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Structural Breaks and Unit Root in Macroeconomic Time Series: Evidence from Nigeria

Omorogbe Joseph Asemota[1]* and Adejumo Oluwasegun Agbailu[2]
[1]Department of Research and Training, Department of Statistics, National Institute for Legislative Studies, University of Abuja, Abuja.
[2]Department of Statistics, University of Abuja.
*Corresponding Author: asemotaomos@yahoo.com

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ABSTRACT

The discourse on the properties of macroeconomic time series has received a considerable interest in recent literature. This is because the presence of unit in a realization of a stochastic process implies that shocks to the time series have a persistent effect with policy implications. Hence, this paper investigates the unit root properties of ten Nigerian macroeconomic time series using quarterly data from 1981-2015. For comparison, first we apply the conventional augmented Dickey-Fuller unit root test to examine the null of a unit root in the ten macroeconomic series, and we proceed to examine the unit root properties using the Lagrange Multiplier (LM) endogenous unit root tests that account for the presence of one-break and two-break as proposed by Lee and Strazicich (2003, 2013). On employing the augmented Dickey-Fuller test that does not account for structural breaks, our empirical results indicate that the unit root null hypothesis cannot be rejected for nine of the ten series considered in the study. However, on utilizing the Lagrange Multiplier (LM) endogenous one and two structural breaks test, we reject the unit root null in favour of the one and two-break stationary alternative for six of the ten series (60% rejection) considered in our study. These results imply that unit root tests that do not account sufficiently for the presence of structural breaks lead to misleading inference. These findings have important implications for the macroeconomic policy-making, modeling and forecasting of the Nigerian economy. We therefore, recommend that structural breaks should be taken into account in the econometric analysis of Nigerian macroeconomic variables.

Keywords: macroeconomic time series, recession, structural breaks, stationarity, unit roots.JEL Classification: C20, C22, C51, C52, C53

1. Introduction

1.1 Introduction to the Research Problem

Studies on macroeconomic time series properties have received a considerable interest in recent literature. One of the most topical debates among economists is whether macroeconomic time series can be characterised as a random walk (unit root) or trend-stationary. The conventional views of the business cycle theories suggest that output fluctuations (shocks) are temporary deviations from their long-run stable path. Hence, the impact of shocks on output growth will eventually fade and output will return to its trend rate of growth. This implies that output series such as GNP is characterised as trend stationary. This traditional view of economists is, however, contrary to what empirical findings suggested. The findings challenge the traditional view in treating economic time series as temporary fluctuations around a deterministic trend function as opposed to the permanent changes reflected in the trend. In their seminal contribution to the unit root properties of macroeconomic time series, Nelson and Plosser (1982) revealed that the GDP series of USA followed a random walk. They argued that most of the changes in the GDP are permanent, indicating that there is no tendency for output growth to revert to its underlying trend following a shock. Hence, shocks will persist in every future period and GDP is said to follow a random walk.

Perron (1989) demonstrated that Nelson and Plosser's strong evidence in support of the unit root hypothesis is due to the failure to account for structural changes in the data. Perron (1989) incorporated an exogenous structural break for the 1929 crash in the conventional unit root test (augmented Dickey-Fuller test). On accounting for structural break, the unit root hypothesis is rejected for eleven out of the fourteen series analysed by Nelson and Plosser (1982). However, during the early 1990s, Banerjee et al.(1992), Christiano (1992) and Zivot and Andrews (1992) opined that choosing the structural break(s) exogenously could lead to over-rejection of the unit root hypothesis. To address this problem, they proposed the one endogenous structural break test.

Lumsdaine and Papell (1997) modified the endogenous break methodology to account for two endogenous breaks in the trend equation. They found more evidence against the unit root hypothesis than Zivot and Andrews (1992), but less than Perron (1989). Specifically, Lumsdaine and Papell (1997) rejected the unit root hypothesis at the five per cent level for seven out of thirteen series considered by Nelson and Plosser (1982) and at the ten per cent level for additional two series. A limitation of the augmented Dickey-Fuller (ADF)-type endogenous break unit root tests, such as the Zivot and Andrews (1992) and Lumsdaine and Papell (1997) tests, is that the critical values are derived while assuming no break(s) under the null. Nunes et al.(1997) and Lee and Strazicich (2003) show that this assumption leads to size distortions in the presence of a unit root with one or two breaks. Hence, when utilizing the Zivot and Andrews (1992) and Lumsdaine and Papell (1997) tests, spurious rejections may occur. To circumvent these spurious rejections, Lee and Strazicich (2013) propose a one break Lagrange Multiplier (LM) unit root test as an alternative to the Zivot and Andrews (1992) test, while Lee and Strazicich (2003) developed a two-break LM unit root test as a substitute for the Lumsdaine and Papell (1997) test. In contrast to the ADF test, the LM unit root test incorporates breaks under the null and alternative hypotheses. Tatoglu (2009) investigated the stationarity of real effective exchange rates using panel unit root tests with structural breaks, and he found evidence in support of structural breaks. Chaudhuri and Wu (2003) investigated whether stock prices of seventeen emerging markets can be characterised as random walk (unit root) or mean reversion processes. They implemented a test that accounts for structural breaks in the underlying series and noted that failure to account for structural breaks lead to erroneous conclusion that these indices are characterized by random walk.

Folawewo (2012) applied the unit root with structural break test to test for the presence of hysteresis in Nigerian unemployment rate. Waheed et al. (2006) examined the unit root with structural break for the Pakistani macroeconomic time series. On employing the conventional unit root test without structural breaks, all the 11 macroeconomic variables of the Pakistani economy were non-stationary. However, on employing the Zivot-Andrews unit root test with structural break, they found evidence of stationarity in two of the macroeconomic series. In addition, structural break was detected in ten of the eleven series considered in their study. Narayan and Smyth (2005) analysed the random walk hypothesis of stock prices in OECD countries using unit root tests that account for one and two structural breaks in the trend function. They concluded that structural break in stock prices has had a detrimental effect on movements in stock prices in the G7 countries. In addition, Luísa et al. (2006) pointed out that standard unit root tests provided mixed evidence on the stochastic behaviour of the Brazilian gross domestic product series. Furthermore, Bjørnland (2010) investigated the dynamic properties of several macroeconomic variables in Norway using different unit root tests and measures of persistence. He found that on accounting for a structural break in the trend alternative, the unit root hypothesis for unemployment, government consumption, investment and real wage was rejected.

1.2 Research Problem

Howbeit, most of the previous studies on Nigerian macroeconomic time series [Adaramola (2012), Osamwonyi and Osagie (2012), Tamunonimim (2013) etc.] have never employed the two structural breaks LM test in their empirical analysis.

This study is being proposed against this backdrop. With this, we hope to fill an existing lacuna in the empirical literature. To the best of our knowledge, this study is the first attempt to utilize the Langrage multiplier one-break and two-break unit tests to model the Nigerian macroeconomic time series. It contributes to the empirical literature by providing evidence of structural break(s) in Nigerian major economic time series. In addition, the conventional ADF test is used as a benchmark in this analysis. The rest of the paper is structured as follows: Section 2 explains the econometric methodology. Section 3 presents the data and the empirical results and the last section concludes.

2. Econometric Methodology

This section briefly discussed the methodology of this empirical study.

2.1. The augmented Dickey-Fuller (ADF) Test

It has become a tradition in the statistical analysis of macroeconomic time series, that the unit root hypothesis is first tested for each of the variables to ascertain its order of integration. The augmented Dickey-Fuller (Dickey and Fuller, 1979, 1981) test is the most commonly used test for ascertaining the presence of unit root. In the case of trending data, it is based on the following regression:

$$\Delta y_t = \alpha + \emptyset y_{t-1} + \beta^* t + \sum_{i=1}^{k} \theta_i \, \Delta y_{t-i} + \varepsilon_t \qquad (1)$$

This involves a regression of Δy_t on y_{t-1}, Δy_{t-1}, Δy_{t-2}, …, Δy_{t-p} as well as an intercept $\alpha$and time trend$\beta^* t$, t = 1,2, … T and ε_ta pure white noise disturbance with variance of σ^2. $\Delta y_{t-i}$is the lagged first differences to correct for serial autocorrelation in the errors. The optimal lag length (k) is selected using t-sig approach as proposed by Hall (1994) with k-max=4. Ng and Perron (1995) used a simulation study to show that the‘t-sig’ approach is preferable to the information based criteria.

2.2. Lee and Strazicich Structural Break Model

The Langrange Multiplier (LM) based structural break test was developed by Lee and Strazicich (2003) to circumvent the spurious rejection problems associated with the Zivot and Andrews (1992) and Perron (1989) endogenous break test. Consider the data generating process (DGP) as follows:

$$y_t = \delta' Z_t + e_t, \quad e_t = \beta e_{t-1} + \varepsilon_t, \qquad (2)$$

where Z_t is a vector of exogenous variables and $\varepsilon_t \sim$ IID $N(0, \sigma^2)$. Two structural breaks can be considered as follows: Model A allows for two shifts in level and is described by Z_t= [1, t, D_{1t}, D_{2t}]', where D_{jt} = 1 for t ≥ T_{Bj} + 1, j = 1, 2, and 0 otherwise. T_{Bj} denotes the time period when a break occurs. Model C includes two changes in level and trend and is described by Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]', where DT_{jt} = t - T_{Bj} for t ≥ T_{Bj} + 1, j = 1, 2, and 0 otherwise. Note that the DGP includes breaks under the null (β = 1) and alternative (β < 1) hypothesis in a consistent manner. For instance, in model A (a similar argument can be applied to model C), depending on the value of β, we have:

Null $\quad y_t = \mu_0 + d_1 B_{1t} + d_2 B_{2t} + y_{t-1} + \nu_{1t} \quad (3)$

Alternative $\quad y_t = \mu_1 + \gamma t + d_1 D_{1t} + d_2 D_{2t} + \nu_{2t} \quad (4)$

where ν_{1t} and ν_{2t} are stationary error terms; $B_{jt} = 1$ for $t = T_{Bj} + 1$, j=1,2 and 0 otherwise; and d = (d_1, d_2) and γ is the trend parameter. In model C, D_{jt} terms are added to (3) and DT_{jt}terms to (4), respectively. Note that the null model (3) includes dummy variables B_{jt}. Perron (1989, p.1393) showed that including B_{jt} is necessary to ensure that the asymptotic distribution of the test statistic is invariant to the size of breaks (d) under the null. The two-break LM unit root test is implemented using the regression as follows:

$$\Delta y_t = d' \Delta Z_t + \phi \tilde{S}_{t-i} + \sum_{i=1}^{k} \lambda_i \Delta \tilde{S}_{t-j} + \varepsilon_t \qquad (5)$$

where $\tilde{S}_t$ is a de-trended series such that $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t \tilde{\delta}$, $t = 2, \ldots, T$. $\tilde{\delta}$ is a vector of coefficients in the regression of Δy_ton $\Delta Z_t$and $\tilde{\psi}_x = y_1 - Z_1 \tilde{\delta}$, where y_1 and Z_1 are the first observations of $y_t$and Z_t, respectively, and Δ is the difference operator, $\varepsilon_t$is the contemporaneous error term and distributed with zero mean and finite variance, $\Delta \tilde{S}_{t-j}$, $j = 1, \ldots, k$, terms are added to correct for serial correlation. Analogous to the two-break equivalent of Perron (1989) Model C, with two breaks in level and trend, $Z_t$is defined by [1, t, $D_{1t}, D_{2t}, DT_{1t}, DT_{2t}$] to allow for a constant term, linear time trend, and two structural breaks in level and trend. The unit root null hypothesis is given as $\phi = 0$, and the LM test statistics are given by:

$\tilde{\rho} = T\tilde{\phi}$,

$\tilde{\tau} =$ t-statistic for the null hypothesis $\phi = 0$.

To endogenously determine the break points (T_{Bj}), the minimum LM unit root test uses a grid search as follows:

$$LM_\rho = \inf_{\lambda} \tilde{\rho}\,(\tilde{\lambda}) \qquad (6)$$

$$LM_\tau = \inf_{\lambda} \tilde{\tau}\,(\lambda) \qquad (7)$$

where $= T_b/T$, and T is the sample size. Vougas (2003) indicated that in the application of LM test, the studentized version $(\tilde{\tau})$ takes, into account, the variability of the estimated coefficients and is more powerful than the coefficient test$(\tilde{\rho})$. The breakpoints are determined to be where the test statistic is minimized. As expected in endogenous break test, a trimming region of (0.15T, 0.85T) is used to eliminate endpoints. Critical values are tabulated in Lee and Strazicich (2003).

3. Data and Empirical Results

3.1 Data

The methodology described in section 2 is applied to 10 Nigerian macroeconomic time series data. The Government Final Expenditure, Gross Domestic Product, All Share Index, Exports of Goods and Services, Imports of Goods and Services, Compensation of Employees (Wages), Crude Oil Price, Inflation Rate (CPI), Exchange Rate and Money and Quasi Money (M2). Data are quarterly and are extracted from the Central Bank of Nigeria (CBN) Statistical Database. With the exception of the government final expenditure, crude oil price, inflation rate, official exchange rate and money supply (M2) which are analyzed in levels, the other series are converted to logarithm for variance stabilization. The EViews and RATS statistical packages are used in carrying out all the analysis in this study. Table 1 presents the macro variables and their codes as used in the analysis.

Table 1: Variable description

Variables	Code
1. Government Final Expenditure	GOFE
2. Gross Domestic Product	LGDP
3. All Share Index	LASHI
4. Exports of Goods and Services	LEXPO
5. Imports of Goods and Services	LIMPO
6. Compensation of Employees (Wages)	LWAGE
7. Crude Oil Price	CROP
8. Inflation Rate	INFL
9. Official Exchange Rate (Naira to Dollar)	EXCH
10. Money and Quasi Money (M2)	M2

Note: L denotes natural logarithm. Variables are in local currency (Naira)

3.2 Unit Root Test without Structural Break

The ADF test without structural break is first employed to analyze the unit root properties of the series. The results from the ADF test with a linear time trend are reported in Table 2. Using the ADF test, the unit root cannot be rejected for 9 of the

10 series. However, the unit root can be rejected for imports of goods and services at 10 per cent level of significance. From the analysis of the 10 Nigerian macro-economic time series, we found little evidence against the unit root hypothesis. Howbeit, according to Perron (1989), the ADF test could lead to misleading inferences if potential structural breaks are ignored.

Table 2: ADF test without structural break

Macro-variables	$\hat{k}$	Test statistic	Inference
GOFE	4	-1.43486	Unit Root
LGDP	0	-1.42051	Unit Root
LEXPO	1	-2.71713	Unit Root
LIMPO	0	-3.33309*	Stationary
LASHI	4	-1.16024	Unit Root
LWAGE	0	-2.34995	Unit Root
CPI	4	-0.38763	Unit Root
EXCH	0	-2.06246	Unit Root
CROP	2	-2.27129	Unit Root
M2	2	2.67948	Unit Root

* denote statistical significance at 10%

Note: Linear trend is included in the estimation of the model. The critical values for the above ADF test are -4.03 and, -3.45and -3.15 for at 1, 5 and 10 percent respectively. $\hat{k}$ is the AIC lag term is used to select the optimal lag, to make the residuals white noise.

Perron (1989) demonstrated that if there is a structural break, the power to reject a unit root decreases when the stationary break alternative is true and structural break(s) is ignored. Hence, this finding is consistent with the unit root literature and is due to the low power of the ADF when structural breaks are present in the series.

3.3 Unit Root Test with One Structural Break

The results Lee and Strazicich unit root test with one endogenous structural break are presented in Table 3. Using the LM one-break endogenous test, the unit root hypothesis can be rejected for gross domestic products at 1% level of significant and for government final expenditure at 5% level significant. The empirical results reported in Table 3 indicates that 20% of the 10 Nigerian macroeconomic series reject the unit root hypothesis at conventional (5%) level of significant and 80% of the 10 Nigeria macroeconomic series could not reject the unit root hypothesis.

Table 3: One endogenous structural break Lee-Strazicich unit root test

Variables	$\hat{k}$	**Break Date**	**Test Statistic**	**Break Point (λ)**	**Inference**
GOFE	4	2008:03	-4.5451**	0.8	Stationary with one-break
LGDP	3	2009:03	-5.6392***	0.8	Stationary with one-break
LEXPO	1	2009:04	-3.8236	0.9	Unit Root
LIMPO	0	1986:03	-4.1956	0.2	Unit Root
LASHI	4	2004:03	-2.9145	0.7	Unit Root
LWAGE	0	2004:02	-3.0869	0.7	Unit Root
CPI	4	2006:01	-2.9975	0.5	Unit Root
EXCH	1	1999:02	-2.8088	0.5	Unit Root
CROP	2	2004:02	-3.8490	0.7	Unit Root
M2	4	2003:03	-3.9320	0.7	Unit Root

***, ** and * denote statistical significance at 1%, 5% and 10% respectively.
Note: $\hat{k}$ is the AIC lag term is used to select the optimal lag, to make the residuals white noise. denotes the estimated break points.

Table 4: Lee and Strazicich Critical Values for One Structural Break Test

Break points	**Critical values**		
= (T_B/T)	1%	5%	10%
= (0.1)	-5.11	-4.5	-4.21
= (0.2)	-5.07	-4.47	-4.20
= (0.3)	-5.15	-4.45	-4.18
= (0.4)	-5.05	-4.50	-4.18
= (0.5)	-5.11	-4.51	-4.17

3.4. Unit root test with two structural breaks

The results of the Lee and Strazicich unit root test with two endogenous structural breaks are presented in Table 5. The two-break test rejects the unit root in favour of the two-break stationary alternative for a total of 6 of the 10 macroeconomic series considered. With the Lee-Strazicich (LM) test, we reject the unit root null in favour of the stationarity with two structural breaks alternative at 1% for government final expenditure and gross domestic products, at 5% for crude oil price and at 10% for exports of goods and services, exchange rate and money and quasi money (M2).

Table 5: Two endogenous structural breaks Lee-Strazicich unit root test

Variables	$\hat{k}$	**Break date 1**	**Break date 2**	**Test statistic**	**Break fractions (λ)**	**Inference**
GOFE	4	2003:03	2009:04	-9.1702***	0.7, 0.8	Two breaks stationary
LGDP	3	2007:03	2010:04	-8.2632***	0.8, 0.9	Two breaks stationary
LEXPO	4	1988:01	2008:03	-5.4988*	0.2, 0.8	Two breaks stationary
LIMPO	0	1986:04	2006:04	-5.1668	0.2, 0.8	Unit root
LASHI	3	1994:04	2003:04	-4.4992	0.3, 0.6	Unit Root
LWAGE	0	1989:04	2005:04	-4.7804	0.3, 0.8	Unit Root
CPI	4	1999:01	2009:03	-4.4290	0.2, 0.7	Unit Root
EXCH	4	1998:03	2002:03	-5.5221*	0.5, 0.6	Two breaks stationary
CROP	1	2002:02	2011:04	-6.2850**	0.6, 0.9	Two breaks stationary
M2	4	1997:04	2004:01	-5.3801*	0.5, 0.7	Two breaks stationary

***, ** and * denote statistical significance at 1%, 5% and 10% respectively.
Note: $\hat{k}$ is the AIC lag term is used to select the optimal lag, to make the residuals white noise. λ denotes the estimated break points.

Table 6: Lee and Strazicich Critical Values for Two-Structural Break Test

Break points	**Critical values**		
= (T_{B1}/T, T_{B2}/T)	1%	5%	10%
= (0.2 , 0.4)	-6.16	-5.59	-5.27
= (0.2 , 0.6)	-6.41	-5.74	-5.32
= (0.2 , 0.8)	-6.33	-5.71	-5.33
= (0.4 , 0.6)	-6.45	-5.67	-5.31
= (0.4 , 0.8)	-6.42	-5.65	-5.32
= (0.6 , 0.8)	-6.32	-5.73	-5.32

Source: Lee and Strazicich (2003)

In addition, the two endogenous structural breaks test rejects the unit root hypothesis

more than one endogenous structural break test; this is possibly due to under specification of the number of structural breaks. This is consistent with Ohara (1999) findings. Ohara (1999) proved that tests with fewer than the true number of structural breaks fail, incorrectly, to reject the unit root null even asymptotically. Howbeit, the minimum LM two-break test and the one-break test considered in our study could not reject the unit root null hypotheses of import of goods and services, all share index, compensation of employees (Wages) and inflation rate.

4.0 Conclusion and Recommendations

This paper provides a comprehensive examination of the unit root hypothesis and structural breaks of 10 Nigerian macroeconomic time series utilizing quarterly data from 1981 – 2015. Utilizing the ADF test, the study finds very weak evidence against the unit root null hypothesis as the unit root null hypothesis could only be rejected for one of the ten series. However, on employing the end ogenous one-break and two-break tests, it was found that evidence against the unit root hypothesis increased. In fact, 60% of the series considered in this study, rejected the unit root hypothesis in favour of the one or two breaks stationary alternative. Some of the estimated break dates were quite significant because they corresponded to important economic events such as the Nigeria transition to democracy in 1999, the stock market crash in 2002 and the global financial crises in 2008. The findings that six of the macroeconomic series are stationary with one or two breaks is quite important for econometric modeling of the macroeconomic variables because if a variable is stationary with structural break(s), but erroneously regarded as a unit root series, misleading inferences would inevitably result. Since most of the macroeconomic series considered in the study appear to be stationary with structural break(s), this implies that the effects of shocks to these series will be transitory and thus eliminated as time elapses.

This empirical analysis does not address the possibility of a model with three or more breaks. In addition, there has been increased interest on how structural breaks affect fractional intergregration and long memory, see for examples, Perron and Qu (2010) and Varneskov and Perron (2011). Moreover, the detection of structural break using the state space model via the Kalman filter is also a recent focus in the literature. We are aware of these shortcomings and new direction and the hope to report empirical analytical results on these issues in subsequent research.

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