Laborda, 2017), among others, there has been little or no attention accord the role of monetary union in their investigation of inflation persistence. Even the few notable exceptions in this regard limited their focus to the case of the European Monetary Union (EMU). Meller and Nautz (2009) for example, investigate the extent to which monetary integration such as EMU enhance the effectiveness of monetary policy to reduce the degree of inflation persistence. In addition to their findings of considerable differences in the dynamic of inflation prior to the introduction of the monetary union across the Euro area, the study also attributes their findings of a significant decline in the persistence of inflation to the adoption of monetary integration in the Euro area. For the case of the monetary union in the Caribbean, Cuestas and Dobson (2011), employ different time series methods to investigate the inflation rate of the member countries. Their empirical results suggest that shocks to inflation are not permanent but temporary. Similar to the case of EMU, the study attribute their findings of a mean reverting the process of inflation to the quest to fulfil the convergent criteria of single-digit inflation among the member countries in the investigated monetary union.

In his evaluation of the determinants of inflation differentials in a panel, WAMZ states vis-à-vis the benchmark set for macroeconomic convergence, Balogun (2010) explore a stylized 5-country model to analyse the difference in the inflation of WAMZ member countries in the light of their specific monetary shocks. Finding from the study shows that despite the proposed monetary integration, price stabilization around the set target of single-digit inflation is still far from being a reality despite the advent of proposed monetary policy integration. Overall and to the best of our knowledge, Alagidede et al. (2010) seem the only study closer to this study. But, unlike Alagidede et al. (2010) that mainly focus on the long term-term sustainability of monetary union, the present study is extending the argument to include the extent to which the degree of inflation persistence vary 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 an MGARCH modelling approach with the potential to address the time-varying property of inflation.

3. Methodology

3.1 The model

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

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

where π denotes inflation at time t and ε is the residual uncorrelated series. To measure persistence, equation (1) can be re-parameterised as follows:

$$\Delta\pi = \alpha + \sum_{j=1}^{k-1} \delta_j \Delta\pi_{t-j} + (\rho - 1)\pi_{t-1} + \varepsilon_t \qquad (2)$$

where $\rho = \sum_{j=1}^{k} \beta_j$ is the persistence parameter, while $\delta_{j=1} = -\sum_{i+1+j}^{k} \beta_i$ is the transformation of the AR coefficients in equation (1).

In the context of equation (1), inflation persistence can be defined as the speed at which inflation converges to equilibrium after a shock in the disturbance term. For robustness purposes, 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 that drive inflation may bias the results by amplifying the impact of inflation persistence. Thus, the multivariate version of the inflation persistence framework in equation (1) can be represented as below.

$$\pi = \alpha + \sum_{j=1}^{k} \beta_j \pi_{t-j} + \sum_{n=0}^{N} \lambda_n X_{t-n} + \varepsilon_t \qquad (3)$$

where λ is a vector of the coefficient on explanatory variables (lagged n times), β is coefficient on the past value of inflation (π_{t-j}), while X is a matrix of explanatory variables, which in the context of this study will be represented as monetary policy shocks in each of the WAMZ member states?

3.2 Estimation technique

The simplest econometric technique to estimate the univariate model in equation (1) has been the unit root testing approach to determining the degree of inflation persistence. For robustness and completeness purposes, we consider a number of conventional unit root tests both from the perspective of time series and panel data specifications. There is, however, a growing concern regarding the accuracy of the traditional unit root tests to modelling inflation persistence. To circumvent some of these concerns, we complement the traditional unit root models with a GARCH-based unit root test (see Naranya and Liu, 2015 for detail on the specification of GARCH-based unit root test). This allows us to account for structural shift and potential time-varying property of the inflation series. However, both the traditional and GARCH-based unit root follows a univariate-modelling framework, to capture the extent to which shocks to monetary policy accelerate or reduce the degree of inflation persistent, the univariate GARCH model is further extended to a multivariate GARCH model. The MGARCH model[1] is though not a unit root test, it is, however, an all-encompassing that enables us to capture the potential time-varying property of the persistence and yet account for the role of monetary policy shocks in the evaluation of inflation persistence.

3.3 Data and preliminary analysis

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 utilized as a measure for their respective monetary policy shocks. Using a monthly data frequency, all the variables of interest are sourced from the Central Bank database of the respective WAMZ member countries. The data scope will be portioned into the period before and after the introduction of monetary union ranging from 1980 to 1999 and 2000 to 2017, respectively.

Presented in Table 2 is the summary statistic to include the mean, the standard deviation, kurtosis, skewness, and the Jaque-Bera for the variables under consideration. We observe that the mean value for Sierra Leone and Gambia interest rates are 28.50% and 27.33%, respectively, making them the countries with the highest average monthly interest rates. Guinea follows by Nigeria are the countries with the least average interest rate when compared to the mean value of the interest of other WAMZ countries under consideration. Consistent with the theoretical assertion of higher interest rate-lower inflation rates nexus is the case of the Gambia, which is the only country with the average single-digit inflation rate. Sierra Leone appears to be the most inflationary economy given its average monthly inflation rate of 32.17 as against 20.22%, 21.99% and 24.50% for Nigeria, Ghana and Guinea, respectively. Consequently, both Gambia and Ghana are the countries whose inflation has the least standard deviation statistic making the countries whose inflation rates are relatively the less volatile when compare to that

[1] See the appendix section for detail specification of the estimated MGARCH model

of other countries. In addition to Nigeria, Ghana and Gambia are also the countries with the least volatile interest rates.

Table 2: Summary Statistics

Statistics	Inflation Rates				
	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

A further look at table 2 shows that the skewness is positive for the inflation series in all of the WAMZ member countries, thus implying the flatness of inflation to the right. The skewness statistic is also non-zero for the interest rate series, but while it is positive for virtually all the countries, 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 values of the skewness and the mainly platykurtic nature of the series is the Jarque-Bera normality test whose null of normality was consistently rejected.

4. Empirical Results

4.1 Results based on the conventional unit root tests

As a basic approach to estimating inflation persistence, we consider a number of alternative time-series unit root tests such as Augmented Dickey-Fuller (ADF) unit root test, the DF-GLS unit root test, the Ng and Perron (Ng-P) unit root test, the Phillps and Perron (NP) unit root test as well as the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test. Presented in Table 3 is the summary representation of the unit root test for the periods before and after the introduction of monetary union.

Table 3(A): 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 3(B): 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 3(C): Ng-P 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 3(D): KPSS stationarity test results						
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: the term *a* denote a model with constant only, *b* indicate a model with both constant and trend, while the exogenous lags are determine using Schwarz info criteria. ***, ** and * suggest that a series is stationary at 1%, 5% or 10% levels of significance.

Starting with the ADF test results in Table 3(A), we find that prior to the introduction of the monetary union in WAMZ; the null hypothesis of unit root consistently holds for virtually all the countries, but Guinea. This by implication suggests that, for the Guinea economy, shocks to inflation tend to have transitory effects and the variable will revert to its long-run equilibrium eventually, while for the rest of the WAMZ member countries, the effects seem permanent (persistent). However, for the well-known low power problem of the ADF test, we then subject this finding to robustness check by turning our attention to other statistics. The non-rejection of the null of unit root prior to the introduction of monetary union seems robust to the various alternative unit root tests considered. This empirically suggests that the effects of shocks to inflation have been permanent (persistent) in almost all the WAMZ member countries with the exception of Guinea.

Contrary to the results of the unit root tests that consistently suggest that the effects of shocks to inflation are permanent in the pre-WAMZ periods, the evidence is rather mixed after the introduction of monetary union in WAMZ. While both the ADF and PP tests show that, the null hypothesis of unit root does not hold for Ghana, Guinea, and Nigeria, the rejection of the null of unit root do not hold for Nigeria when the test is DF-GLS and mainly for Ghana when the unit root tests are NP and KPSS. Saying it differently, we find that irrespective of the unit root test performed, the effects of shocks to inflation are permanent in Gambia and Sierra Leone despite the introduction of monetary union in WAMZ. However, the effects of the shocks are consistently transitory for Ghana but mixed for Guinea and Nigeria across the different unit root tests considered.

4.2 Result based on panel data unit root tests

Analysing inflation persistence from the perspective of univariate unit root tests (as presented in the preceding section) are likely to be biased given the potential of the tests to exhibit lower power, particularly when they are applied to a finite sample. To correct for such probable biases, panel unit root tests are often found to be useful given their ability to combine the cross section and temporal dimensions that allow for an increase in the power of integration. To ensure robustness and consistency, we consider a number of panel unit root tests namely, Levin, Lin and Chu (2002) test [LLC]; Harris and Tzavalis (1999) test [HT]; Breitung (2000) test [Breitung]; Im, Pesaran and Shin (1997) test [IPS]; Maddala and Wu (1999) Fisher-type test

[Fisher- ADF]; and Hadri (2000) Lagrange Multiplier test [Hadri]. Presented in Table 4 are panel unit root test results.

Prior to the advent of monetary union, we find the null hypothesis of unit root with the common process to hold for inflation in all the WAMZ member countries in the case of LLC, Breitung, and HT panel unit root tests. However, the permanence or transitory nature of shocks to inflation when the null of a unit root is with individual process appears to be mixed for IPS and Fisher- ADF tests. That is, while the IPS fails to reject the null of unit root thereby reaffirming the persistence of inflation in WAMZ prior to the introduction of monetary union, the evidence is rather on the contrary for the ADF-Fisher test. Echoing the persistence of inflation in WAMZ before the introduction of monetary union is the Hadri test statistic failure to reject the null hypothesis of no unit root with common unit root process. Our findings are similar to those reported in Alagidede et al. (2012) whose study also uses the case of WAMZ in their evaluation of inflation persistence.

Table 4: Panel unit root test results

Test Method	**Pre-WAMZ Periods**			**WAMZ Period**		
	Level test	***Test in first difference***	***I(d)***	***Level test***	***Test in first difference***	***I(d)***
Panel unit root test with the null hypothesis of 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)
Panel unit root test with the null hypothesis of unit root with individual 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)
Panel unit root test with the null hypothesis of no unit root with common process						
Hadri Z-stat.	99.0039***	0.5520	I(1)	48.1274***	-1.1523	I(1)

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

4.3 Results from GARCH –based unit root test

It has become standard practice in the literature to account for structural breaks when using unit root tests to evaluate the degree of inflation persistence. Perron (1989, 1994, 1997, 2005), Zivot and Andrews (1992), and Narayan and Popp (2010) have been the prominent unit root tests to testing persistence in inflation, particularly when accounting for the role structural breaks. However, there has a new strand of studies such as Caporin and Gupta (2016), where it has been pointed out that not only is the level of inflation persistence that is important in economic analysis, but also the question of whether the persistence varies over time. Thus, in order to account for this potential time-varying property in addition to structural breaks in the unit root test approach to an estimate of inflation persistence, we herein employ the new dimension to unit root testing that is gradually evolving in the literature. This new approach to unit root testing which is pioneered by Cook (2008) and was later extended by Narayan and Liu (2013, 2015) to account for heteroscedasticity and structural breaks among others, was termed "GARCH-based unit root tests". To determine the appropriateness of the GARCH – based unit root test approach to inflation persistence in the WAMZ, we start by testing for the presence of conditional time-varying and structural breaks in the inflation of WAMZ member countries.

Using Engle's (1984) ARCH LM test, the results in Table 5(A) confirm that inflation in the WAMZ member countries is heteroscedastic. For instance, it has conditional time-varying property regardless of the lag length and whether the period is before or after the introduction of the monetary union. Also, presented in Table 5(B) is the Ljung-Box Q statistic that provides evidence of a significant presence of autocorrelation in the inflation series across the different lag lengths under consideration. More so, we test for the presence of structural shifts in the inflation of WAMZ member countries using the Bai-Perron (2003) structural break test. Although the structural break test results as represented in table 5(A&B) tend to vary for the period before and after the introduction of the monetary union in WAMZ, it, however, reveals significant evidence of breaks in the inflation of WAMZ member countries. It is all these inherent statistical features of inflation in WAMZ that further reaffirm our extension of the unit root tests to GARCH –based unit root testing of inflation persistence in WAMZ.

Table 5(A): Conditional Heteroscedasticity Test (ARCH LM)

WAMZ Countries	**Pre-WAMZ Periods**			**WAMZ Periods**		
	$k=2$	$k=4$	$k=6$	$k=2$	$k=4$	$k=6$
The 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 5(B): Serial Autocorrelation (Q-stat.)

WAMZ Countries	**Pre-WAMZ Periods**			**WAMZ Periods**		
	$k=2$	$k=4$	$k=6$	$k=2$	$k=4$	$k=6$
The 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***

Note: Reported in the table are Ljung-Box Q-statistics and ARCH-LM F-statistics for serial correlation and conditional heteroscedasticity, respectively. For the purpose of robustness, difference lag lengths (k) are considered, while *** indicates significance at 1%.

Table 6(A): Bai-Perron Multiple Structural Breaks for Pre-WAMZ Period

WAMZ Countries	T_1		T_2		NSB
	$\sup F_T(\ell+1\|\ell)$	Break Date	$\sup F_T(\ell+1\|\ell)$	Break Date	
The 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 6(B): Bai-Perron Multiple Structural Breaks for WAMZ Period

WAMZ Countries	T_1		T_2		NSB
	$\sup F_T(\ell+1\|\ell)$	Break Date	$\sup F_T(\ell+1\|\ell)$	Break Date	
The 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 $\sup F_T(\ell+1|\ell)$ test statistics for the breaks are reported in parentheses. The critical values for $\sup F_T(\ell+1|\ell)$ at 10% level of significance as obtained from the Bai and Perron (2003) paper are 7.04and 8.51 respectively for $\ell = 1, 2$.

Having shown that there are heteroscedasticity and significant evidence of structural breaks in the inflation series of the various WAMZ member countries under consideration, we then proceed to extend the unit root tests to GARCH –based unit root test. 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 roots, particularly in the periods before WAMZ. Table 7 shows that we are able to reject the null hypothesis of the unit root when we account for time-varying and structural breaks. Put differently, we find 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 unit root for inflation using the conventional unit root tests may be due to the presence of heteroscedasticity, time trend and structural breaks. It may be argued in this light therefore, that the unit root test for inflation in WAMZ is better modelled with the 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 are permanent (persistent) or transitory (temporary).

Table 7: 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)
The 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 a period before and after the introduction of WAMZ.

4.4 Results from MGARCH model

Thus far, we have been able to validate our hypothesis that the historically observed inflation differentials in WAMZ are likely to manifest in the rate at which inflation returns to its mean level either in the period before and after the introduction of the monetary union. In addition, we have shown that the degree of inflation persistence in WAMZ might be influenced by the time-varying property of inflation rates in the zone. However, whether the varying degree of inflation persistence across the member countries in WAMZ is attributable to monetary policy shocks remain unknown. To find out this, we extend the univariate approach to estimating inflation persistence to a multivariate framework in order to capture the role of monetary policy in the estimate of inflation persistence. Since our interest includes reflecting the time-varying property of the inflation series in addition to capturing the role of monetary policy shocks, the Vector Autoregressive Moving Average GARCH (VARMA-GARCH) rather than the conventional multivariate GARCH model is employed.

Tables 8(A&B) present the estimated coefficients as obtained from the VARMA-DCC-GARCH model. The fact that coefficients on DCC are reported as significant both in the period before and after the introduction of WAMZ further supports our earlier argument, that to arbitrary assume that shocks to inflation are constant over time when modelling inflation persistence may bias the estimate. Starting with the periods before the introduction of the monetary union, the empirical results in table 8(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, however, the degree of the persistence of the effects of both the inflation's own shocks and monetary policy shocks are relatively lower and substantially less than 1 Ghana, Nigeria and Sierra Leone.

Table 8(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)*
α_{11}	0.2304(0.0133)*	1.0417(0.0045)*	0.2361(0.0003)*	1.1240(0.0319)*	3.2430(0.0473)*
α_{12}	0.2364(0.2364)*	-0.0108(0.0040)*	-3.6673(0.0115)*	0.3894(0.0417)*	-0.0506(0.0037)*
β_{11}	0.5039(0.0100)*	0.0761(0.0041)*	0.8574(0.0002)*	0.3063(0.0156)*	-0.0011(0.0001)
β_{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.

Unlike the periods before the introduction of the monetary union, the empirical estimates reported in table 8(B) shows that the degree of persistence of the effects of shocks to inflation has been relatively lower since the introduction of WAMZ. This suggests that the role of monetary policy for moderating the effect of shocks to inflation has been more effective since the introduction of the monetary union.

Table 8(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)*
α_{11}	0.5666(0.2397)*	0.9207(0.0001)*	0.6970(0.0074)*	0.1313(0.0000)*	1.4824(0.0107)*
α_{12}	-0.0846(0.0209)*	-1.1602(0.0001)*	0.0083(0.1671)	0.0410(0.0001)*	-0.2644(1.6269)
β_{11}	-0.0503(0.0293)	0.0018(0.0000)*	-0.1039(0.0011)*	0.8795(0.0000)*	-0.0352(0.0001)*
β_{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.

5.1 Conclusion

This study hypothesised that WAMZ as a monetary union matters in the degree of the persistence of the effects of shocks to inflation. In addition to the traditional univariate time-series and panel data –based unit root tests to testing inflation persistence, we also consider a GARCH –based unit root test to account for the time-varying feature of the inflation series. Validating our hypothesis is the consistent evidence of declining inflation persistence across the various univariate and multivariate models consider, particularly since the introduction of the monetary union. We also observed the rate of the decline in the persistence of inflation to be relatively more evident when we control for conditional time-varying and monetary policy shocks, thus making the multivariate GARCH –based model all encompassing for analysing inflation persistence. It is based on this, among other, that we infer that it is not only the level of inflation persistence that is important in economic analyses but also whether the persistence varies over time particularly within the context that allows for the role of monetary policy shocks in a monetary union framework. More importantly, it is observed that shocks to inflation are likely to have different implications for each WMAZ member countries given the differences in the length of time it takes the effect of the shocks to die out.

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Appendix

VARMA-DCC-GARCH Specification

The VARMA-GARCH as proposed by Ling and McAleer (2003) is instrumental in determining the conditional volatility dynamics of the series under consideration as well as the conditional interdependence for both the cross effects and shocks between series. Thus, the generalised framework for the VARMA-GARCH can be described in the following specifications:

The Conditional Mean Equation

$$\Phi(L)(Y_t - \mu) = \Psi(L)\varepsilon_t \tag{a1}$$

$$\varepsilon_t = D_t \eta_t \tag{a2}$$

The Conditional Variance Equation

$$H_t = W + \sum_{l=1}^{r} A_l \varepsilon_{t-l}^2 + \sum_{l=1}^{s} B_l H_{t-l} \tag{b}$$

where $D_t = diag\left(h_{i,t}^{1/2}\right)$ for $i = 1, \dots, m$, $H_t = (h_{1t}, \dots, h_{mt})'$ $\Phi(L) = I_m - \Phi_1 L - \cdots \Phi_1 L^p$ and $\Psi(L) = I_m - \Phi_1 L - \cdots \Phi_1 L^q$ are polynomials in the lag operator (L), and $\varepsilon = \left(\varepsilon_{1t}^2, \dots, \varepsilon_{mt}^2\right)'$. Note also that $h_{i,t}^{1/2}$ and $h_{i,t}$ are a conditional standard deviation and conditional variance for the inflation variable. W is a vector of constants and A_l for $l = 1, \dots, r$ and B_l for $l = 1, \dots, s$ are $m \times m$ matrices that represent the ARCH and GARCH effects respectively. The conditional variance capture shock spillover effects of monetary policy shocks in addition to shocks due to past values to inflation. Starting with the conditional mean equation, the [VARMA-GARCH (1, 1)] is as given below:

$$z_t = \mu + \Phi z_{t-1} + \varepsilon_t \tag{c}$$

where z_t a 2 x 1 vector of inflation and monetary policy (interest rate) and μ is a vector of constants for inflation and interest rate such that $\mu = (\mu_1, \mu_2,)$. The spillover effect of shocks to monetary policy on inflation as well as effect shocks due to lagged terms of the series are captured as $\Phi = \begin{bmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{bmatrix}$ is a (2×2), while $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t},)$ is a vector of disturbance terms for mean equations of inflation and interest rates. The spillover effects further represented using individual mean equations given by:

$$z_{1t} = \mu_1 + \phi_{11} z_{1t-1} + \phi_{12} z_{2t-1} \qquad (d)$$

$$z_{2t} = \mu_2 + \phi_{21} z_{1t-1} + \phi_{22} z_{2t-1} \qquad (e)$$

Equations (d) and (e) are the respective mean equations for inflation and interest rates (monetary policy variable). However, our interest is the monetary policy (interest rates) mean spillovers to inflation measured by ϕ_{12}. Understanding the mean spillovers from inflation to interest rates measured by ϕ_{21} will assist in understanding if the monetary policy in WAMZ is reacting to inflation dynamics or the policymakers are proactive in their policy stance. We employ the quasi-maximum likelihood estimator (QMLE) to estimate the model parameters.

The conditional variance specification of the VARMA-GARCH model in equation (c) is given in equation (f).

$$H_t = W + A\varepsilon_{t-1}^2 + BH_{t-1} \qquad (f)$$

where $H_t = (h_{1t} \ \ h_{2t})'$, $\varepsilon_t = (\varepsilon_{1t} \ \ \varepsilon_{2t})'$, and W A, and B are (2×2) matrices of constants, ARCH effects and GARCH effects respectively. Equation (f) could be further simplified into individual conditional variance equations as described below:

$$h_{1t} = c_1 + \alpha_{11}\varepsilon_{1t-1}^2 + \alpha_{12}\varepsilon_{2t-1}^2 + \beta_{11} h_{1t-1} + \beta_{12} h_{2t-1} \qquad (g)$$

$$h_{2t} = c_2 + \alpha_{21}\varepsilon_{1t-1}^2 + \alpha_{22}\varepsilon_{2t-1}^2 + \beta_{21} h_{1t-1} + \beta_{22} h_{2t-1} \qquad (h)$$

The shock spillover effects are more evident in equations (g) and (h), where the shock spillover effects from monetary policy (interest rate) to inflation are captured by the parameters (α_{12}) and (β_{12}) respectively (see (4.13)), while (α_{21}) and (β_{21}) measure the effects of shocks spillover from inflation to monetary policy. The short-run inflation persistence is captured as $\alpha_{11} + \alpha_{12}$ while the long run persistence is represented by $\beta_{11} + \beta_{12}$.