Co – Integration Analysis of Inflation Rates of West African Economy from (2006 – 2016).

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Abstract
This work seeks to know the statistical significance relationship between the inflation rates of countries within the sub-regional economy of West Africa. The study was limited to secondary data from the six (6) selected ECOWAS member nations' (Nigeria, Ghana, Mail, Benin Republic, Gambia and Sierra Leone) statistical bureau on the monthly inflation rate (time series) of their country from 2006M1 to 2016M12. The method of Co-Integration analysis was used to test the statistical significance of the Co – Integration of the series using the Augmented Dickey – Fuller (ADF) unit root tests and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) stationarity test to determine the stationarity or otherwise of the time series with emphasis on considering drift and trend conditions. The Johansen's Co –integration test was carried out to determine the number of co – integration equations and relationship between the inflation rates. Also, the Granger causality test was performed to show if there exist a cause-effect relationship among the series. The result obtained shows that the inflation rate of the ECOWAS member state is stationary for both tests. The Johansen's co-integration test indicated that there is a minimum of five (5) co-integrating equations for the variable in both the trace and maximum eigenvalue statistics (λ_{max}) pointing to a long-run co-integration relationship between inflation rate from ECOWAS member states. The Granger Causality test shows that, except Benin Republic and Ghana, Nigeria inflation rate has no causal relationship with inflation rates of some ECOWAS member states, and does not give any statistically significant information about future rate of inflation from other ECOWAS member states. Finally, the inflation rates of ECOWAS Nations are better characterized as "collective"- meaning that they are co-integrated.

***Key Word**: Co – integration, inflation rates, West African economy.*

Introduction
This work is mostly related with the co-integration analysis of inflation rates from selected sample of West African Nations Economy on monthly basis from January 2006 to December 2016. Co-integration is a probabilistic concept (Murray, 1994). The evidence of co-integration is its rich application to non-stationary time sequences (Alexander, 1999a). It is a modern method of modeling multi-dimensional non-stationary time sequences (Neubauer, 2006). Co - integration was defined as an incident where non-stationary processes will take a linear combination that is stationary (Granger, 1981). Co – integration has been a useful method for examining the relationships between times series especially in the area of finance and economics (Arendarski and Potesk, 2012), including in the area of medicine and geography. Since a univariate series cannot co-integrate, two non-stationary series may have the property that a particular linear combination of them is stationary and multivariate series can co –

integration and the linear combinations of the variables is stationary (Hendry and Juselius, 2000). Co – integration is an econometrics characteristics of multivariate series. According to Constantin and Cernat – Gruici (2010), if more than one series are independently integrated with a certain linear pattern having a lesser order of integration of the series, then the series can be said to be co – integrated. A frequent situation is where the separate series are first – order integrated, denoted by I (1), but linear combination of vector of coefficients occurs to form a stationary series (Constantin and Cernat – Gruici 2010). So far the majority of literature works on co – integration have been dedicated to the analysis of economic data (Neubauer, 2006).
The aim of this paper is to investigate if time series of inflation rate from West African economy are co-integrated of order d (i.e. $\boldsymbol{I(d)}$, where $d \geq 0$) or are stationary, that is integrated of order zero (i.e. $\boldsymbol{I\ (0)}$). To investigate if West African economy inflation rate are better characterized as 'individualized' or 'collective'. This will test the hypothesis that West African economy inflation rate are co-integrated.

Literature Review

Before the 1980s, most economists utilized direct regression on non – stationary time series data. According to Granger (1981) in his work, most properties of time series data and their applications in econometric simulation description using linear regression on non-stationary data produces false correlation; that is, it shows a relationship between variables where no such relationship exists.
Engle and Granger, 1987 in their work "co-integration: The Engle and Granger approach using the co-integration vector approach accelerated techniques for exploring long run relationships between time series. McNew and Fackler (1997), in their work "Testing market equilibrium: Is co-integration informative?" argued that a better – integrated, efficient market does not need to be co-integrated and that the number of co-integrated relationships among prices is a less good indicator of the degree to which a market is integrated; making the argument that co-integration does not certainly mean integration.
Alexander (1999b) applied co-integration to pricing, Hedging and Trading portfolios of financial assets, specifically equity index tracking and hedging of international portfolios. Gil – Alana (2000) proposed a "two –step testing procedure of fractional co-integration in macroeconomic time series" in his work "unemployment and input prices: A fractional co-integration approach" using quarterly and seasonal adjusted data from 1966 Q1 to 2000 Q2 using the method of testing for fractional integration and co-integration.

Hendry and Juselius (2001) formalized the equilibrium – correction model which is relevant for economic data with unit roots and resolves the spurious regression problem. They further went on to analyze the characteristics of this model in further detail and brought out the changes needed to validate inference procedures, illustrating the influential new modeling procedures with gasoline price series relevant for energy economics. Gunes (2006), in his work "Functional income spreading in Turkey: A co-integration and VECM analysis" using quarterly data 1987 Q1 to 2005 Q4 (functional income component such as wage income, non-wage agricultural income and operating surplus) used co-integration to evaluate the patterns of income spread in Turkey and observed that the functional income components are co – integrated, thus cannot flow extremely far apart.
Kurita et al. (2009) studied a likelihood analysis of the order I(2) co-integrated vector auto regression analysis with piecewise linear deterministic terms to emphasis the importance of a change in normal price trends in the U.S economy after the 1980's, using the limiting behaviour of the maximum likelihood estimators to derive the restraining spread of the likelihood ratio statistic for the co-integration ranks.

Rabanal et al. (2009) studied "Co -integrated TFP processes and International Business cycles" using quarterly data from the "Bureau of Economic Analysis and employment data from the payroll survey from 1973: 1 to 2007: 3"; using unit root test with co-integration analysis provided evidence that total factor productivity (TFP) processes for the U.S and a sample of her industrialized trade partners take to a unit root and are co-integrated.

Methodology

3.1 Augmented Dickey – Fuller (ADF) Unit Roots TEST

The prevalence of a unit root indicates that the time series is non - stationary but that differencing will make it to stationarity (Said and Dickey, 1981). The Augmented Dickey – Fuller test (Said and Dickey, 1984) removes all the structural effect in the time series before carrying out the Dickey – Fuller Autoregressive Unit root test (Dickey and Fuller, 1979).
Consider the simple AR (1) model:

$$y_t = \phi y_{t-1} + \varepsilon_t, \qquad t = 1,2,3,\ldots, \qquad (3.1)$$

The regression model (3.1) can be written as

$$\nabla y_t = [\phi - 1]\, y_{t-1} + \varepsilon_t, \qquad (3.2)$$

Where ∇ is the 1st t difference operator, y_t is the variable of interest, t is the index, ϕ a coefficient, and ε_t is the error term. The research hypotheses of interest are as follows:

H_0: $\phi = 1$ (unit root in $\phi(z) = 0$) $\Rightarrow y_t \sim I(1)$)
H_1: $|\phi| < 1 \Rightarrow y_t \sim I(0)$.
The time series y_t converges (as $t \to \infty$) to a stationary series, if $|\emptyset| < 1$. If $|\phi| < 1$, the series is non stationary and the variance of y_t is $t\sigma^2$. The time series with $\phi = 1$ is occasionally called a chance walk. If $|\phi| > 1$, the series is not stationary and the variance of the time series increase exponentially as t increases.

3.2. Choosing the Lag Length for the ADF Test.

An important practical issue for the execution of the ADF test is the description of the lag length p. If p is larger, then the power test will suffer.
Ng and Perron (1995) proposed the following data dependent lag length for selected procedure that will results in stable size of the test and minimal power loss:

- Set up an upper limit, p_{max} for p.
- Estimate the ADF test regression with $p = p_{max}$.
- If the absolute value of the t – statistic for the significance of the last lagged difference is greater than 1.6 than set p = p_{max} and carry out the unit root test. Otherwise, reduce the lag length by one and repeat the process.

3.3 Kwiatkowski, Phillips, Schmidt and Shin (KPSS) Stationarity Tests

Rather than testing for unit roots, one can test for Stationarity (Johansen, 2004). The ADF unit root test is for the null hypothesis that a time series y_t is *I (1)*. Stationarity test, on the other hand, is the null hypothesis that y_t is *I (0)*.
. Stationarity is a composite null hypothesis in the model

$$y_t = \alpha + \delta t + \phi y_{t-1} + u_t \qquad (3.3)$$

Let y_t, t = 1,2,3,….., T, be the observed time series for which we wish to test stationarity. We accept that we can collapse the series into the sum of a deterministic trend, a chance walk, and a stationary error: $y_t = \beta' D_t + u_t$ (3.4)
Here $u_t = u_{t-1} + \varepsilon_t$, $\varepsilon_t \sim \mathrm{WN}(0, \sigma_\varepsilon^2)$ (3.5)
Where D_t contains deterministic components (constant or constant with time trend), u_t is $I(0)$ and may be heteroskedastic. Notice that u_t is a real random walk with innovation

variance , σ_ε^2. The initial value , u_0 , is tested as fixed and serves the role of an intercept. The hypotheses to be tested are as follows:

1. The stationarity hypothesis is simply formulated as
   H$_0$: σ_ε^2 = 0, which means that u_t is constant.

3.4 Johansen's Co-Integration Test

Granger (1983) defined co – integration as the phenomenon that non-stationary processes can have linear combinations that are stationary and used it for modeling long – run economic relations. In other words, two or more $I(1)$ processes are said to be co – integrated when a linear combination of them become an $I(0)$ process. Johansen (1988) suggests a method for both determining how many co –integrating vectors there are and also estimating all the distinct relationships, that is, obtaining estimates of the long – run and short – run coefficients at the same time. Johansen's test is both a test of stationarity (with regards to its maximum eigenvalue test) and a test of co – integration. For this analysis the co – integration idea is modeled using the unobserved component formulation, which is discussed as follows. Let y_t be given by

$$y_t = \Sigma_{j=1}^{t} \varepsilon_i + u_t \qquad (3.6)$$

Where u_t is a linear process, typically independent of the process ε_t , which is an independently and identically distributed with mean zero and finite variance.

The hypotheses of different ranks are cased in this formulation too. The parameters are related to the autoregressive design by $\xi = \beta_\perp$ and $\eta = \alpha_\perp$, where for any $p \times r$ matrix A of rank $r \leq p$, we define $A_\perp$ as a $p \times (p - r)$ matrix of rank $p - r$, for which $A^1 A_\perp = 0$. Therefore, both adjustment and co integration can be discussed in this formulation. In general, given a non–stationary time series variable, $\{Y_{1,t}, Y_{2,t}, \ldots, Y_{n,t}\}$. Where ;

$$Y_{1,t} = \alpha_1 + \phi_{11}X_{1,t} + \phi_{12}X_{2,t} + \ldots + \phi_{1p}X_{p,t} + \varepsilon_{1,t}$$
$$Y_{2,t} = \alpha_2 + \phi_{21}X_{1,t} + \phi_{22}X_{2,t} + \ldots + \phi_{2p}X_{p,t} + \varepsilon_{2,t}$$
$$Y_{3,t} = \alpha_3 + \phi_{31}X_{1,t} + \phi_{32}X_{2,t} + \ldots + \phi_{3p}X_{p,t} + \varepsilon_{3,t}$$
$$.$$
$$Y_{n,t} = \alpha_k + \phi_{k1}X_{1,t} + \phi_{k2}X_{2,t} + \ldots + \phi_{kp}X_{p,t} + \varepsilon_{k,t} \qquad (3.7)$$

There exists a linear combination consisting of all variables with a vector β, such that:

$$\beta_1 Y_{1,t} + \beta_2 Y_{2,t} + \beta_3 Y_{3,t} + \ldots + \beta_k Y_{n,t} \sim I(0) \qquad (3.8)$$

Where $\beta_j \neq 0$, j = 1, 2, 3, …, n. if this is the case, then the Y's are co-integrated.

3.5 Trace Test

Under the trace test, we wish to know the amount of linear combinations to see if the input variables are co-integrated or not. The trace test analysis studies the amount of linear combinations (k) to be equal to a given value k_o and the alternative hypothesis for k to be greater than k_o.

H$_0$: k = k_o

H$_1$: k > k_o

To test the presence of co-integration using the trace test, we set k_o= 0 (no co-integration), and see whether the null hypothesis can be rejected. If this is the case, then we infer that there is only one co-integrating relationship. In this case we fail to accept the null hypothesis to ascertain the incidence of co-integration between the variables.

3.6 Maximum Eigenvalue Test (λ_{max})

Under the maximum eigenvalue test, we wish to see if the number of linear combinations equal to the number of input variables. This is because if the amount of linear combinations is equal to the amount of input variables, the variables are stationary to begin with which would have made the co-integration test unnecessary in the first place. With the maximum eigenvalue test, we also ask the same question as the Johansen trace test. The difference, however, is an alternate hypothesis:

H_0 : k = k_o

H_1 : k =k_o+ 1

So, starting with k_o= 0 and disallowing the null hypothesis suggests that there is only one likely combination of the non-stationary time series variables to give a stationary process. But if there is one or more combination, the test may become less powerful than the trace test for the same k_o values. A special case for using the Maximum Eigenvalue Test is when k_o = n - 1, where disallowing the null hypothesis suggests the presence of possible linear combinations. This is not possible unless all the input time series variables were stationary. This is impossible unless all the input time series variables were stationary (i.e. $I(0)$) from the onset.

3.7 Granger Causality Test

The co-integration of more than one variables does not necessarily suggest that one of the co-integrated variables can provide statistical significant information about the prospective value of other variable or vice versa. Where the co-integration of more than one variables suggests that they shared a familiar stochastic drift in the past, causality on the contrarily implies that one of the series can be used to predict future values of the other. The Granger causality test is a test for determining if one-time series is useful in providing statistically significant information about prospective values of another. A time series X is said Granger Cause Y if it can be seen that after many series of test and F-test on lagged values of X (and with lagged values of Y also included), that those Y values provide information about prospective/ future values of Y.

Multivariate Ganger causality is often carried out by fitting a vector auto regressive model (VAR) to the time series. In particular, let $y(t) \in \mathbb{R}^{dx1}$ for t = 1,…,T; a d dimension multivariate time series. Granger causality is carried out by fitting a VAR model with L time lags as follows:

$$Y(t) = \Sigma_{\tau=1}^{L} A_{\tau} Y(t-\tau) + (t), \quad (3.9)$$

Where (t) is a white Gaussian random vector.

A time series Y_i is known as Granger cause of another time series Y_j , if one or more of the elements A_τ (j, i) for τ =1,…,L is significantly greater than zero (in absolute value). The hypotheses are as follows:

H_0 : $Y_j \nsim Y_i$, meaning that Y_i does not Granger cause Y_j

H_a : $Y_j \sim Y_i$, meaning that Y_i does Granger causeY_j

The null hypothesis that Y_i does not Granger cause Y_j is accepted if and only if no lagged values of Y_i are held in the regression.

It must note that Granger causality does not often imply true causality. For instance, if two processes Y_i and Y_j each with lag k are done by a common third process Y_c with a different lag say l, one might still accept the alternative of Ganger causality.

Empirical Result

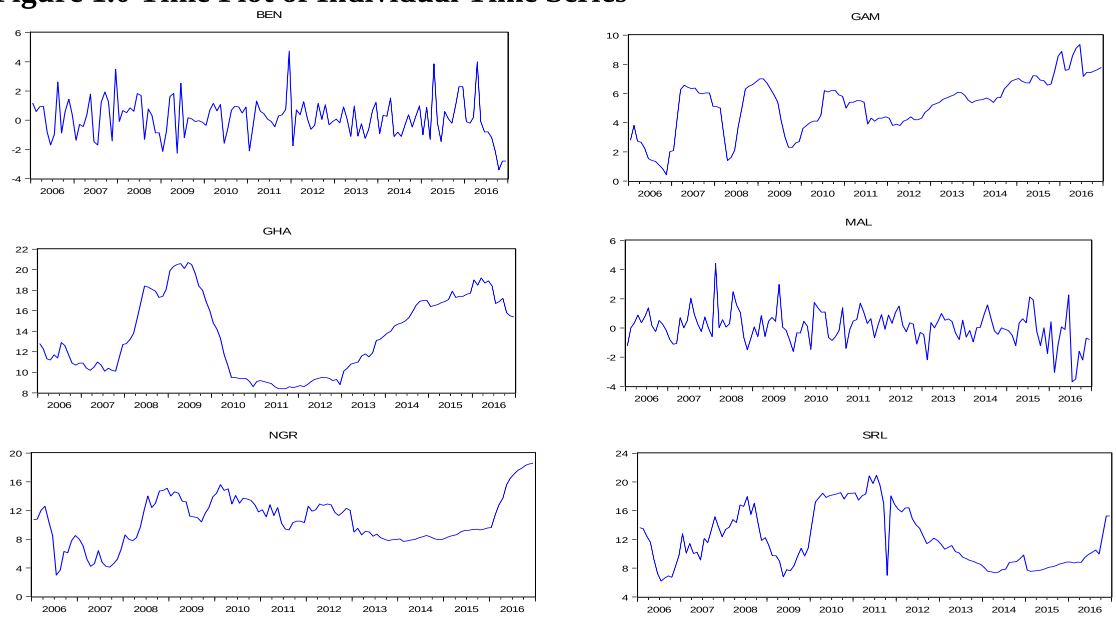
4.1 Presentation of Data

The data for this analysis were downloaded from the website of the selected countries national statistical agencies, www.tradingeconomics.com/countrynames/ inflation rate/period. The data are monthly and run from January 2006 to December 2016; which means the data contains 120 observations for each variable under investigation. Table 4.1 below shows the list of countries under investigation, the labels or codes used in the analysis for the respective ECOWAS countries.

Table 4.1: Countries and Codes

COUNTRY	CODE
BENIN REPUBLIC	BEN
GAMBIA	GAM
GHANA	GHA
MALI	MAL
NIGERIA	NGR
SIERRA LEONE	SRL

Figure 1.0 Time Plot of Individual Time Series



- A glance at the plot of the individual time series as shown in figure above show a non – identical time series plot of all input variables with BEN and MAL showing a more stationary trend than others.

Figure 2.0 Time Plot of First Differencing of Individual Variables (inflation rate, I(1))

Figure 3.0 Time Plot of Second Differencing of Individual Variables (inflation rate, I(2))

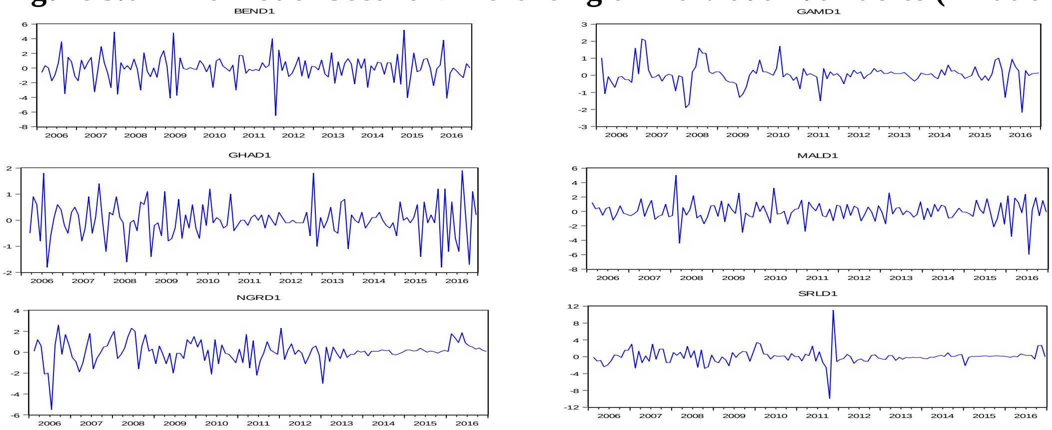


Figure 2.0 above which is a graph of first difference for the individual time of the variables shows that after differencing once, the problem of non – stationarity still exists. Although the time series have mean zero, their variance is still not constant.

Figure 3.0 above which is a graph of second difference shows the differenced series oscillating around mean zero with a constant variance, this means that the time series are all non – stationary and integrated of order 2.

Table 4.2: Summary Result of ADF unit Root Test with Drift (constant/intercept) with critical values for test statistic

country	ADF_t	Critical value @ 5% levels	Decision.
SRL	-13.98166	-2.883753	Has no unit root
NGR	-6.821919	-2.883930	Has no unit root
MAL	-10.33040	-2.884291	Has no unit root
GHA	-7.451251	-2.883753	Has no unit root
GAM	-8.228479	-2.883753	Has no unit root
BEN	-9.762146	-2.884291	Has no unit root

Table 4.3: Summary Result of ADF unit Root Test with Drift and Trend with Critical Values for Test Statistic

country	ADF_t	Critical value @ 5% levels	Decision.
SRL	-13.95146	-3.44756	Has no unit root
NGR	-10.08896	-3.44756	Has no unit root
MAL	-10.31168	-3.44559	Has no unit root
GHA	-7.420328	-3.44756	Has no unit root
GAM	-8.199206	-3.44756	Has no unit root
BEN	-9.797111	-3.44559	Has no unit root

Table 4.4 Summary Result of KPSS stationary Test with Drift and critical values for test statistic

country	KPSS(Drift) LM - statistic.	Critical value @ 5% levels	Decision.
SRL	0.073981	0.46300	H_0. Rejected
NGR	0.155777	0.46300	H_0. Rejected
MAL	0.179620	0.46300	H_0. Rejected
GHA	0.095079	0.46300	H_0. Rejected
GAM	0.029824	0.46300	H_0. Rejected
BEN	0.126378	0.46300	H_0. Rejected

The ADF test statistics for the variable both when the drift is taken into consideration (Table 4.2) and when the drift and trend is taken into consideration (Table 4.3), are less than the critical values at 5% levels when compared with the critical values in Table 4.2 and Table 4.3 respectively and correspondingly which means that we accept the null hypothesis for both ADF Unit Root Test along the drift and along the trend, signifying that the variables are stationary. The Augmented Dickey – Fuller unit root tests are for the null hypothesis that a time series has unit root. The Kwiatkowski, Phillips, Schmidt and Shin (KPSS) stationarity tests, however, are used to test the hypothesis that a time series is stationary. Stationarity is a composite null hypothesis. The test is performed with consideration to drift and trend and its critical value at 5%. The result compares the results of LM - statistics with those of the critical value in the same table to decide if the null hypothesis should be accepted or rejected. From Table 4.4 above, it must be seen that the KPSS value (LM -statistics) of each variable, both when drift is considered and when both drift and time trend is considered and are less than their respective critical values at 5% levels.

4.2 Johansen's Co – Integration Tests.

This section is separated into two parts; Part 1 discusses Trace statistics Johansen's co-integration Test, while Part 2 discusses Maximal Eigenvalue statistics Johansen's co-integration Test. Table 4.5 and Table 4.6 contain the results and the critical values necessary for making a decision about our null hypothesis (H_0).

Table 4.5: Result of Trace Statistics and Critical Value of Johansen's Co-Integration Test

No. of Linear Combinations	Trace statistics	Critical value @ 5% levels	Decision.
K = 0	95.09993	85.93712	Not Co-integrated
$K \leq 1$	54.85153	60.06141	Co-integrated
$K \leq 2$	28.24334	40.17493	Co-integrated
$K \leq 3$	13.73484	24.27596	Co-integrated
$K \leq 4$	5.653123	12.32090	Co-integrated
$K \leq 5$	0.020293	4.12906	Co-integrated

This section is separated into two parts; Part 1 discusses Trace statistics Johansen's co-integration Test, while Part 2 discusses Maximal Eigenvalue statistics Johansen's co-integration Test. Table 4.5 and Table 4.6 contain the results and the critical values necessary for making a decision about our null hypothesis (H_0).

The test statistics are the compared with the critical values at 5%. If the value of the test statistics be more than that of the critical value at 5%, we keep moving downward till we find the test statistics that has a lesser value than its corresponding critical value. At this point, we say that the number of co-integration equation are less than or equal to the value on the extreme left hand of the table. From the co-integrated result the trace test indicates one co-integrating equation at 5% levels. More so the maximal eigenvalue test equally confirms that there is only one/single co-integrating equation at 5% levels; meaning that the variables shows that there exists a long – run equilibrium relationship among the six (6) variables used in the analysis. It shows that variables move together with long run association.

Table 4.6: Result of Maximal Eigenvalue Statistics and Critical Value of Johansen's Co-Integration Test

No. of Linear Combinations	Maximal Eigenvalue. λ_{max}	Critical value @ 5% levels	Decision.
K = 0	40.24840	36.63019	Not Co-integrated
$K \leq 1$	26.60819	30.43961	Co-integrated
$K \leq 2$	14.50850	24.15921	Co-integrated
$K \leq 3$	8.081714	17.79730	Co-integrated
$K \leq 4$	5.632830	11.22480	Co-integrated
$K \leq 5$	0.020293	4.129906	Co-integrated

4.3 Granger Causality Tests.

In this section, we are testing the hypothesis that Nigeria inflation does not Granger causes inflation rate of some other ECOWAS member Nations against the hypothesis that it does. That those Y values provide significant information about future values of Y the Granger Causality

Table 4.7: The Result of Granger Causality Test.

Null Hypothesis	Obs.	F-test statistics	Prob.	Decision
NGR does not Granger cause BEN	130	3.855	0.0237	Accepted
BEN does not Granger cause NGR		6.735	0.0017	Accepted
NGR does not Granger cause GAM	130	3.469	0.0342	Accepted
GAM does not Granger cause NGR		0.259	0.7725	Not Accepted
NGR does not Granger cause GHA	130	1.424	0.2445	Not Accepted
GHA does not Granger cause NGR		4.186	0.0174	Accepted
NGR does not Granger cause MAL	130	1.693	0.1881	Not Accepted
MAL does not Granger cause NGR		0.250	0.7719	Not Accepted
NGR does not Granger cause SRL	130	0.128	0.8800	Not Accepted
SRL does not Granger cause NGR		0.484	0.6173	Not Accepted

Conclusions

According to Table 4.7, at 5% levels with lag 2. NGR does not Granger cause GAM, MAL and SRL since the p – values for this test are 0.7725, 0.7719 and 0.6173 respectively are more than 0.05 or 5%; which means that according to the data, Nigeria inflation rate does not give statistically significant information about the future rate of inflation of Gambia, Mail and Sierra Leone. Nigeria does Granger cause Benin Republic and Ghana with a p- value of 0.0017 and 0.0174 respectively. While NGR – BEN has a bilateral (bi-directional) causality, NGR – GHA has unilateral (Uni-directional) causality from GHA – NGR, which means that Nigeria inflation rate gives statistically significant information about the future of the inflation rate of Benin Republic more than about that of Ghana. The Granger Causality test analysis performed series shows that with exception of Benin Republic and Ghana, Nigeria inflation rate does not provide any statistically significant data about the future inflation rate of other ECOWAS members. This means that Nigeria inflation rate does not have a causal relationship with inflation rate of ECOWAS member states. The inflation rate of ECOWAS is stationary and integrated of order 2. ECOWAS Nations inflation rate are better characterized as "Collective". Meaning that the inflation rates are co – integrated.

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