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STRUCTURAL BREAKS IN NATURAL GAS CONSUMPTION AND ECONOMIC GROWTH IN NIGERIA: EVIDENCE FROM NEW TIME SERIES TESTS THAT ALLOW FOR STRUCTURAL BREAKS

PRZERWY STRUKTURALNE W ZUŻYCIU GAZU ZIEMNEGO I WZROST GOSPODARCZY W NIGERII: DOWODY Z NOWYCH TESTÓW CIĄGÓW CZASOWYCH, KTÓRE DOPUSZCZAJĄ PRZERWY STRUKTURALNE

Abstract

This paper analyzes structural breaks in the natural gas consumption and economic growth relationship in Nigeria. The Residual Augmented Least Squares-Lagrange multiplier (RALS-LM) unit root test with breaks also known as "RALS-LM test with trend breaks and non-normal errors" proposed by Meng-Lee-Payne (2017) and the structural breaks testing proposed by Kejriwal–Perron (2010) are among the tools used for the investigation. Our empirical findings provide significant evidence that the series of natural gas consumption and economic growth are station-ary with one or two trend breaks. Furthermore, the investigation has identified significant incidences of structural breaks in the relationship between natural gas consumption and economic growth in 1990, 2004, 2009 and, all the breaks were found to be significant at the respective periods. The evaluation of the sub-sample periods based on the break dates revealed that the first and second breaks were positive and have had positive / bolstering effect on the relationship while the last break appeared to have a negative /retarding effect on the relationship. Moreover, the estimate of the long-run elasticity is significant where a 1% increase in the natural gas consumption induces the growth of Nigerian economy by 0.15% and, all the dummies that represent the breakpoints were significant as the break that occurred in 2004 appeared to have a more significant effect on the relationship than did the 1990 and 2009 breaks. The implication of the results is that shocks to the series of natural gas consumption and economic growth in Nigeria have transitory effect, and hence, modeling the relationship between natural gas consumption and economic growth in Nigeria using

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linear models without taking structural breaks into consideration could produce biased and unreliable statistical results, and that the Nigerian economy depends significantly on the natural gas consumption.
Keywords: *Structural Breaks, Natural Gas Consumption, Economic Growth*

Streszczenie

W niniejszym artykule przeanalizowano problem strukturalnych przerw w zużyciu gazu ziemnego i wzrostu gospo-darczego w Nigerii. Nowatorski test RALS-LM znany również jako „test RALS-LM z przerwami trendów i błędami nietypowymi" zaproponowany przez Meng-Lee-Payne (2017) i nowe testy zaproponowane przez Kejriwal-Perron (2010) należą do narzędzi wykorzystywanych w badaniu. Odkrycia empiryczne dostarczają znaczących dowodów na to, że seria zużycia gazu ziemnego i wzrost gospodarczy są nieruchome z jednym lub dwoma przerwami w trendach. Ponadto w badaniu zidentyfikowano znaczące przypadki przerw strukturalnych w związku między zużyciem gazu ziemnego a wzrostem gospodarczym w latach 1990, 2004, 2009 i wszystkie daty przerw zostały uznane za znaczące. Ocena okresów podprób na podstawie dat przerw ujawniła, że pierwsza i druga przerwa są potencjalne, podczas gdy ostatnia jest destrukcyjna. Co więcej, oszacowanie elastyczności długookresowej jest znaczące, gdy wzrost zużycia gazu ziemnego o 1% powoduje wzrost gospodarki nigeryjskiej o 0,15%, a wszystkie próby ślepe reprezentu-jące punkty przerwania są również znaczące, natomiast przerwa z 2004 r. miała większy efekt od innych przerw. Implikacją wyników jest to, że wstrząsy w serii zużycia gazu ziemnego i wzrostu gospodarczego w Nigerii mają przejściowy efekt, modelowanie zależności między zużyciem gazu ziemnego a wzrostem gospodarczym w Nigerii bez uwzględnienia przerw strukturalnych może prowadzić do stronniczych i niewiarygodnych wyników statystycznych, i istnieje ekonomicznie istotna zależność gospodarki nigeryjskiej od zużycia gazu ziemnego.
Słowa kluczowe: *przerwy strukturalne, zużycie gazu ziemnego, wzrost gospodarczy*

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Statement of the problem in general outlook and its connection with important scientific and practical tasks.

Issues related to structural breaks have received considerable attention in econometric literature (Kejriwal and Perron, 2008). Unpredicted and sudden events such as abrupt energy policy changes are often the cause of breaks / structural change in economic and financial variables of a country. Such actions affect economic variables such as the demand and supply of energy (Shahbaz et al., 2014). Hence, it is imperative to take the issue of structural breaks into consideration while examining such variables. First, it helps to avoid having spurious order of integration which could lead to biased results /estimates. Second, since this procedure can identify the period of the break occurrence, it can thus provide valuable information for analyzing whether a structural break in a certain variable or relationship is associated with a particular government policy, economic crises, war, regime shifts, sudden policy changes inter alia and, whether the break is significant (Glynn et al., 2007). Third, ignoring the

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presence of breaks could lead to forecasting errors; thus, taking structural breaks into account in forecasting models could help minimize forecasting errors. Therefore, taking structural breaks into cognizance while studying a time series provides vital information and safeguards against having misleading order of integration of the series and hence biased estimates. Although there is a number of studies that examined the series or the statistical relationship between natural gas consumption and economic growth in Nigeria in contrast to those studies, this paper adds something to the existing literature. First, the paper makes use of the recent unit root test with breaks, namely the Meng-Lee-Payne (2017) also known as "RALS-LM unit root test with trend breaks and non-normal errors" that is more powerful than the usual LM test which does not incorporate information on non-normal errors and other tests that are not free from nuisance pa-rameters as well as the problem of spurious rejection (Meng et al., 2017). Second, its ability to employ the recent estimation technique for testing structural breaks, namely the Kejriwal–Perron (2010) structural breaks testing which to the best of the Authors' knowledge has not until now been applied to a relation. Third, going by the existing literature, studies that have used the Kejriwal–Perron (2010) structural breaks testing were only able to evaluate the regime changes using sub-samples based on the break dates without going further to estimate the longrun elasticity of the relationship whereas the test allows for consistent estimation of breaks as indicated by the novel founders of the test. Thus, the current paper adopts the dynamic ordinary least squares (DOLS) to esti-mate the long-run elasticity of the relationship and the choice of the DOLS over other classes of OLS is justified by the fact that test corrects for the potential endogeneity in the regression which could cause simultaneity bias (Kejriwal, 2008).

In view of these, this paper is designed to:

I. Investigate whether shocks to natural gas consumption and economic growth have permanent or transitory effect in Nigeria.

II. Examine whether the periodic occurrence of some events, namely incorporating the Nigerian Liquefied Natural Gas (NLNG) as a limited liability company in 1989; the establishment of Fiscal Incentives, Guarantees and Assurance Decree No. 39 in 1990; the power reforms of 2004; and the shutdown of Soku Gas Gathering and Condensate Plant of 2008/2009 have had effects on the relationship between natural gas consumption and economic growth.

III. To evaluate the break dates using subsamples so as to see how the relationship might have changed over time.

IV. To analyze whether there is significant dependence of the Nigerian economy on natural gas consumption.

The rest of the paper is organized according to sections. Section one provides a review of the existing literature. Section two discusses the methodology used in achieving the objectives of the paper. Section three presents the empirical findings of the paper, while section four gives the conclusion and policy recommendation based on the findings of the paper.

Analysis of latest research where the solution of the problem was initiated.

Energy has been a well-studied topic in the field of energy economics because of the

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importance it has in presentday economies, ranging from developed economies to developing ones. Nevertheless, a majority of studies have not considered structural breaks and, ignoring structural changes in economic time series could lead to misleading results and this is what arouses the interest of Economists to incorporate structural breaks in examining economic relationships (Saatci and Dumrul, 2013). Table 1 summarizes some of the existing studies on the relationship between natural gas/energy consumption and economic growth using both country-specific studies as well as multicountry studies. The literature review revealed three gaps. First, only a very few studies have used unit root tests with double breaks which are statistically superior and more robust to unit root tests. Second, to the best of the authors' knowledge, no study has used unit root test with double breaks, namely the Meng-Lee-Payne (2017) also known as "RALS-LM unit root test with trend breaks and non-normal errors" in examining the relationship. Third, the recent estimation technique for testing structural breaks, namely the Kejriwal–Perron (2010) structural breaks testing has not until date been applied to relationship between natural gas consumption and economic growth and, even those that applied the technique on other relations were only able to estimate the breaks and evaluate the regime changes without estimating the long-run elasticity of the relationship. To fill these literature gaps, this paper uses one-break and two-breaks Lagrange Multiplier (LM) unit root tests proposed by Lee and Strazicich (2003) and its im-proved version, namely the RALS-LM test proposed by Meng et al. (2017), the Kejriwal–Perron (2010) structural breaks testing, and the Stock-Watson (1993) dynamic ordinary least squares (DOLS) for the estimation of the long-run elasticity of the relationship.

Table 1. Summary of some of the studies on natural gas/energy consumption (G) and economic growth (Y) relationship.

Authors	Countries	Sample Period	Methodology	Variables	Results
Narayan & Smyth (2008)	G7 countries	1972–2002	Panel cointegration, Granger causality	Energy consumption, real GDP per capita, real GFCF, real GDP, natural gas consumption	Capital formation and energy consumption Granger cause real GDP positively in the long run where a 1% increase in energy consumption increases real GDP by 0.12–0.39% while a 1% increase in capital formation increases real GDP by 0.1–0.28%.
Saatci & Dumrul (2013)	Turkey	1960– 2008	Lee-Strazicich unit root test and Kejriwal cointegration test with breaks	Real GDP, petroleum, coal, electricity, combustible renewables, and waste	Turkey's energy consumption and economic growth shows a positive relationship with a varying quantity of structural breaks.
Shahabaz *et al*. (2014)	Pakistan	1972QI –2011QIV	ARDL with breaks	Natural gas consumption, labour, capital, and real GDP	There is evidence of structural changes in the relationship and natural gas consumption stimulates the growth of the economy.
Waheeed (2014)	Saudi Arabia	1971-2012	Zivot-Andrews (1992) and Perron (1997) unit root tests with breaks, Gregory and Hansen (1996) cointegration tests with breaks	Energy consumption, natural gas consumption, oil consumption, and real GDP	There is evidence of structural changes in the relationship and cointegration among the variables in the presence of breaks.
Mehmet (2015)	OECD Countries	1991 – 2013	FMOLS, DOLS, and VECM Granger causality test	Natural gas consumption, GDP growth, gross fixed capital formation, and trade openness	There is evidence of cointegration among the variables where natural gas consumption in OECD countries was found to affect GDP growth positively but only in the long-run, with evidence of unidirectional causality from natural gas consumption to GDP growth in the short run and bidirectional causality in the long run.
Sakiru & Muhammad (2015)	Malaysia	1971 – 2012	ARDL with breaks	Gas consumption, GDP, foreign direct investment, capital and trade openness	There is evidence of structural changes in the relationship and that natural gas consumption is positively impacting the growth of Malaysian economy.
Destek (2016)	OECD Countries	1991 – 2013	Panel FMOLS, Panel DOLS, and VECM Granger causality test	Natural gas consumption, GDP growth, gross fixed capital formation, and trade openness	There is evidence of cointegration where natural gas consumption is positively impacting GDP growth in the long-run. Furthermore, in the short run there is unidirectional causality running from natural gas consumption t GDP growth while in the long run there is bidirectional causality.
Dogan (2016)	Turkey	1961 – 2009	ARDL model and VECM Granger causality	real GDP, combustible renewable and waste, consumption per capita, total energy consumption, non-renewable energy, GFCF and labor.	There is evidence of cointegration and the findings support conservation hypothesis and feedback hypothesis between renewable energy consumption and economic growth in the short run and long run respectively while there is feedback hypothesis between non-renewable energy consumption and economic growth both in the short run and the long run.
Kahouli (2017)	6 SMCs	1995–2015	ARDL model	energy consumption, financial development, and gross domestic product	The results revealed the short-run causal relationships (unidirectional) at least once for each country (except Egypt). The Granger causality results for individual countries give mixed results.

Source: Authors' Depiction (2018)

Notes: Gross Domestic Product (GDP), Gross Fixed Capital Formation (GCF), Autoregressive Distributed Lag (ARDL) model, Organization for Economic Co-operation and Development (OECD) countries, South

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Mediterranean Countries (SMCs), Panel Fully Modified Ordinary Least Square (FMOLS), the Panel Dynamic Ordinary Least Square (DOLS), Vector Error Correction Model (VECM).

Aims of paper. Methods

The methodology involves the use of the Lagrange Multiplier (LM) unit root test with breaks proposed by Lee-Strazicich (2003), the residual augmented least squares-Lagrange multiplier (RALS-LM) unit root test with breaks also known as the "RALS-LM test with trend breaks and non-normal errors" proposed by Meng-Lee-Payne (2017), the structural breaks testing proposed by Kejriwal–Perron (2010), and the dynamic ordinary least squares (DOLS) developed by Stock-Watson (1993).

Sources of Data

The data used is secondary from 1981 – 2015 which includes real GDP (Y) as a proxy of economic growth and natural gas consumption (G) both in logarithmic form. The variables were sourced from the World Bank development indicators and Organization of Petroleum Exporting Countries (OPEC) statistical bulletin of the year (2016).

Unit root tests with breaks

Unit root testing without incorporating a structural break often leads to the rejection of the hypothesis of station-arity of time series even if such series are stationary. Thus, the need to adopt unit root test that takes the presence of break into consideration is of paramount importance (Weideman, 2016). However, the importance of structural breaks for the implementation and interpretation of unit root tests was first emphasized by Perron (1989) and the Perron's procedure is characterized by a single exogenous (known) break in accordance with the underlying asymptotic distribution theory. Perron uses a modified Dickey-Fuller (DF) unit root test that includes dummy variables (1 for a break in a particular date and 0 for otherwise) to account for one known, or exogenous structural break. However, the breaking point of the trend function is fixed (exogenous) and chosen independent of the data generating process.

Based on Perron (1989), the following three models were estimated to test for the unit root. The equations take into account the existence of three kinds of structural breaks: Model A (eqn. 1) a 'crash' model which allows for a break in the level (or intercept) of a series; Model B (eqn. 2) a 'changing growth' model, which allows for a break in the slope (or the rate of growth) of a series; and lastly, Model C (eqn. 3) a 'combined' model that allows for both effects to occur simultaneously, i.e. one time change in both the level and the slope of the series.

$$x_t = \alpha_0 + \alpha_1 DU_t + d(DTB)_t + Bt + px_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta x_{t-1} + \varepsilon_t \quad (1)$$
$$x_t = \alpha_0 + \delta DT_t^* + Bt + px_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta x_{t-1} + \varepsilon_t \quad (2)$$
$$x_t = \alpha_0 + \alpha_1 DU_t + d(DTB)_t + \delta DT_t + Bt + px_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta x_{t-1} + \varepsilon_t \quad (3)$$

where the intercept dummy 〖DU〗_t represents a change in the level; 〖DU〗_t=1 if (t > TB) and zero otherwise; the slope dummy 〖DT〗_t (also DT_t^*) represents a change in the slope of the trend function; DT^* = t-TB (or DT_t^*= t if t>TB) and zero otherwise; the crash dummy (DTB) = 1 if t = TB +1, and zero otherwise; and TB is the break date. It is noteworthy that each of the three models has a unit root with a break

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under the null hypothesis, as the dummy variables were incorporated in the regression under the null hypothesis of a unit root. The alternative hypothesis is a broken trend stationary process.

However, Perron (1989) assumption of the break date was criticized, most notably by Christiano (1992) as 'data mining'. Christiano argues that the data based procedures are typically used to determine the most likely location of the break and this approach invalidates the distribution theory underlying conventional testing. Since then, several studies have been developed using different methodologies for endogenously determining the break date. However, according to Christiano (1992), Zivot and Andrews (1992), and Perron and Vogelsand (1992), identification of the break date may not be unrelated to the data and, if the critical values of the test assume the opposite, there may be substantial size distortions (i.e. the tests will have a tendency to over reject the null hypothesis of unit root). These studies have shown that bias in the usual unit root tests can be reduced by endogenously determining the time of structural breaks and their main innovation is to suggest that the date of the break be identified endogenously while testing for breaks.

Lee-Strazicich (2003) has developed an endogenously determined unit root with breaks test within the Lagrange Multiplier (LM) unit root test suggested by Schmidt and Phillips (1992). It improves the power of Perron (1997) unit root test with breaks that is based on the assumption that no structural break under the null of a unit root since this assumption can result in spurious rejections, hence their test is unaffected by whether or not there is a break under the null (Divino et al., 2009). More so, they argued that earlier unit root tests with structural changes, such as those by Zivot and Andrews (1992) and Lumsdaine and Papell (1997), may provide misleading conclusions when the null hypothesis of unit root is rejected which implies that the series may embody structural changes and yet be either stationary or a unit root process. This means that the rejection of the null hypothesis does not always imply that the series is trend-stationary because the null hypothesis of those earlier unit root tests with structural breaks does not incorporate the possibility of structural changes (Cuestas and Staehr, 2011). Therefore, these are the reasons for adopting this test. The LS test is a unit root test with single and double breaks and it has two models. These models are the Model A which allows for a one-time change in level and model C which allows for a change in both the level and trend where the critical values of the models were reported by Lee and Strazicich (2003). The LS test can be performed by estimating the following equation:

$$\Delta y_t = \delta' \Delta Z_t + \phi \bar{S}_{t-1} + \sum_{i=1}^{k} \gamma \Delta \bar{S}_{t-i} + \mu_t \qquad (4)$$

where $\bar{S}_t = y_t - \bar{\psi}_x - Z_t \bar{\delta}$, $t = 2, 3, \ldots, T$; $\bar{\delta}$ are the coefficients from the regression of Δy_t on ΔZ_t and $\bar{\psi}_x$ is the restricted MLE of $\psi_x (\equiv \psi + X_0)$ given by $y_1 - Z_1 \bar{\delta}$.

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The Δ terms were included to correct for possible serial correlation and Zt is a vector of exogenous variables contained in the data generating process. The null of unit root is given by = 0 and the LM test statistic, called , is the t-statistic under the null and the test selects the model which provides more evidence against the null hypothesis (Cuestas and Staehr, 2011). However, in this test, to determine the location of the breaks a grid search was used and the break was endogenously determined by minimizing the t-statistics (Krištić et al. 2019). Nonetheless, the critical values of this test were taken from Table 2 of Lee and Strazicich (2003).

Finally, Meng-Lee-Payne (2017) has improved upon the LM test of Lee-Strazicich (2003) by incorporating information on non-normal errors and thus, more powerful than the usual LM test (Krištić et al. 2019). It is a unit root test with single and double breaks that allows for structural breaks in both the intercept and the slope and adopts the residual augmented least squares (RALS) procedure to gain a more statistically improved power when the error term follows a non-normal distribution. The test is free of nuisance parameters that indicate the location of the structural break and also free from the problem of spurious rejection, thus, the rejection of the null hypothesis can be considered as more accurate evidence of stationarity (Meng et al., 2017). The transformed RALS-LM test can be performed by estimating the following equation:

$$\Delta y_t = \delta' \Delta Z_t + \phi \bar{S}_{t-1} + \sum_{i=1}^{k} \gamma \Delta \bar{S}_{t-i} + a \hat{w} + v_t \qquad (5)$$

where y_t is the logarithm of the series, Δ is the difference operator, k is the optimal lag length, δ' represents the coefficients of the exogenous series, Z_t is a vector of exogenous series, $\bar{S}_t$ denotes the transformed form of the detrended variables, a is the coefficient of the nonnormal errors, $\hat{w}$ is the series that contains the information of non-normal errors which augments the LM procedure, and v_t is an error term with $\varepsilon_t = a\hat{w} + v_t$ where $\hat{w}$ is uncorrelated with ε_t. However, the null of the unit root is tested using $\phi = 0$ and the RALS-LM statistic (τ^* RALS-LM) is produced through the normal least squares method which is utilized to analyze the test equation. More so, the optimal number of lags is again obtained using general to a specific method and the critical values are computed using a 'RATS program' based on the codes provided by Meng *et al*. (2017) at https://www.degruyter.com/view/j/snde.2017.21.issue-1/snde-2016-0050/snde-2016-0050.xml

Kejriwal and Perron (2010) structural breaks testing

Kejriwal and Perron (2010) structural breaks testing is a technique for detecting and testing the significance of structural breaks in a relationship. The technique consists of three types of statistics for testing structural breaks. The first is the sub-Wald test of the

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null hypothesis of no structural break versus the alternative hypothesis of a fixed number of *k* breaks. The mathematical depiction of the test is:

$$SupF_T^*(k) = \sup_{\lambda \in \Lambda_\varepsilon} \frac{SSR_0 - SSR_k}{\delta^2}, \quad \textbf{(6)}$$

where SSR_0 represents the sum of squared residuals under the null hypothesis of no breaks; SSR_k denotes the sum of squared residuals under the alternative hypothesis of *k* breaks; $\lambda = \{\lambda_1, \ldots, \lambda_m\}$ indicates the vector of the break fraction defined by $\lambda_i = T_i / T$ for $i = 1, \ldots, m_i$; and T_i are the break dates.

The second type of the test applies when the alternative hypothesis involves an unknown number of breaks between 1 and some upper boundary *M*. Hence, following Bai and Perron (1998), test which considers a double-maximum test (UD_{max}) based on the maximum of the individual tests for the null of no break versus *m* breaks ($m = 1 \ldots M$), the mathematical form of the test equation can be represented by:

$$UD_{MAX}\, F_T^*(M) = \underset{1 \le k \le m}{MAX}\, F_T^*(k) \quad \textbf{(7)}$$

This test is arguably the most useful for determining the presence of structural breaks (Bai and Perron, 2006; Kejriwal and Perron, 2010). The rule is that always test whether the UD_{max} is significant; if yes, then go ahead with the next step which is the sequential procedure or its alternatives so as to select /estimate the number of breaks in the relationship (Dülger, 2016). Moreover, the UD_{max} test was developed in order to test the existence of multiple structural breaks in cointegration relationship (Dumrul and Dumrul, 2015).

The third test involves a sequential procedure (*SEQ*) also known as the sequential procedure for breakpoint testing. It tests the null hypothesis of, say, *k* breaks, versus the alternative hypothesis of *k* +1 breaks. The mathematical representation of the test is:

$$SEQ_T(K+1|k) = \max_{1 \le j \le k+1} \sup \left\{ \frac{A_T(k) - B_T(\tau, k)}{\hat{\delta}_{k+1}^{2}} \right\} \quad \textbf{(8)}$$

where $A_T(k) = SSR_T(\hat{T}_1, \ldots, \hat{T}_k)$, $B_T(\tau, k) = SSR_T(\hat{T}_1, \ldots, \hat{T}_{j-1}, \hat{T}_j, \ldots \hat{T}_k)$ and $\wedge_{j,e} = \{\tau: \hat{T}_{j-1} + (\hat{T}_j - \hat{T}_{j-1}) \in \le \tau \le \hat{T}_j - (\hat{T}_j - \hat{T}_{j-1}) \in\}$. $\hat{\delta}_{k+1}^2$ is a consistent estimator of the long-term variance under the null hypothesis. The model with *k* breaks is obtained by a global minimization of the sum of squared residuals, as in Bai and Perron's (1998) study.

Kejriwal (2008) also used two alternatives to the *SEQ* procedure to select the number of breaks in a relationship, namely the Bayesian Information Criterion (*BIC*) suggested by Yao (1988) and the modified Schwarz Criterion proposed by Liu-Wu-Zedik (1997) (*LWZ*). The Bayesian Information Criterion (BIC) defined as:

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$$BIC(m) = \ln \hat{\sigma}^2(m) + p^* \ln(T)/T \quad \textbf{(9)}$$

where $p^* = (m+1)q + m + p,$ and $\hat{\sigma}^2(m) = T^{-1} S_T(\hat{T}_1,...,\hat{T}_m),$ $\hat{T}_1,...,\hat{T}_m$ denoting the estimated break dates and $S_T(\hat{T}_1,...,\hat{T}_m)$ the sum of squared residuals under m breaks. Nonetheless, q is the number of coefficients which are allowed to change and p is the number of coefficients that are held fixed. On the other hand, the modified Schwarz Criterion (*LWZ*) takes the form:

$$LWZ(m) = \ln(S_T(\hat{T}_{1,...,} T_m)/(\hat{T} - p^*)) + (p^*/T)c_0(\ln(T))^{2+\delta_0} \quad \textbf{(10)}$$

where $\delta_0 = 0.1$ and $c_0 = 0.299$ as suggested by the inventors of the test.

However, Kejriwal and Perron (2010) show via simulations that their tests maintain the correct size in finite samples and are much more powerful than the commonly used *LM* tests, which potentially suffer from statistical problems of non-monotonic power in the presence of serial correlation in the errors. Kejriwal and Perron (2010) use the following approach to determine if the data suggests structural changes in a cointegrating relationship or a spurious regression i.e. no cointegration between the variables. According to them, suppose that one is willing to put an upper bound *M* (say 5) on the number of breaks. Then, if the system is not spurious and thus, cointegrated, the test would detect the number of breaks less than the upper bound number of breaks allowed by (*M*) and as such, the sequential testing procedure is said to consistently estimate the number of breaks in the relationship. On the other hand, if the regression is spurious, the number of breaks selected will be the maximum number of breaks allowed. Thus, selecting the maximum allowable number of breaks by the sequential test can be indicative of the presence of I(1) errors i.e. no cointegration. After verification via simulations, the same is true when information criteria are used to select the number of breaks and therefore, the sequential procedure enables consistent estimation of the number of breaks as well as distinguishes a cointegrated model from a spurious one (Kejriwal and Perron, 2010). Furthermore, given the span of our data, it seems unreasonable to expect the occurrence of four or more breaks. Hence, as a rule of thumb, such case is to be treated as evidence in favor of a spurious regression rather than cointegration with a break (*see* Kejriwal and Perron, 2006a; and Kejriwal 2008). However, one more advantage of this testing approach is that it allows for using both I(0) and I(1) regressors(Note that, since the structural breaks testing statistically dominates a purely spurious regression as pointed by the founders of the tests; this paper intends to employ a suitable cointegration test to complement the tests so as to verify

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whether the variables are indeed cointegrated. However, since both variables were found to be stationary at level i.e, cointegrated of order zero there is no need for testing for cointegration between them. In fact, the idea of testing for cointegration between the variables that are both I(0) is statistically nonsensical and would not be informative of any cointegrating relationship between them since any combination of stationary variables would in principle, be stationary and therefore, we can rely on standard linear regression analysis and test, for example, whether a variable is a significant predictor of the other variable.

Dynamic Ordinary Least Squares (DOLS)

The Dynamic Ordinary Least Squares (DOLS) developed by Stock and Watson (1993) can estimate the coefficients of regression more accurately compared to the ordinary least squares (OLS) method and maximum likelihood method as it allows for using both I(0) and I(1) regressors in a regression (Kaplan, 2015). The method involves augmenting the cointegrating regression with lags and leads ΔX_t so that the resulting cointegrating equation error term is orthogonal to the entire history of the stochastic regressor innovations. However, in this paper, since there are three breaks in the relationship, following Kaplan (2015), Polbin and Skrobotov (2016), we proceed to the estimation of the long-run elasticity of the relationship as:

$$\log y_t = c + \gamma \log G_t + \beta_1 DT_t(\hat{T}_1) + \beta_2 DT_t(\hat{T}_2) + \beta_3 DT_t(\hat{T}_3) + \mu_t \quad (11)$$

where c, γ, β_1, β_2, and β_3 represent the coefficients of the constant, natural gas consumption and, that of the first, second and third breaks respectively, $DT_t(\hat{T}_1)$, $DT_t(\hat{T}_2)$, and $DT_t(\hat{T}_3)$ represent the related break dates while μ_t is the error term.

Exposition of main material of research with complete substantiation of obtained scientific results. Discussion.

This section presents the results of the paper. The results reported include the time series plot of the variables, unit root tests with breaks; structural breaks testing, and the estimates of the long-run elasticity of the relationship.

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Figure 1., Figure 2. The trend of both the variables used in the analysis over the period 1981 – 2015 at a level.

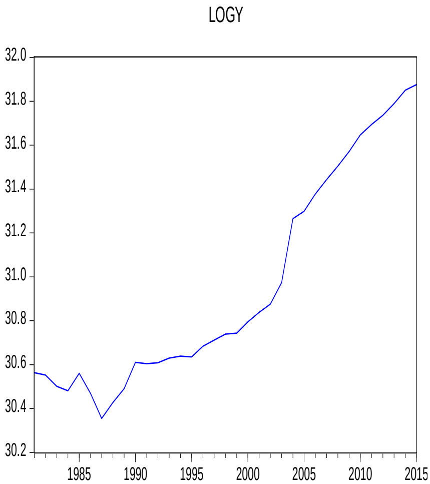

Fig. 1

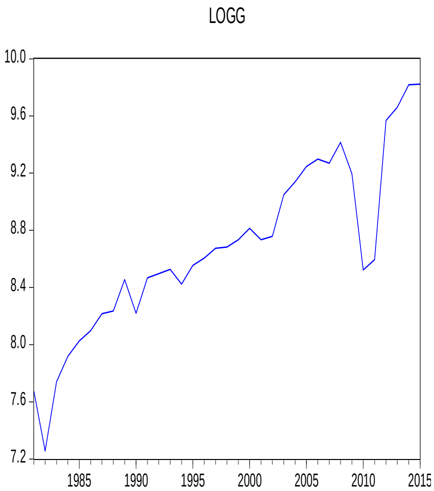

Fig. 2

Source: Researchers' computation

A visual inspection of the graphs of the series indicate that both variables, namely natural gas consumption and economic growth seem to have breaks at a low degree of persistence of the series trends.

Table 2. One-Break LM and RALS-LM Unit Root Tests.

Variables	LM τ^*_{LM}	RALS-LM $\tau^*_{RALS-LM}$	RALS-LM $\hat{\rho}^2$	$\hat{T}_R$	$\hat{k}$
Log Y	-4.7492*	-4.6665*	0.77251	2002	8
Log G	-3.8095*	-5.6215*	0.64629	2009	0

Source: Researches' Computation

Notes: τ^*_{LM} and $\tau^*_{RALS-LM}$ are the *t*-statistics, $\hat{\rho}^2$ denotes the test coefficients, $\hat{T}_R$ denotes the estimated breakpoint, and $\hat{k}$ is the optimal number of lagged first-differenced terms. * denotes the significance level of the test statistic at 1%. However, due to the fact that the LM test and RALS-LM test are similar in searching for the breakpoints and the relevant optimal lags, we only report one time to conserve space.

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Table 2 reports the LM test and the RALS-LM procedure with one structural break. It shows that with one structural break (the left-hand side of the table); the unit root hypothesis of a unit root can be rejected at 1% and 5% levels of significance for both the series of economic growth and natural gas consumption with break dates occurring at 2002 and 2009 respectively. Nevertheless, when a model with two structural breaks is considered (the right-hand side of the table); the null hypothesis of a unit root can be rejected at 1% level of significance for the two series with breaks occurring in 2002 and 2009 respectively. Hence, both series are stationary at level.

Table 3. Two-Break LM and RALS-LM Unit Root Tests.

Variables	LM τ^*_{LM}	RALS-LM $\tau^*_{RALS-LM}$	RALS-LM $\hat{\rho}^2$	$\hat{T}_R$		$\hat{k}$
Log Y	-7.4257*	-8.31824*	0.67049	1995	2002	8
Log G	-6.7099*	-6.22310*	0.96704	2007	2010	8

Source: Researches' Computation

Notes: τ^*_{LM} and $\tau^*_{RALS-LM}$ are the t-statistics, $\hat{\rho}^2$ denotes the test coefficients, $\hat{T}_R$ denotes the estimated breakpoint, and $\hat{k}$ is the optimal number of lagged first-differenced terms. * denotes the significance level of the test statistic at 1%. However, due to the fact that the LM test and RALS-LM test are similar in searching for the breakpoints and the relevant optimal lags, we only report one time to conserve space.

Table 3 presents the LM and RALS-LM tests results with two breaks. The null hypothesis that the series is not stationary with break was rejected in both the series of economic growth and natural gas consumption at 1% level with break dates at 1995 & 2002 and, 2007 & 2010 respectively. In other words, under the assumption that there are breaks in the series, the results show that the series are stationary at level.

However, since both the LM and the RALS-LM unit root tests with breaks show that both variables are stationary at level, then there is no need for further cointegration testing. Hence, the paper proceeds to adopt the structural breaks testing that would estimate the number of breaks in the relationship and goes further to evaluate the regime changes using sub-samples based on the break dates to see how the relationship with regards to breaks may have changed over time, and lastly, estimates the long-run elasticity of the relationship

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Table 4. Kejriwal–Perron (2008, 2010) Structural Break Tests.

Specifications[a]					
$y_t = \{p_t\}$	$z_t = \{1, d_t\}$	$x_t = \{\emptyset\}$	$q = 2$	$p = 0$	$M = 5$
Tests[b]					
Sup F_T (1)	Sup F_T (2)	Sup F_T (3)	Sup F_T (4)	Sup F_T (5)	UD_{max}
46.33690*	121.7065*	117.9623*	102.1358*	79.47011*	243.4129*
Number of Breaks Selected					
SEQ	3	1990	2004	2009	
LWZ	2	1991	2009	–	
BIC	3	1990	2004	2009	

Source: Researches' Computation

Notes:[a] y_t, z_t, q, p, and M denote the dependent variable, the regressors, the number of I(1) variables, the number of I(0) variables, and the maximum number of breaks allowed, respectively. Although the Kejriwal-Perron (2010) table for critical values is designed solely for the pure I(1) and a mixture of I(1) and I(0) series, the variables in this paper are I(0) which falls in the second category, hence, tests in this paper are based on the latter.

[b]The model was evaluated based on the Kejriwal and Perron (2010) table for critical values at $p^b = 2$ category (b); case 4 in which both the I(0) coefficients, as well as the intercept, were allowed to change at $a = .99$ confidence interval under trending case and $\epsilon = .15$. Nonetheless, eventhough the paper goes further to compare the critical values in the remaining cases under category (b) and all the cases under category (a), the test results validate the same thing at a higher level of statistical significance.

The Asterisks: *, **, and *** denote statistical significance at 1%, 5%, and 10% respectively.

Table 4 reports the Kejriwal–Perron tests for testing structural breaks. The upper part of the table reports the specifications of the tests. The center of the table reports the break test results based on Sup-Wald test and UD_{max} test. Both tests reject the null hypothesis of no structural break at 1% level in favor of a break occurrence / existence and, this shows that there is a strong evidence of structural change in the relationship. The lower part of the table presents the stability test results as well as the number of breaks selected by the sequential procedure (*SEQ*) and the information criteria (*LWZ* and *BIC*) respectively. The *SEQ*, *LWZ*, and *BIC* select 3, 2, and 3 breaks respectively. Following Kejriwal 2008, the *SEQ* criterion is to be used except if there is any model where the number of breaks from the *SEQ* criterion is zero, then the *LWZ* and *BIC* criteria can be used. However, given that the number of breaks selected by the sequential procedure is less than the maximum number of breaks allowed (*see* Kejriwal, 2008; Kejriwal and Perron, 2006a), it can be inferred that the regression is not spurious and thus, there is

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cointegration with breaks between the variables. This corroborated the earlier findings of the paper in Tables 2 and 3 that both variables under consideration are stationary at level which suggests no need for further cointegration assessment.

Furthermore, Table 4 shows that the breaks in the relationship between natural gas consumption and economic growth occurred in 1990, 2004, and 2009. The 1990 break corresponds to the incorporation of the Nigerian Liquefied Natural Gas (NLNG) as a limited liability company on the 17th of May 1989 and also the establishment of Fiscal Incentives, Guarantees and Assurance Decree No. 39 of 1990 as a policy that provided the necessary incentives to the NLNG at the time. However, the 2004 break corresponds to the power reforms of 2004 and one of these, was the policy introduced to abrogate the Nigerian Electric Power Authority (NEPA) with a view to proscribing the NEPA monopoly by changing its name to Power Holding Company of Nigeria (PHCN) which had paved way for the entry of Independent Power Producers (IPPs). Conversely, the 2009 break tallies with the shutdown of Soku Gas Gathering and Condensate Plant in November 2008 by the Shell oil company in order to carry out some repair of its pipelines which lasted until 2009.

Table 5. Estimated Regression Parameters under Breaks.

Break Date	Regime and Regime Period	Constant Coefficients and Standard Errors of the Regimes	Slope Coefficients and Standard Errors of the Regimes
1990 2004 2009	1. Regime (1981 - 1989) 2. Regime (1990 - 2003) 3. Regime (2004 - 2008) 4. Regime (2009 - 2015)	31.38559 (0.0000)* 26.32400 (0.0000)* 23.15143 (0.0026)* 30.39554 (0.0000)*	-0.112678 (0.0898) *** 0.509786 (0.0000) * 0.887052 (0.0449) ** 0.144149 (0.0624) ***

Source: Researches' Computation

Note *, **, and *** denotes statistical significance at 1%, 5%, and 10% levels respectively.

Table 5 reports the results of regime changes in the relationship between natural gas consumption and economic growth using sub-samples. From the table, it can be gathered that the regimes include the pre-1990, 1990, 2004, and 2009 and, the coefficients of both the constant and the slope of the regimes are positive and statistically significant. The first and the second breaks indicate a significant influence of natural gas consumption on economic growth from -0.112678 to 0.509786 and, from 0.509786 to 0.887052 respectively, while the third break, indicates that natural gas consumption had considerably slowed down economic growth over the sample period as the marginal effect fell from 0.887052 to 0.144149. Therefore, the first and second breaks have had significant positive effect / influence on the relationship, while the last had negative effect on the relationship. In colloquial terms, the response of real economic growth to natural gas consumption is statistically different in each regime and hence, the relationship has

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significantly changed over time due to the presence of structural breaks.
The next thing now is the estimation of the long-run elasticity alongside the dummies of the break dates. This approach for estimating the long-run elasticity alongside the dummies of the break dates was used by various researchers, e.g. Kaplan (2015), Polbin and Skrobotov (2016) among others.

Table 6. Estimate of the Long-Run Elasticity.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGG	0.145680	0.069029	2.110417	0.0320**
D1990	0.150932	0.076970	1.960928	0.0611***
D2004	0.582294	0.086482	6.733126	0.0000*
D2009	0.358167	0.078703	4.550860	0.0001*
C	29.32088	0.628397	46.65982	0.0000*
R^2 0.89				

Source: Researches' Computation

Note *, **, and *** denotes statistical significance at 1%, 5%, and 10% levels respectively while D1990, D2004, and D2009 are the dummies of the respective breaks.

The estimates reported in Table 6 show that the value of the long-run elasticity of natural gas consumption on economic growth is approximately 0.15% per 1% increase in natural gas consumption and is statistically significant at 5% level. Also, all the three break dates, namely 1990, 2004, and 2009 are significant at 10%, 1%, and 1% respectively, where the 2004 break had a bigger effect among other breaks. This implies that structural breaks affect the economic growth in Nigeria.

Conclusions.

This paper has analyzed the notion of structural breaks in the relationship between natural gas consumption and economic growth in Nigeria from 1981-2015. The Lee-Strazicich (2003) unit root test with breaks, the Meng-Lee-Payne (2017) unit root test with breaks, the Kejriwal–Perron (2010) structural breaks testing, and the Stock-Watson (1993) dynamic ordinary least squares techniques were used. Our empirical findings provide significant evidence that the two time series, namely natural gas consumption and economic growth are stationary with one or two breaks at level. Furthermore, the paper has identified significant incidences of structural breaks in the relationship between natural gas consumption and economic growth over the periods: 1990, 2004, 2009 and all the breaks were found to be significant. The 1990 break corresponds to the incorporation of the Nigerian Liquefied Natural Gas (NLNG) as a limited liability company on 17 May 1989 and also the establishment of the Fiscal Incentives, Guarantees and Assurance Decree

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No. 39 of 1990; the breakpoint of 2004 tallies with the power reforms of 2004; and, the 2009 break commensurate with the shutdown of the Soku Gas Gathering and Condensate Plant in November 2008 which lasted until 2009. The evaluation of the subsample periods based on the break dates revealed that the first and second breaks were significant and have had positive and significant effect / influence on the relationship, while the last break appeared to have a negative and retarding effect on the relationship. Moreover, the estimate of the long-run elasticity of the relationship is significant where a 1% increase in natural gas consumption induces the growth of Nigerian economy by 0.15% and all the dummies that represent the breakpoints are significant where the 2004 break had a bigger effect among the breaks. The implication of the results is that shocks have transitory effects on the series of natural gas consumption and economic growth in Nigeria, and, modeling the relationship between natural gas consumption and economic growth in Nigeria using linear models without taking structural breaks into consideration could produce biased and unreliable statistical results, and that there is an economically significant dependence of the Nigerian economy on natural gas consumption. Therefore, the paper recommends that the Nigerian policymakers take the issue of breaks into account while examining the relationship between natural gas consumption and economic growth while using linear models. They also ought to intensify efforts towards increasing the demand for natural gas, and be wary of implementing energy policies that would lower natural gas consumption in the country.

For further research, the paper suggests analyzing relationship between the energy consumption of West African countries and the respective growth rates of the countries using panel data techniques that allow for examining breaks in the series.

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