Asymmetric Cointegration and Causality between Natural Gas Consumption and Economic Growth in Nigeria

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Abstract

This paper investigates asymmetric cointegration, asymmetric adjustment, and causality between natural gas consumption and economic growth in Nigeria using the momentum threshold autoregressive (M-TAR) model and the Granger-causality test in a momentum threshold error correction model (M-TECM). The results revealed evidence of asymmetric cointegration and asymmetric adjustment which suggests that the negative discrepancies from the equilibrium error adjust more rapidly than the positive discrepancies and that there is bidirectional causality between the two variables. The implication of the results is that a shock that decreases the impact of natural gas consumption on economic growth adjusts more rapidly than a shock that increases it and that a consistent natural gas supply increases growth and similarly a rise in growth induces an increase in natural gas consumption. Therefore, policymakers in Nigeria need to confine more attention to the shocks stemming from the decrease in natural gas consumption and the country should adopt energy exploration policies

Keywords: asymmetric cointegration, asymmetric adjustment, causality, natural gas consumption, economic growth.

JEL classification: C32, Q43, F15.

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1. Introduction

Nigeria has abundant reserves of natural gas. In energy terms, the quantity of natural gas is at least twice as much as the oil, and the horizon for the availability of natural gas is definitely longer than that of oil. The known reserves of natural gas have been estimated at about 2.4 x 10^{12} cm^3 and are expected to last for more than a century as a domestic fuel and a major export (Gbadebo and Chinedu, 2009). Nigeria is the largest natural gas producer and has the largest gas reserves in the continent and, is among the top 5 natural gas producers in the world (EIA, 2015). In Nigeria like other countries in the world, gas is being used as a source of energy to petrochemical industries for heating, electricity generation, fuel mix strategy especially nuclear energy, fuel for vehicles, domestic use such as cooking, chemical feedstock which is used in the manufacture of plastics and other commercially organic chemicals industries (James, 2013). The rates of gas flaring in Africa over the years stood at approximately 75% in 1998, 63% in 2000 and, 24.3% in 2010 and in Nigeria it stood at 46% (Kareem et al., 2012c).

Since the oil boom of the early 1970s, the relationship between energy consumption and economic growth has become an issue of discussion in the literature (Zhixin and Xin, 2011). However, studies on energy consumption often tend to evaluate whether the economic benefits from high energy consumption can neutralize the externalities generated by its consumption and other energy-related economic activities (Adelman, 1993). A plethora of econometric techniques have been employed by various studies to investigate the relationship between natural gas consumption and economic growth across the world. Nonetheless, only little attention has been paid to Africa particularly Nigeria which is construed as the economic giant of the continent. This paper is a didactic attempt to examine asymmetric cointegration and causality between natural gas consumption and economic growth in Nigeria using the momentum threshold cointegration tests of Enders and Siklos (2001) with asymmetric error-correction process. To the best of the authors' knowledge this is the first paper to use such technique to examine non-linear cointegration and causality between natural gas consumption and economic growth in Nigeria. This techniuque can be deemed more robust statistically than the traditional linear cointegration tests with symmetric adjustment if the true adjustment process is asymmetric (Woo and Jia, 2013). Moreover, the momentum threshold cointegration method allows the model to display differing speeds of autoregressive decay depending upon whether the changes in discrepancies from equilibrium are climbing up or falling down (Enders and Siklos, 2001). Hence, the analysis of threshold adjustment is helpful in smoothening out large fluctuations.

The specific objectives of this paper is to examine nonlinear dynamics between natural gas consumption and economic growth in Nigeria, to investigate the causal relationship between natural gas consumption and economic growth and to offer policy recommendations based on the findings of the paper.

The rest of the paper is structured into four sections, namely the literature review, methodology, empirical results and conclusion.

2. Literature Review

The literature on the relationship between natural gas consumption and economic growth can be categorized into four aspects. The first aspect relates to unidirectional growth hypothesis, the second aspect relates to the conservation hypothesis, the third aspect postulates bidirectional hypothesis and is termed as "feedback" hypothesis; the last aspect is based on neutral hypothesis which delineates no causality between natural gas consumption and economic growth. Among these studies, Lee and Chang (2005) have analyzed energy consumption and economic growth in Taiwan from 1954 to 2003. The variables used are the coal, oil, natural gas consumption, electricity and GDP. Using weak exogeneity test and Johansen cointegration techniques they found unidirectional causality running from natural gas consumption to economic growth. Zamani (2007) has investigated the relationship between energy consumption and economic activities in Iran for the period 1967 to 2003. The variables used are the real GDP and Natural gas consumption; using Johansen cointegration test and vector error correction model (VECM) granger causality approach, evidence of cointegration and bidirectional causality has been observed between the two variables. Olusegun (2008) has examined the relationship between energy consumption and economic growth in Nigeria from 1970 to 2005. The variables used are the total energy consumption, oil consumption, gas consumption, electricity consumption, and gross domestic product. Using autoregressive distributed lag (ARDL) model and Toda & Yamamoto (1995) non-causality test he found no evidence of cointegration between natural gas consumption and economic growth but only a unidirectional causality running from natural gas consumption to economic growth. Apergis and Payne (2010) have investigated the relationship between natural gas consumption and economic growth for a panel of 67 countries within a multivariate framework from 1992 to 2005. The variables used include the real GDP, natural gas consumption, real gross fixed capital formation, and labor force. Using Pedroni (1999, 2004) heterogeneous panel cointegration test, they found evidence of a long-run relationship among these variables. Adegbemi *et al*. (2013) examine the causal nexus between energy consumption and economic growth in Nigeria from 1975 to 2010. The variables used are economic growth, total energy consumption, petroleum, natural gas, electricity, and coal. Using Johansen cointegration test and ordinary least square (OLS) techniques they obtained evidence of long run relationship between gas consumption and economic growth. Dogan (2014) investigates the relationship between energy consumption and economic growth in the low-income countries of Sub-Saharan Africa from 1971 to 2014 using Johansen cointegration and VAR Granger causality tests. The variables used are the real GDP per capita and energy consumption denoted as kg of oil equivalent per capita. The findings of the Johansen cointegration test demonstrate that the variables are not co-integrated for Kenya and Zimbabwe. The Granger causality test indicates that there is a unidirectional causality running from energy use to economic growth in Kenya and no evidence of causality between energy consumption and economic growth in Benin, Congo and Zimbabwe. Sahbi and Muhammad (2014) have examined the role of natural gas consumption and trade in Tunisia for the period 1980 to 2010. The variables used are gas consumption, GDP, trade and real gross fixed capital formation. Using autoregressive distributed lag (ARDL) model and Toda-Yamamoto (1995) approach they found evidence of cointegration and bidirectional causality between GDP and gas consumption. Shahbaz *et al*. (2014) have pored over the dynamic relationship between natural gas consumption and economic growth in Pakistan using quarterly data from 1972_{QI} to 2011_{QIV}. The variables used are the Natural gas consumption, labour, capital and economic growth. They have employed the autoregressive distributed lag (ARDL) model and Granger causality test and found evidence of cointegration and bidirectional causality between natural gas consumption and economic growth. Al-Shubiri (2015) conducts a study on the impact of economic and financial variables on cash conversion cycle of energy, and oil and gas sectors listed on the Muscat Security Market. The results show that there is a statistically significant impact of growth sales, firm size, cash flow as financial variables and average daily production of oil, consumer price index, total merchandise import and total government expenditure as economic variables on cash conversion cycle. Furthermore, the results show that there is a statistically significant impact of all financial factors on cash conversion cycle. Agbonifo (2016) investigates the relationship between natural gas distribution infrastructure and the quest for environmental sustainability in the Niger Delta in Nigeria using descriptive analysis. The findings identified the various natural gas utilization projects in the domestic, regional and international networks to stimulate economic growth as well as the quest for environmental sustainability across the gamut of Nigeria. These projects enable the gas to be harnessed for socioeconomic and environmental benefit, eliminate undue gas flaring and create the much needed gas infrastructure for development. Dogan (2016) analyzes the linkage between renewable and non-renewable energy consumption and economic growth by considering the structural breaks in the time-series data of Turkey from 1961 to 2009 using autoregressive distributed lag (ARDL) model and VECM Granger causality techniques. The variables he used include the real gross domestic product per capita, combustible renewable and waste (kg of oil equivalent) is used for renewable energy, consumption per capita, the difference between total energy consumption (kg of oil equivalent) and combustible renewable and waste (kg of oil equivalent) is used for non-renewable energy consumption per capita; gross capital formation as a percentage of GDP, and labor force per capita. The results revealed that renewable energy consumption has an insignificant impact on economic growth while non-renewable energy consumption has a significant positive effect on it. The coefficients on capital and labor are statistically significant. Furthermore, the findings revealed evidence in support of conservation hypothesis and feedback hypothesis between renewable energy consumption and economic growth in the short run and the long run respectively. Dogan *et al.* (2016) explore the relationship between agricultural electricity consumption and agricultural output for a panel of 12 regions of Turkey for the period 1995 to 2013 using the ordinary least squares (OLS) with regional fixed effects and the Dumitrescu-Hurlin panel Granger causality test. The variables used are the value of crop production and the electricity consumption for irrigation at agriculture sector in MWh. By using the OLS with regional fixed effects, the study finds that the coefficient of electricity consumption on output is statistically significant and positive for the overall regions, coastal region as well as the non-coastal regions. Moreover, the results from the Dumitrescu-Hurlin Granger causality test show that there is unidirectional causality running from agricultural output to electricity consumption for non-coastal regions, and there is bidirectional causality between agricultural electricity consumption and output for the overall panel and the coastal regions. Zamani (2016) undertakes a study on the global structural relationship between the prices of crude oil and natural gas from 1989m_1 to 2014m_2 using the identification scheme adopted by Kilian (2009). The variables used consist of the percentage change in the world crude oil production, the index of real economic activity, the real price of crude oil, and the real price of natural gas. The results revealed that the crude oil market affects the natural gas market through a combination of demand shocks rather than through oil supply shocks. The uncertainty about future oil supply causes precautionary demand in the oil market, which shifts to the natural gas market and increases the natural gas price as the primary substitute for oil. Karacaer-Ulusoy and Kapusuzoglu (2017) examine the dynamics of financial and macroeconomic determinants in the natural gas and crude oil markets of the organization for economic cooperation and development/gulf cooperation council/organization of the petroleum exporting countries from 2000m_1 to 2014m_{12}. They used the Johansen cointegration and Granger causality techniques. The variables used include world oil and natural gas prices and stock market, liquidity level and industrial production where the results they obtained indicate that there are multidirectional relationships among the variables.

3. Methodology

The paper adopts the Momentum Threshold Autoregressive Model (M-TAR), Momentum Threshold Error Correction technique(M-TECM) and non-linear Granger Causality tests based on Momentum Threshold Error Correction to investigate the relationship. The data used is an annual time series data collected through secondary sources consisting of 35 observations for the period 1981 to 2015.The chosen variables are the real GDP and natural gas consumption and following Apergis and Payne, (2010); Kum et al. (2012); Shahbaz et al. (2014); Dogan (2015), labour and capital were added as additional determinants of economic growth and natural gas consumption. The data on real GDP, labour, and capital were sourced from the World Bank Development Indicators (2016) statistical bulletin while that of natural gas consumption was sourced from the Organization of Petroleum Exporting Countries (2016) statistical bulletin.

The econometric specification of the model is:

$$\Delta\hat{\mu}_t = \rho_1 I_t \hat{\mu}_{t-1} + \rho_1(1 - I_t)\hat{\mu}_{t-1} + v_t \quad (1)$$

where $$I_t = \begin{cases} 1 & if \quad \mu_{t-1} \geq \tau \\ 0 & if \quad \mu_{t-1} < \tau \end{cases} \quad (2)$$

I_t denotes the heaviside indicator, ρ_1 and ρ_2 represent the speed of adjustment coefficients in the two regimes, μ is the series of residuals from the cointegrating equation, v_t is the error term which is independent of $\mu_t(j < t)$, and τ is the value of the threshold. The consistently estimated value of τ which is called attractor since $\Delta\mu_t$ has an expected value of zero when $\mu_{t-1} = \tau$, this can be searched for from equation (1). The adjustment in the series is said to be symmetric if $\rho_1 = \rho_2$, otherwise it is asymmetric. Nevertheless, it is noteworthy that from equation (2), the TAR model allows μ_t to display differing amounts of autoregressive decay depending on whether its previous value μ_{t-1} is greater or smaller than the threshold value.

Enders and Siklos (2001) show that equation (1) may not be sufficient to capture the dynamic adjustment of μ_t towards the long run equilibrium value. However, while working with any time series model, it is essential to ensure that the errors approximate a white-noise process. Enders and Siklos (2001) show that the different amounts of autoregressive decay depend on whether the previous change in μ_{t-1} is climbing up or falling down, and since the exact nature of the nonlinearity might be unknown, it is possible to allow the adjustment to depend on the change in μ_{t-1} (i.e. $\Delta\mu_{t-1}$) instead of the level of μ_{t-1} (Hu and Lin, 2008). Enders and Skilos (2001) argue that a convenient way is to augment (1) with lagged changes in the μ_t sequence and this gives rise to the momentum threshold autoregressive (M-TAR) model with the following specification:

$$\Delta\hat{\mu}_t = \rho_1 M_t \hat{\mu}_{t-1} + \rho_2(1 - M_t)\hat{\mu}_{\tau-1} + \sum_{i=1}^{k} \gamma_i \Delta\hat{\mu}_{t-1} + v_t \qquad (3)$$

where $$M_t = \begin{cases} 1 & if \quad \Delta\mu_{t-1} \geq \tau \\ 0 & if \quad \Delta\mu_{t-1} < \tau \end{cases} \qquad (4)$$

he M_t represents the heaviside indicator and the M-TAR adjustment i.e. p_1 and p_2 can be especially useful when policy makers are viewed as attempting to smoothen out any large changes in series under investigation (Enders and Sikolas,2001). For example, Nigerian authorities might take strong measures to offset shocks in natural gas consumption if such shocks are considered to induce decrease in natural gas consumption by widening the discrepancies in the relationship between natural gas consumption and economic growth in Nigeria.

According to Enders and Sikolas (2001), to test the threshold cointegration there are two sequential steps to follow – one is to test for the linear cointegration and the other one is to test for the nonlinear adjustment process. The first step is the cointegration test which tests the null hypothesis that $\rho_1 = \rho_2 = 0$ using the *F*-statistic. But, the F-statistic is non-standard under the null hypothesis and, the corresponding critical values are those of Enders and Siklos (2001) obtained from simulation and are found in Table 5 of Enders and Siklos (2001). If the *F-joint* statistic is greater than the critical values which implies rejection of the null hypothesis of no cointegration, then the null hypothesis of symmetric adjustment i.e. $\rho_1 = \rho_2$ with the standard *F*-statistic, which in this paper is represented by *F-equal* is rejected. The *F-equal* is used to test the null hypothesis of symmetric adjustment behavior against the alternative of asymmetric adjustment in the series. If the null hypothesis of $\rho_1 =$

ρ_2 is rejected, then there is asymmetric adjustment / cointegration between the series. Moreover, the above threshold coefficient (ρ_1) accounts for the positive phase of the natural gas consumption disequilibrium while the below threshold coefficient (ρ_2) accounts for the negative phase of the natural gas consumption disequilibrium (Aviral and Mihai, 2016).

3.1. The Momentum Threshold Error Correction Model (M-TECM)

After testing for cointegration, the next thing is to examine the speed of adjustment in the system and by extention test for the causal relationship among the series. This paper adopts nonlinear/asymmetric error-correction technique in testing causality among the variables rather than the conventional Granger causality test which is normally applied to check for linear causality. The aim is to estimate the long run cointegration adjustment – expansionary (increase) and contractionary (decrease) and to test for Granger nonlinear causality. Using equation (5), the long run adjustment of the nonlinear cointegration relation are to be measured based on the coefficients of ρ_{1y} and ρ_{2y}.

The momentum error correction model (M-TECM) is:

$$\Delta log\, y_t = a_0 + M_t\, \rho_{1y}\hat{\mu}_{t-1} + (1 - M_t)\rho_{2y}\hat{\mu}_{t-1} \quad (5)$$

$$+ \sum_{i=1}^{r} a_{1i}\Delta log\, Y_{t-j} + \sum_{i=1}^{r} a_{2i}\Delta log\, G_{t-j} + \sum_{i=1}^{r} a_{3i}\Delta log\, L_{t-j} + \sum_{i=1}^{r} a_{4i}\Delta log\, K_{t-j} + \varepsilon_t$$

where α_0 is the intercept, ρ_{1y} and ρ_{2y} are the asymmetric adjustment coefficients to be estimated for positive and negative deviations from the long run equilibrium. The coefficients on the lagged asymmetric error correction terms i.e. ρ_{1y} and ρ_{2y} represent the long-run adjustment back to equilibrium, whereas the coefficients on the lagged differences for the variables denote the short-run dynamics.

The optimal lag order is *r* chosen based on the model criterion, and ε_t is the error term that is assumed to be white-noise. The significance of the coefficients ρ_{1Y} and ρ_{2Y} depends on the value of τ. If the value of $\tau \geq \rho_{1Y}$, it implies that the upper regime is significant and, if the value of $\tau < \rho_{2Y}$, it means the lower regime is significant. Woo and Jia (2013) show that the M-TAR adjustment can be especially useful when policy makers are viewed as attempting to smoothen out any large changes in a series and therefore, authorities might take strong measure to offset shocks to the natural gas consumption if such shocks are deemed as significant enough to influence the relationship between natural gas consumption and economic growth and how the response variable deviates from equilibrium in the shortrun.

3.2. The Granger-Causality Test in a Momentum Threshold Error Correction Model

The evidence of causality is useful for policy makers. If natural gas consumption Granger causes economic growth, it implies that it provides useful information for predicting the rate at which the economy grows. Similarly, if economic growth Granger causes natural gas consumption, then it can help policy makers to predict future changes in natural gas consumption.

The non-linear Granger causality causality tests are based on the following equations:

$$\Delta\log y_t = a_0 + M_t\,\rho_{1y}\hat{\mu}_{t-1} + (1 - M_t)\rho_{2y}\hat{\mu}_{t-1} \qquad (6)$$

$$+\sum_{i=1}^{r} a_{1i}\Delta\log Y_{t-j} + \sum_{i=1}^{r} a_{2i}\Delta\log G_{t-j} + \sum_{i=1}^{r} a_{3i}\Delta\log L_{t-j} + \sum_{i=1}^{r} a_{4i}\Delta\log K_{t-j} + \varepsilon_{1t}$$

$$\Delta\log G_t = \beta_0 + M_t\,\rho_{1G}\hat{\mu}_{t-1} + (1 - M_t)\rho_{2G}\hat{\mu}_{t-1} \qquad (6)$$

$$+\sum_{i=1}^{r} \beta_{1i}\Delta\log G_{t-j} + \sum_{i=1}^{r} \beta_{2i}\Delta\log Y_{t-j} + \sum_{i=1}^{r} \beta_{3i}\Delta\log L_{t-j} + \sum_{i=1}^{r} \beta_{4i}\Delta\log K_{t-j} + \varepsilon_{2t}$$

where α_0 and β_0 are the intercepts, and ρ_{1y}, ρ_{2y}, ρ_{1G}, ρ_{2G} are the asymmetric adjustment coefficients to be estimared. The optimal lag order will be determined / chosen based on the value of *r* from the model. The ε_{1t} and ε_{2t} are error terms that are assumed to be white-noise. The equation (6) will be used to test for causality between the series. The hypothesis to be tested is: $H_0 : \rho_{1y} = \rho_{2y} = \alpha_{2j} = 0$, against $H_1 : \rho_{1y} = \rho_{2y} \neq 0$ for all *j* with the standard Wald statistic. The inclusion of $\rho_{1y} = \rho_{2y} = 0$ in the causality test is because of the inclusion of $log\ G$ series in the previous period's disequilibrium denoted as μ_{t-1} (Woo and Jia, 2013). If the Wald statistic indicates rejection of the null hypothesis then $\log G$ Granger causes $\log Y$. The direction of causality from $\log Y$ to $\log G$ can equally be tested using equation (7) under the null hypothesis:$\rho_{1G} = \rho_{2G} = \beta_{2j} = 0$, for all *j*. The inclusion of $\rho_{1G} = \rho_{2G} = 0$ in the causality test is due to the inclusion of $\log Y$ series in the previous period's disequilibrium (μ_{t-1}). If the standard Wald statistic indicates rejection of the null hypothesis it implies that $\log Y$ Granger causes $\log G$.

4. Results And Analysis

4.1. The Momentum Threshold Autoregressive (M-TAR)

To allow for the possibility of nonlinearity in the adjustment process, the paper uses the *F-joint* test from the M-TAR model to examine asymmetric cointegration between the variables.

The hypothesis to be tested is:

H_0: There is no asymmetric cointegration between natural gas consumption and economic growth in Nigeria.

H_1: There is asymmetric cointegration between natural gas consumption and economic growth in Nigeria.

Table 1 – The Asymmetric Cointegration Test

Variable	Coefficient	Std. Error
Above Threshold	-0.181908	0.147451
Below Threshold	-1.628933	0.254825
Differenced Residuals(t-1)	0.010264	0.136772
Threshold value (tau):	-0.077515	
F-equal:	23.943420	(8.313637)*
T-max value:	-1.233685	(-2.176070)*
F-joint (Phi):	21.275560	(9.015526)*

Source: Researchers' computation
**Simulated critical values for 5% significance level*

Number of simulations: 10000

Elapsed simulation time: 0 hours 1 minute 55 seconds.

From Table 1 above, it can be observed that the null hypothesis $\rho_1 = \rho_2 = 0$ of no asymmetric cointegration can be rejected at 5% level. Moreover, it can be observed that the null hypothesis $\rho_1 = \rho_2$ of symmetric/linearrelationship between the variables can be rejected at 5% level. This implies that the variables are cointegrated and that the adjustment mechanism is asymmetric.

From the table, the threshold value is -0.077515 and this is an appealing result considering the fact that the value is very close to zero. It can be seen that the above threshold coefficient is not significant while the below threshold coefficient is significant at 1% level. However, the negative sign in both the ρ_1 and ρ_2 indicates convergence and since $/\rho_1/ < /\rho_2/$, then the negative discrepancies from the equilibrium error adjust more rapidly than the positive discrepancies.

The implication of the results is that a shock that decreases the impact of natural gas consumption on economic growth adjusts more rapidly than a shock that increases it. Therefore, policymakers in Nigeria need to confine more attention to the shocks stemming from the decrease in natural gas consumption.

However, the estimates form equations (3) and (4) are:

$$\Delta\hat{\mu}_t = \underset{(-1.233684)}{-0.181908}\, M_t\hat{\mu}_{t-1} - \underset{(-6.392359)}{1.628933}(1 - M_t)\hat{\mu}_{t-1} + \underset{(0.075045)}{0.010264}\Delta\hat{\mu}_{t-1} + v_t$$

where $M_t = \begin{cases} 1 & if \quad \Delta\mu_{t-1} \geq -0.077515 \\ 0 & if \quad \Delta\mu_{t-1} < -0.077515 \end{cases}$

4.2. The Momentum Threshold Error Correction (M-TEC)

Since evidence of a long-run relationship (i.e., cointegration) has been found between the variables, the asymmetric error-correction model can be used to estimate the long-run equilibrium relationship. It is worth noting that after estimation, one could trim down the number of lags to check whether the results are statistically robust in order to ensure the statistical adequacy of the model.

Table 2 – The Momentum Threshold Error Correction Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.929985	0.403172	-2.306674	0.0293
DLOGY(-1)	0.153520	0.147119	1.043503	0.3063
DLOGG	-0.001288	0.038149	-0.033775	0.9733
DLOGL	36.90727	15.61977	2.362856	0.0259
DLOGK	0.112261	0.043117	2.603668	0.0150
ZPLUS	-0.195899	0.173984	-1.125961	0.2705
ZMINUS	-0.830275	0.190633	-4.355363	0.0002

Source: Researchers' computation

Table 2 above reports the estimates of the momentum threshold error correction model (M-TECM). It presents the nonlinear short run coefficients and the speed of adjustment of the asymmetric cointegrating relationship. From the table, it can be observed that the coefficients of the lagged value of economic growth and natural gas consumption are insignificant which implies that they do not contribute to economic growth in the short run. This statistically insignificant link between natural gas consumption and economic growth in the short-run is not quite surprising due to the fact that growth and the gas sector development do require time and resources to develop. Hence, the impact might not be felt immediately in the short run. However, the coefficients of labour and capital are both statistically significant at 5% level which implies that the two variables contribute to economic growth in the short run. The *z*-plus and *z*-minus are the asymmetric long run speed of adjustment parameters which measure the speed at which the model adjusts to the long run equilibrium whenever there is disequilibrium in the short run. In the model, they are denoted as ρ_{1Y} and ρ_{2Y}. Nonetheless, from Table 2 it can be gleaned that both the coefficients of ρ_{1Y} and ρ_{1Y} have the correctmathematical sign (negative) but only the latter is statistically significant. The error correction terms indicate that 20% of positive deviations are eliminated per year during the increase/positive shocks whereas negative deviations are eliminated at a rate of 83% during same time frame. Moreover, these adjustment coefficients indicate that any short-run deviations from the steady-state equilibrium during period of high natural gas consumption will take 5.1years (1/0.195899) to automatically correct/adjust to the long-run equilibrium while in the period of low natural gas consumption it takes 1.2years (1/0.830275) to adjust. This implies that the speed of adjustment towards steady-state equilibrium in the lower regime is faster than in the higher regime.

The estimates of the M-TEC model are as follows:

$$\Delta \log y = \underset{(-2.306674)}{-0.929985} - \underset{(-1.125961)}{0.195899}\, M_t \hat{\mu}_{t-1} - \underset{(-4.355363)}{0.830275}(1 - M_t)\hat{\mu}_{t-1}$$

$$+\underset{F_{11}=0.31}{a_{11}(L)\Delta \log Y_{t-1}} + \underset{F_{12}=0.97}{a_{12}(L)\Delta \log G} + \underset{F_{13}=0.00}{a_{13}(L)\Delta \log L} + \underset{F_{14}=0.31}{a_{14}(L)\Delta \log K} + \varepsilon_t$$

where *L* is the lag operator, t-statistics are in parentheses, F_{ij} is the *prob*-value that all coefficients in the polynomial *aij*(*L*) = 0, and M_t is the M-TAR indicator.

Having confirmed the presence of cointegration in the relationship with its long run adjustment, the paper can now focus on testing for causality between natural gas consumption and economic growth. As previously discussed, we will examine the causal effect between natural gas consumption and economic growth under the null hypothesis ($\rho_{1Y} = \rho_{2Y} = \alpha_{2j} = 0$) and from economic growth to natural gas consumption under the null hypothesis ($\rho_{1G} = \rho_{2G} = \beta_{2j} = 0$) for all *j* with the aid of standard Wald test. The results are reported in Table 3 below.

Table 3 – The Granger-Causality Test

Null Hypothesis	Wald Statistics	*p-value*	Direction of Causality
Log G does not Granger cause Log Y	6.888641	0.0014*	↔
Log Y does not Granger cause Log G	6.688400	0.0017*	

Source: Researchers' computation
Note * denotes the statistical significance at 1% level of significance with t-statistics in ( ) and *p*-values in [ ] while ↔ means bidirectional causality

Table 3 above shows evidence of bidirectional causality between natural gas consumption and economic growth. Hence, the null hypothesis that natural gas consumption does not Granger cause economic growth and the null hypothesis that economic growth does not Granger cause natural gas consumption are rejected at 1% level of significance.

The implication of the results is that a consistent natural gas supply increases growth and a rise in economic growth induces an increase in natural gas consumption.

5. Conclusion and Policy Recommendation

This paper has investigatedasymmetric cointegration, asymmetric adjustment, and causality between natural gas consumption and economic growth in Nigeria from 1981 to 2015. The paper has employed the Momentum Threshold Autoregressive (M-TAR) model to examine non-linear dynamics between natural gas consumption and economic growth in Nigeria. It further implements Granger-causality test based on the Momentum Threshold Error Correction Model (M-TECM) to investigate the causal relationship between the series. The results revealed evidence of asymmetric cointegration and asymmetric adjustment in the two variables which suggests that negative discrepancies from the equilibrium error adjust more rapidly than positive discrepancies and that there is bidirectional causality between the two variables. The implication of the results is that a shock that decreases impact of natural gas consumption on economic growth adjusts more rapidly than a shock that increases it and, a consistent natural gas supply increases growth. Furthermore, a rise in growth leads to a rise in natural gas consumption. Therefore, policymakers in Nigeria need to confine more attention to the shocks stemming from the decrease in natural gas consumption and the country should adopt energy exploration policies.

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