Structural Breaks, Parameter Stability and Energy Demand Modeling in Nigeria

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Abstract

This paper extends previous studies in modeling and estimating energy demand functions for both gasoline and kerosene petroleum products for Nigeria from 1977 to 2008. In contrast to earlier studies on Nigeria and other developing countries, this study specifically tests for the possibility of structural breaks/regime shifts and parameter instability in the energy demand functions using more recent and robust techniques. In addition, the study considers an alternative model specification which primarily captures the price-income interaction effects on both gasoline and kerosene demand functions. While the conventional residual-based cointegration tests employed fail to identify any meaningful long run relationship in both functions, the Gregory-Hansen structural break cointegration approach confirms the cointegration relationships despite the breakpoints. Both functions are also found to be stable under the period studied. The elasticity estimates also follow the a priori expectation being inelastic both in the long- and short run for the two functions.

Keywords: Energy demand modeling, structural breaks, parameter stability, cointegration

JEL Classification: C13, C22, C51

1. Introduction

Central to the estimation of energy demand functions in both developed and developing economies are the issues of variables' long run relationship and elasticity estimates. These issues fundamentally inform the forecasting power of energy demand models. Investigating the cointegration relationship among energy demand, prices and income is germane to establishing any meaningful policy inference regarding energy planning. In the same vein, understanding the sensitivity or responsiveness of energy demand to changes in price and income is essential in evaluating different implications of energy related policies such as

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carbon emissions reduction, optimal energy taxation, efficient energy pricing and energy conservation.

To this end, many empirical studies in the literature have been devoted to formulating and estimating demand functions for different energy products such as gasoline and kerosene (see, Cheung and Elspeth, 2004; Dahl and Kurtubi, 2001; Dahl, 1994, 2006; De Vita et al., 2006; Eltony, 2003, 2004; Halicioglu, 2007a; 2007b; Hendry and Juselius, 2000, 2001; Hughesn et al., 2006; Polemis, 2006). The empirical findings from these studies with respect to the long run relationship among energy demand, energy prices and income seem to be univocal. They all reveal the existence of cointegration relationship among the variables and the significance of price and income elasticity estimates, though with varying degree, in their respective economies.

However, most of the empirical studies fail to notice the fact that cointegration relationship may have a structural break during the sample period. Structural break in the cointegration relationship eventually implies a significant change in the cointegration parameters or even a change in the existence of cointegration relationships. Previous studies investigating long-run elasticities of energy demand in Nigeria and other developing countries heavily rely on the assumptions of time series with no structural changes and of long-run relationships that are temporally stable (see, Iwayemi et al., 2010; Dayo and Adegbulugbe, 1987; Akinboade et al., 2008; Cheung and Elspeth, 2004; Dahl and Kurtubi, 2001). However, this may not be the case given the fact that economic data often come from processes with time dependent parameters. Also, apart from the possibility of structural break, one of the fundamental challenges in energy demand modeling concerns the interaction between the price elasticity of energy demand and income.

The conventional cointegration techniques which are mostly used in the literature often fail to account for structural break effects on the relationship leading to biased estimation. This also has implications on knowing the stability of the parameters over the period under consideration (Granger and Newbold, 1974; Phillips, 1986; Leybourne and Newbold, 2003). In allowing for the effects of regime shifts in energy demand modeling in Nigeria, this study employs the Gregory and Hansen (1996) residual based test which accounts for endogenous structural break and also Hansen (1992) and Quandt and Andrews (1993) tests for parameter stability[1].

On the specification of alternative energy models, this study employs two models, namely; the *Basic model and Price-Income Interaction Parameter model.* The latter captures the extent to which the responsiveness of energy consumption to price changes increases or decreases as income changes, while former represents the conventional specification of energy consumption expressed as a function of price and income. For instance, the sort of a model employed in the estimation of energy demand, to a large extent, determines the eventual results and findings as regards the elasticity estimates. In this respect, to test the robustness of price and income elasticity estimates produced by the basic energy demand

[1] Given the rejection of cointegration with unknown break in the parameter, Gregory and Hanson (1996) technique allows the test of the null of no cointegration for the variables under consideration with I(1) order in the presence of structural break in the cointegration relationship.

model, there is need for alternative energy model specification. While there are different studies on energy demand estimation, only a few really considered alternative energy model specification, issue of structural breaks and parameter stability. However, in the case of Nigeria, no empirical study has extensively considered these issues. In lieu of this, the study contributes to the literature by making an ingenious attempt by employing alternative model specification and also addressing the issue of structural breaks and parameter stability in energy demand modeling in Nigeria.

The research questions this study seeks to answer are: What are the policy implications of the existence of structural breaks and/or regime shifts on the cointegration relationship of energy demand model in Nigeria? How sensitive are price and income elasticity estimates to alternative energy model specification when considering the price elasticity and income interaction possibility in the case of Nigeria? It should, therefore, be stressed here that while the objectives of this study are drawn from the above highlighted research questions, the contribution of this paper are as follows. This study employs an alternative cointegration technique under the assumption of possibility of structural break/regime shift in energy (gasoline and kerosene) demand functions in Nigeria. Also, the study reformulate and re-estimate energy (gasoline and kerosene) demand model specifications with the aim of capturing the interaction effect between price elasticity of energy demand and income in Nigeria.

The rest of the paper is structured as follows. Section 2 presents basic theory of cointegration with structural breaks/regime shifts. While section 3 concerns the model specification and description of data employed, section 4 involves the empirical analysis and results discussion. Finally, section 5 concerns the policy relevance of the study and conclusion.

2. Basic Theory of Cointegration with Structural Breaks/Regime Shifts

In investigating the relationship among economic variables in the face of structural breaks, the concept and dynamics of cointegration in time series econometrics has been further examined. Different types of cointegration with structural breaks haven been identified namely: cointegration with parameter changes, partly cointegration and cointegration with mechanism changes[2]. Based on the works of Perron (1989), Banerjee, Lumsdaine, and Stick (1992), Perron and Vogelsang (1992) and Zivot and Andrews (1992) where the null of a unit root in univariate time series is tested against the alternative of stationarity while allowing for a structural break in the deterministic component of the series, Gregory and Hansen (1996) developed a residual-based cointegration approach that

[2] Simply speaking, cointegration with parameter changes means the parameters of the cointegration equation happen to change at some time, but the cointegration relationship still exists. Partly cointegration means the cointegration relationship exists before or after some time but disappears in other periods. Cointegration with mechanism changes means the former cointegration relationship is destroyed because new variables enter the system and they form a new type of cointegration relationship (see, Baochen and Shiying, 2002).

allows for regime shifts. This approach centers on deriving an alternative hypothesis of one break in the cointegrating vector.[3] According to Gregory and Hansen (1996), the power of the Engle-Granger (1987) test of the null of no cointegration is substantially reduced in the presence of a break in the cointegrating relationship. To overcome this problem, they extended the Engle-Granger test in order to allow for breaks in either the intercept or trend of the cointegrating relationship at an unknown time. Therefore, given the rejection of cointegration with unknown break in the parameter, Gregory and Hanson (1996) technique allows testing the null of no cointegration of variables with I(1) order in the presence of structural break in the cointegrating relationship[4].

3. Data and Model Specification

3.1 Data

Given the underlying objectives of this study, the data used are: real gross domestic product per capita, real gasoline and kerosene prices, gasoline and kerosene consumption per capita. All data are further expressed in their natural log forms. The analytical scope of the data ranges from 1977 to 2008. All data are sourced from the Central Bank of Nigeria (CBN) Statistical Bulletin various issues.

3.2 Model Specification

Throughout the literature, energy demand function specification had rather assumed the standard consumer theory-based demand model specification. Basically, the demand function of a typical rational economic agent presupposes consumption of a commodity as a function of income, price of the commodity, price of other commodity etc. The econometric model used in this study reflects previous studies of energy demand function (see, Iwayemi et al., 2010). Apart from the fact that it is a common energy demand specification used in a large number of previous studies, it is also convenient for us to adopt this model since it allows for direct comparison with previous results from the literature. Therefore, for the case of simplicity and parsimony, we adopt the basic energy demand model (q) which is essentially specified as a function of energy price (p) and income (y). Specifically, we estimate the following model for both gasoline and kerosene demand functions:

$$q_t = \alpha_0 + \alpha_1 p_t + \alpha_2 y_t + e_t \tag{1}$$

[3] In the presence of structural break(s)/regime shift, the common test for cointegration between variables becomes bias since the distributional theory of evaluating the residual-based tests is not the same. In Gregory and Hansen (1996), Nason and Watt (1996), the impact of break in the test for cointegration is further explained as the rejection frequency of the ADF test is said to fall dramatically in the presence of a break in the cointegration vector.

[4] See the appendix for details

Meanwhile, it should be recalled here that one of the fundamental objectives of this study is to estimate demand functions for both gasoline and kerosene using an alternative model specification which incorporates price elasticity and income interaction possibility effect. The idea is to capture the extent to which the responsiveness of consumers to price changes increases or decreases as income changes over time. Basically, the price elasticity of energy demand is expected to be equal to:

$$Ep = \alpha_1 + \alpha_2 + \alpha_3 y_t \tag{2}$$

Since the price elasticity is less than zero, a positive coefficient α_3 on the interaction term indicates a decrease in the price response as income rises. Consequently, the following represents the simple price-income interaction model employed:

$$q_t = \alpha_0 + \alpha_1 p_t + \alpha_2 y_t + \alpha_3 p_t y_t + e_t \tag{3}$$

3.3 Econometric Analytical Procedures

The standard econometric analytical procedures of time series model estimation are strictly adhered to in this study. We commence our empirical exercise by performing unit roots test with the aim of confirming the integration properties of the variables employed by employing the Augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) tests (Dickey and Fuller, 1979; Phillips and Peron, 1988). Also, batteries of cointegration techniques including the more recent and robust Gregory and Hansen (1996) approach are employed. Following the results of the cointegration tests (where cointegration relationship is established), we proceed to estimating the elasticity estimates of the functions. Given the fact that the responsiveness of both the price and income varies with the type of model specified among other factors, we specify different energy demand models such as the basic, dynamic and the price-income interaction models with the aim of strengthening the robustness of the analysis. Finally, following the results of the elasticity estimates obtained from these models, we perform different parameter stability tests such as the Hansen test and Quant-Andrews unknown break point test. The intention is to affirm the dynamics of parameter stability over the period under analysis.

4. Empirical Analysis and Discussion

4.1 Unit root test

The study performs the unit root tests on the variables under consideration, namely gasoline consumption per capita, kerosene consumption per capita, income per capita, prices of gasoline and kerosene. As earlier highlighted, two unit root tests- ADF and PP- are used. While the null hypothesis for both tests is that there is a unit root, the optimal lag lengths selection is done by the Schwarz Bayesian criteria. All unit root test regressions are run with a constant and trend term. The results as detailed in Table 1 indicate the existence of unit root for all the variables at their levels. In other words, the tests were unable to reject the null hypothesis for all the variables. However, the variables appear to be stationary at first difference, i.e. integrated at order 1. This result, therefore, implies that examination of possible cointegration relationship among the variables is worthwhile.

Table 1: Unit Root Tests

ADF test Statistic	***Variables***	***t-statistics***	***Prob.****
At Level	GDP (*y*)	-0.232	0.925
	Gasoline Consumption (*q*)	-2.084	0.251
	Gasoline Price (*p*)	6.174	1.000
	Kerosene Consumption (*q*)	-1.733	0.538
	Kerosene Price (*p*)	-0.297	0.841
At First Difference	GDP (*y*)	-4.846	0.000
	Gasoline Consumption (*q*)	-6.747	0.000
	Gasoline Price (*p*)	-2.914	0.053
	Kerosene Consumption (*q*)	-5.011	0.000
	Kerosene Price (*p*)	-3.659	0.022
P-P test Statistic	***Variables***	***t-statistics***	***Prob.****
At Level	GDP (*y*)	-0.412	0.896
	Gasoline Consumption (*q*)	-2.067	0.258
	Gasoline Price (*p*)	8.831	1.000
	Kerosene Consumption (*q*)	-1.617	0.592
	Kerosene Price (*p*)	-0.410	0.901
At First Difference	GDP (*y*)	-4.795	0.000
	Gasoline Consumption (*q*)	-7.762	0.000
	Gasoline Price (*p*)	-2.799	0.060
	Kerosene Consumption (*q*)	-4.371	0.000
	Kerosene Price (*p*)	-8.512	0.000

*MacKinnon (1996) one-sided p-values

4.2 Cointegration tests without structural breaks

Among the cointegration techniques employed here are the VAR-based multivariate Johansen, Engle-Granger, and Phillips-Ouliaris single-equation cointegration techniques. The results of the respective cointegration tests are presented in Table 2, 3 and 4. One of the striking features of the results pertains to the seemingly conflicting cointegration evidences among the variables. For instance, while the VAR-based Johansen maximum likelihood tests suggests the existence of one cointegrating vector among all variables in the two energy demand (gasoline and kerosene) models, findings from both the Engle-Granger and Phillips-Ouliaris single-equation cointegration techniques, refute the cointegration evidence among the variables. It must, however, be noticed that the conventional cointegration tests results in the presence of structural break(s)/regime shift become biased (see, Gregory and Hansen, 1996; Gregory et al., 1996). For instance, it would be erroneous and of course misleading to conclude and/or deduct policy inference based on the results of cointegration tests as seen in Table 3. More specifically, since the power of residual-based cointegration tests such as the Engle-Granger and Phillips-Ouliaris often fall dramatically in the presence of a break in the cointegration vector, there is need for an alternative cointegration test which fundamentally allows for the possibility of structural breaks/regime shifts in our models.

Table 2: Multivariate Johansen Cointegration Test

(a) Gasoline				
Ho	H_A	λ_{tr} ***test***	λ_{tr} *(0.95)*	***Prob***
r = 0	r=1	32.12	29.79	0.026
r ≤ 1	r=2	7.60	15.49	0.509
r ≤ 2	r=3	0.05	3.84	0.819
Ho	H_A	λ_{tr} ***test***	λ_{tr} *(0.95)*	***Prob***
r=0	r=1	24.53	21.13	0.016
r=1	r=2	7.54	14.26	0.427
r=2	r=3	0.05	3.84	0.819
(b) Kerosene				
Ho	H_A	λ_{tr} ***test***	λ_{tr} *(0.95)*	***Prob***
r = 0	r=1	31.58	29.79	0.036
r ≤ 1	r=2	4.38	15.49	0.870
r ≤ 2	r=3	0.01	3.84	0.907
Ho	H_A	λ_{tr} ***test***	λ_{tr} *(0.95)*	***Prob***
r=0	r=1	22.20	21.13	0.042
r=1	r=2	4.36	14.26	0.427
r=2	r=3	0.05	3.84	0.819

Note: Critical values are calculated following the approach in Mackinnon et al. (1999)

Table 3: Conventional Residual-Based Cointegration Tests

(a) Gasoline				
Engle-Granger Test				
Dependent	***tau-statistic***	***Prob.****	***z-statistic***	***Prob.****
y	-0.998559	0.9662	-2.894700	0.9653
p	-1.988986	0.7427	-17.09904	0.1333
q	-3.350912	0.1675	-14.36408	0.2502
Phillips-Ouliaris Test				
Dependent	***tau-statistic***	***Prob.****	***z-statistic***	***Prob.****
y	-1.306669	0.9326	-4.456231	0.9123
p	-1.111021	0.9564	-4.963319	0.8880
q	-3.380565	0.1597	-15.00221	0.2192
(b) Kerosene				
Engle-Granger Test				
Dependent	***tau-statistic***	***Prob.****	***z-statistic***	***Prob.****
y	-2.240376	0.6304	-9.023312	0.6065
p	-2.118709	0.6867	-10.34714	0.5046
q	-3.928277	0.0605	-16.94599	0.1418
Phillips-Ouliaris Test				
Dependent	***tau-statistic***	***Prob.****	***z-statistic***	***Prob.****
y	-1.850440	0.7963	-5.835018	0.8389
p	-1.589986	0.8764	-5.591521	0.8535
q	-3.922518	0.0612	-15.39430	0.2015

Note: Probability values are calculated following the approach in MacKinnon et al. (1996)

4.3 Cointegeration tests with structural breaks

Given the short-coming of the earlier conventional tests in identifying any meaningful long run relationship in the presence of structural breaks, this study finds it needful to further subject the long run relationship among the variables in both energy functions to a more rigorous and robust test which consents to possibility of structural breaks in the relationship. The result of this test is depicted in Table 4. Though, the results reveal that evidence of cointegration is not found when considering the assumption of a level shift and a level shift with trend (i.e. C and C/T models), evidence of cointegration relationships is clearly established when assuming a shift which allows the slope vector to shift (model C/S), otherwise known as structural break in both functions. Having identified plausible breaks in the systems, the test does suggest that a structural break in the cointegration vector is important and needs to be taken care of in the specification of energy demand functions in Nigeria.

Table 4: Gregory-Hansen Structural Break Cointegration Test

(a) Gasoline Demand Model

Model	*ADF**	*Breakpoint*	*Zt**	*Breakpoint*	*Zα**	*Breakpoint*
C	-3.90 (1)	1979	-3.80	1978	-22.01	1978
C/T	-5.70 (1)*	1979	-5.22	1978	-32.71	1980
C/S	-12.56 (1)**	1981	-10.60**	1982	-54.69	1979

(b) Kerosene Demand Model

Model	*ADF**	*Breakpoint*	*Zt**	*Breakpoint*	*Zα**	*Breakpoint*
C	-4.24 (0)	1999	-4.30	1999	-25.68	1999
C/T	-5.00 (1)	1980	-4.60	1980	-29.00	1980
C/S	-34.23 (2)**	1979	-11.38**	1980	53.88	1980

Note: The 5% CVs are -5.50 and -58.33 for the ADF/Zt*and Zα* tests, respectively (see, Table 1 of Gregory and Hansen, 1996)

4.4 Long run estimates

With the aim of estimating more rigorously the elasticity estimates for both the demand for gasoline and kerosene functions, this study embarks on specifying three different models, namely the Ordinary Least Square (OLS), Dynamic OLS[5] and Price-Income Interaction models. While the OLS and Dynamic OLS respectively represent the commonly applied basic models in the estimation of energy demand functions, the Price-Income Interaction model aims at capturing the interaction effect between price elasticity of energy demand and changes in income. As earlier rehearsed, the need is to capture the extent to which the responsiveness of energy consumption to price changes increases or decreases as income changes. Table 5 depicts different long run elasticity estimates as estimated from these three models. As evident from the table, the long run elasticity estimates of both the OLS and DOLS are not significantly different for both the gasoline and kerosene functions. To start with, price and income elasticity estimates seem to follow

[5] The Dynamic Ordinary Least Square (DOLS) is an asymptotically efficient estimator which eliminates the feedback in the cointegrating system as advocated by Stock and Watson (2003) and Stock and Watson (1993). It involves augmenting the cointegrating regression with lags and leads so that the resulting cointegrating equation error term is orthogonal to the entire history of the stochastic regressor innovation.

the *a priori* expectation in terms of their relationships with respect to signs and magnitudes. We find that both price and income elasticity estimates are negatively and positively signed, respectively. They are also shown to be inelastic, though with varying degree (here, income elasticites are found to be higher than price elasticities for both energy demand functions). Meanwhile, the findings from the Price-Income Interaction model show that the coefficients on price, income and the interaction term are significant for the period under investigation for both functions. Finally, the error correction terms of the respective models also follow the expected sign and magnitudes.

Table 5: Long Run Elasticity Estimates

(a) Gasoline

Variables	*OLS*	*Dynamic (OLS)*	*Price-Income Interaction*
Constant	0.063 (4.057)	0.016 (3.862)	0.192 (4.001)
Income	0.714 (2.086)	0.511 (2.171)	0.358 (1.916)
Price	-0.015 (-2.031)	-0.104 (-1.692)	-0.016 (-1.137)
Price-Income	------------	------------	-0.233 (-1.874)
SR Ect(-1)	-0.328 (-3.090)	-0.432 (-0.2.750)	-0.622 (-3.00)
Adj. R^2	0.45	0.57	0.68

(b) Kerosene

Variables	*OLS*	*Dynamic (OLS)*	*Price-Income Interaction*
Constant	0.187 (5.862)	0.022 (3.524)	0.178 (1.969)
Income	0.680 (2.171)	0.403 (2.611)	0.371 (3.057)
Price	-0.195 (-1.728)	-0.0816 (-1.692)	-0.205 (-2.174)
Price-Income	------------	------------	0.109 (1.702)
SR Ect(-1)	-0.495 (-2.897)	-0.212 (-1.880)	-0.398 (-2.710)
Adj. R^2	0.49	0.60	0.74

4.5 Parameter Stability Test

One of the aims of this study is to examine whether the estimated long-run relationship between the energy demand and its determinants in Nigeria really exhibits the desired property of structural stability over time[6]. The study applies two different parameter stability tests, namely the Hansen and Quandt-Andrews breakpoints test for one or more

[6] Since the estimation periods for our study cover the fairly volatile period, it is important to check whether the models (hence, parameters) under estimation are really stable over these periods.

unknown structural breakpoint(s). Basically, Hansen (1992) proposes three tests (Lc, MeanF, and SupF) for parameter instability based on the full modified statistics.[7] The test which is performed using a trimming region of 15% simply examines the null hypothesis of no sudden shift in the regime (Narayan and Narayan, 2010). The results of the test for parameter instability for both functions (gasoline and kerosene) are presented in Table 6 together with their probability values. As evident from the results, these tests show signs of parameter stability. This, result is also confirmed by the G-H Cointegration test, though structural breaks are identified in the system. Therefore, we can conclude that there is strong evidence that parameters are stable for the two energy demand functions.

The study also applies the Quandt-Andrews breakpoints test with the null hypothesis of no breakpoints within a trimming region of 15%. The test statistics which are based on the Maximum statistics, Exp statistic and the Ave statistic (see Andrews, 1993 and Andrews and Ploberger, 1994) are reported in Table 7. The entire summary statistic measures fail to reject the null hypothesis of no structural breaks within the period considered.

Table 6: Hansen Parameter Instability Test

(a) Gasoline				
	Stochastic	*Deterministic*	*Excluded*	
Lc statistic	Trends (m)	Trends (k)	Trends (p2)	Prob.*
0.056113	2	0	0	> 0.2
(b) Kerosene				
	Stochastic	*Deterministic*	*Excluded*	
Lc statistic	Trends (m)	Trends (k)	Trends (p2)	Prob.*
0.052265	2	0	0	> 0.2

[7] The null hypothesis of co-integration goes against the alternative of no co-integration, since the absence of co-integration is captured by an alternative hypothesis of parameter instability (Lee and Chang, 2005)

Table 7: Quandt-Andrews Unknown Breakpoint

(a) Gasoline		
Statistic	*Value*	*Prob.*
Maximum LR F-statistic (1982)	4.776451	0.8295
Maximum Wald F-statistic (1982)	4.776451	0.8295
Exp LR F-statistic	1.480448	0.5889
Exp Wald F-statistic	1.480448	0.5889
Ave LR F-statistic	2.775443	0.4590
Ave Wald F-statistic	2.775443	0.4590
(b) Kerosene		
Statistic	*Value*	*Prob.*
Maximum LR F-statistic (1982)	4.982240	0.8032
Maximum Wald F-statistic (1982)	4.982240	0.8032
Exp LR F-statistic	1.467755	0.5945
Exp Wald F-statistic	1.467755	0.5945
Ave LR F-statistic	2.213750	0.6235
Ave Wald F-statistic	2.213750	0.6235

Note: Since the original equation was linear, the LR F-statistic is identical to the Wald F-statistic.

5. Policy Relevance and Conclusion

The primary goal of the paper centers on investigating the cointgration status of energy demand models with a special focus on structural breaks/regime shifts, parameter stability and alternative model specification. Hence, the study estimates petroleum products demand functions for Nigeria from 1977 to 2008. Specifically, demand functions for both the gasoline and kerosene are estimated under two different models.

The main finding as revealed in this study is that in the energy (gasoline and kerosene) functions, price and income elasticity estimates are inelastic both in the long and short run. Also, the responsiveness of consumers to price changes tends to decreases as income increases over time in the case of kerosene demand. However, in the case of gasoline demand, the results show an increase in the price response as income rises. There are evidences of structural breaks in the cointegration in both models for kerosene and gasoline demand. Also, the result from parameter tests reveals that price and income elasticity estimates in both models are stable. It is envisaged, therefore, that substantial policy lessons would be drawn from the findings of this study especially in the current phase of energy industry deregulation in Nigeria. Having identified plausible breaks in the systems, the test does suggest that a structural break in the cointegration vector is important and needs to be taken care of in the specification of energy demand functions in Nigeria.

Finally, it should be emphasized here that further empirical studies could still explore the short run dynamics of energy demand in Nigeria through the use of other methods such as the Error Correction and VAR techniques as this would further enrich the empirical literature.

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Appendix

Structural Breaks Cointegration

As earlier stated, this cointegration technique is an extension of ADF, Zα, and Zt tests for cointegration and can be seen as a multivariate extension of the endogenous break test for univariate series. Basically, in the G-H tests, there are four different models for the analysis of structural change in the cointegrating relationship. These models are: (i) level shift, C; (ii) level shift with trend, C/T; (iii) regime shift where both intercept and slope coefficient change, C/S; and (iv) regime shift where intercept, slope coefficient and trend change, C/S/T. Hence, the following equations represent the specifications of the models, respectively:

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \alpha y_{2t} + e_t \tag{4}$$

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \delta t + \alpha y_{2t} + e_t \tag{5}$$

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \delta t + \alpha_1^T y_{2t} + \alpha_2^T y_{2t}\varphi_{t\tau} + e_t \tag{6}$$

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \delta_1 t + \delta_2 t\varphi_{t\tau} + \alpha_1^T y_{2t} + \alpha_2^T y_{2t}\varphi_{t\tau} + e_y \tag{7}$$

Equations (4) to (7) represent the generalized standard model of cointegration. The idea here is to allow for both a regime trend shift under the alternative hypothesis (Gregory and Hansen, 1996). The observed data are $y_t = (y_{1t}, y_{2t})$ where y_{1t} is a scalar variable, y_{2t} is a vector of explanatory variables and μ is the disturbance term. While φ represents the dummy variable both y_{1t} and y_{2t} are expected to be I(1) variables. The dummy variable is then defined as:

$$\varphi_{t\tau} = \begin{cases} 0, if \ t \leq [n\tau] \\ 1, if \ t > [n\tau] \end{cases}$$

The unknown parameter, $\tau \in (0,1)$, is the relative timing of the change point and [ ] denotes integer part. Parameters μ_1, α_1 and β_1 measure, respectively, the intercept, slope coefficients and trend coefficient before the break and μ_1, α_1 and β_1 are the corresponding changes after the break. Following the computed cointegration test statistic for each possible regime shift by Gregory and Hansen (1996), equations (4) to (7) are estimated for all possible break date in the sample. The smallest value of ADF(τ), $Z_\alpha(\tau)$ and $Z_t(\tau)$ across all possible break points are selected to reject the null hypothesis of no cointegration[8].

[8] The critical values for the break test are reported in Gregory and Hansen (1996).