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Modeling Gasoline Demand with Structural Breaks: New Evidence from Nigeria

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ABSTRACT: This paper extends previous studies in modeling and estimating demand for gasoline for Nigeria from 1977 to 2008. The ingenious attempt of this study, contrast to earlier studies on Nigeria and other developing countries, lies in its assumption of structural breaks in the long run relationship among the variables employed. The study tests for the possibility of structural breaks/regime shifts and parameter instability in the gasoline demand function in Nigeria using more recent and robust techniques. While the conventional residual-based cointegration tests employed fail to identify any meaningful long-run relationship in the gasoline function, the Gregory-Hansen structural break cointegration approach confirms the cointegration relationships despite the breakpoints. The elasticity estimates also follow the a priori expectations being inelastic both in the long- and short-run for both price and income. 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 gasoline demand functions in Nigeria. 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.

Keywords: Gasoline demand modeling; Structural breaks; Parameter stability; Cointegration
JEL Classifications: C13, C22, C51

1. Introduction

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 carbon emissions reduction, optimal energy taxation, efficient energy pricing and energy conservation. Different empirical studies in the literature have been devoted to formulating and estimating demand functions for different energy products such as gasoline (see Cheung and Elspeth, 2004; Dahl and Kurtubi, 2001; Dahl, 1994, 2006; De Vita, et al., 2006; Eltony, 2003, 2004; Hendry and Juselius, 2000, 2001; Hughesn et al., 2006; and Polemis, 2006). Central to the estimation of gasoline demand function 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. The empirical findings from these studies with respect to the long run relationship among gasoline demand, prices and per capita 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.

Previous studies investigating long-run elasticities of gasoline 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. Hence, an assumption of 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. Therefore, this relationship is likely to be subject to variation as a result of changes in the economy's structure like changes in energy policy or economic development regime, reforms in energy regulation, or institutional developments. In addition, the issue of parameter stability is important if the long-run equilibrium relation is to be useful in long-term energy planning and policy formulation.

The conventional cointegration techniques which are mostly used in the literature in investigating gasoline demand function 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 and Leybourne and Newbold, 2003). In allowing for the effects of regime shifts in gasoline 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. Given the rejection of cointegration with unknown break in the parameter, Gregory and Hanson (1996) technique allows us to test the null of no cointegration for the variables under consideration with I(1) order in the presence of structural break in the cointegration relationship.

Also, long run relationship in gasoline demand models is likely to be subject to variation as a result of changes in the economy's structure like changes in energy policy, reforms in energy market, institutional developments, high and frequent rates of political instability and, of course, incessant policy regime shifts and/or policy reversal. Therefore, an estimation of gasoline demand function with emphasis on structural breaks and parameter stability becomes pertinent in the case of Nigeria. While there are different studies on gasoline demand estimation, only few considered the 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, and in contrast to past empirical works, this study contributes to the literature by making an ingenious attempt by addressing the issue of structural breaks and parameter stability in gasoline demand modeling in Nigeria.

The research question this study seeks to answer is: What are the policy implications of the existence of structural breaks and/or regime shifts on the cointegration relationship of gasoline demand model in Nigeria? It should, therefore, be stressed here that while the objective of this study is drawn from the above highlighted research question, the contribution of this paper are as follows. This study employs an alternative cointegration and parameter stability techniques under the assumption of possibility of structural break/regime shift in gasoline demand function in Nigeria. The rest of the paper is structured as follows. Section 2 highlights basic theory of cointegration with structural breaks/regime shifts. Section 3 details methodological approach employed in this study including data sources, measurement and model specification. While section 4 concerns the empirical results and discussions, conclusion is made in section 5.

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

In investigating the relationship among economic variables in 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. 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). Given the following cointegration equation: $Yt = a + bXt + \varepsilon t$, where Xt , Yt are integration time series with order of d and εt is residual series, the conventional residual-based cointegration test presume that there is no cointegration between variables (Y and X) if the test fails to reject the null hypothesis for a sample period. However, the presence of structural break(s) in this equation simply nullifies, breaks down and disintegrates this assertion or presumption.

Based on the works of Perron (1989), Banerjee et al., (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 allows for regime shifts. Gregory and Hansen (1996) residual-based tests for cointegration centers on deriving an alternative hypothesis of one break in the cointegrating vector.[1] 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, Gregory and Hansen (1996) extended the Engle-Granger test to allow for breaks in either the intercept or the intercept and 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.

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:

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \alpha y_{2t} + e_t \qquad (1)$$

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \delta t + \alpha y_{2t} + e_t \qquad (2)$$

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \delta t + \alpha_1^T y_{2t} + \alpha_2^T y_{2t}\varphi_{t\tau} + e_t \qquad (3)$$

$$y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \delta_1 t + \delta_2 t\varphi_{t\tau} + \alpha_1^T y_{2t} + \alpha_2^T y_{2t}\varphi_{t\tau} + e_t \qquad (4)$$

Equations (1) to (4) 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:

$$\varphi_{t\tau} = \begin{cases} 0, & if\ t \le [n\tau] \\ 1, & if\ t > [n\tau] \end{cases} \qquad (5)$$

The unknown parameter, $\tau \in (0,1)$ is the relative timing of the change point and [ ] denotes integer part. Following the computed cointegration test statistic for each possible regime shift by Gregory and Hansen (1996), equations (1) to (4) 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.[2]

[1] 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.

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

3. Methodology and Data

3.1. Data

Given the underlying objective of this study which centers on re-estimating gasoline demand function with special emphasis on structural breaks (hence parameter stability), this study employs the Nigerian annual time series data. Thus the data used are: real gross domestic product per capita, real gasoline prices and gasoline 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, the macroeconomic 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, therefore, reflects previous studies of gasoline demand (see Iwayemi et. al., 2010). Apart from the fact that it is a common gasoline 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 gasoline demand model which is essentially specified as a function of price and income. The model is specified as follow:

$$q_t = \alpha_0 + \alpha_1 p_t + \alpha_2 y_t + e_t$$

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. Basically, the idea is to test whether the variables are integrated. We consequently employ the Augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) tests (Dickey and Fuller, 1979; Phillips and Peron, 1988). Also, since we are more interested in investigating the long run relationship of the variables under consideration allowing for the incidence of structural breaks, this study employs batteries of cointegration techniques including the more recent and robust Gregory and Hansen (1996) approach which allows for endogenous identification of break in the variables. This is also needful in order to further present a more rigorous cointegration analysis especially when external shocks or policy shift/reversal are assumed in the model. Finally, following the results of the cointegration tests (where cointegration relationship is established) we proceed to estimating the elasticity estimates of the function. Following the results of the elasticity estimates obtained from the model, 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 scope of the period under analysis. This is also fundamental to gasoline demand forecasting exercise.

4. Empirical Results and Discussions

4.1. Unit root test

The study performs the unit root tests on the variables under consideration, namely gasoline consumption per capita, income per capita, prices of gasoline. 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	-0.232	0.925
	Gasoline Consumption	-2.084	0.251
	Gasoline Price	6.174	1.000
At First Difference	GDP	-4.846	0.000
	Gasoline Consumption	-6.747	0.000
	Gasoline Price	-2.914	0.053
P-P test Statistic	***Variables***	***t-statistics***	***Prob.****
At Level	GDP	-0.412	0.896
	Gasoline Consumption	-2.067	0.258
	Gasoline Price	8.831	1.000
At First Difference	GDP	-4.795	0.000
	Gasoline Consumption	-7.762	0.000
	Gasoline Price	-2.799	0.060

*MacKinnon (1996) one-sided p-values

4.2. Cointegration tests without structural breaks

In this study, we embark on investigating the long run relationships among the variables using both conventional and more recent cointegration methodologies. Among the cointegration techniques employed are the VAR-based multivariate Johansen, Engle-Granger, Phillips-Ouliaris single-equation cointegration techniques and the Gregory-Hansen cointegration technique which allows for endogenous identification of structural breaks. The results of the respective cointegration tests are presented in table 2, 3 and 4. One of the striking features of these reports pertains to the seemingly conflicting cointegration evidences among the variables. For instance, while the result from the VAR-based Johansen maximum likelihood tests suggests that there exists one cointegrating vector among all variables, findings from both the Engle-Granger and Phillips-Ouliaris single-equation cointegration techniques, refute the cointegration evidence among the variables in the model.

Table 2. Multivariate Johansen Cointegration Test

Ho	**H_A**	**λ_{tr} test**	**λ_{tr} (0.95)**	**Prob.**
r = 0	r=1	32.12	29.79	0.026
$r \leq 1$	r=2	7.60	15.49	0.509
$r \leq 2$	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

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

It must, however, be noticed that since the plot of the series suggests that the data might have a structural break(s), the conventional cointegration tests results in the presence of structural break(s)/regime shift, become biased following the fact that the distributional theory of evaluating the residual-based tests is not the same (see Gregory and Hansen, 1996 and Gregory et al., 1996). This explains while most findings from earlier studies which predominantly rely on these conventional tests in establishing the long run relationships could be biased. For instance, it would be erroneous and of course misleading to conclude and thus 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

Table 3. Conventional Residual-Based Cointegration Tests

Engle-Granger Test				
Dependent	***tau-statistic***	***Prob.****	***z-statistic***	***Prob.****
GDP	-0.998559	0.9662	-2.894700	0.9653
Price	-1.988986	0.7427	-17.09904	0.1333
CONS	-3.350912	0.1675	-14.36408	0.2502
Phillips-Ouliaris Test				
Dependent	***tau-statistic***	***Prob.****	***z-statistic***	***Prob.****
GDP	-1.306669	0.9326	-4.456231	0.9123
Price	-1.111021	0.9564	-4.963319	0.8880
CONS	-3.380565	0.1597	-15.00221	0.2192

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

4.3. Cointegeration tests with structural breaks

Since the Gregory-Hansen structural break test is based on the notion of regime change, it thus allows for an endogenous structural break in the cointegration vector by considering three alternative models: a level shift (model C), a level shift with a trend (model C/T), and a regime shift which allows the slope vector to shift as well (model C/S). 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 to a more rigorous and robust test which consents to possibility of structural breaks in the relationship. This, therefore, informs our choice for the Gregory-Hansen test in this study. The result of this test is depicted in table 4 for demand for gasoline. 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 gasoline demand functions in Nigeria. Also, the structural breakpoints as identified in the results of both demand functions seem to match clearly with the corresponding critical economic incidents in Nigeria.

Table 4. Gregory-Hansen Structural Break Cointegration Test

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

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 demand for gasoline function, this study embarks on specifying two different models, namely the Ordinary Least Square (OLS) and Dynamic OLS[3] models. Table 5 depicts different long run elasticity estimates as estimated from these models. As evident from the table, the long run elasticity estimates of both the OLS and DOLS are not significantly different for gasoline function. To start with, price and income elasticity estimates seem to follow 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 elasticities are found to be higher than price elasticities). Finally, the error correction term of the model also follow the expected sign and magnitudes.

[3] 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.

Table 5. Long Run Elasticity Estimates for Gasoline Demand Models

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 (-1.975)	-0.622 (-3.00)
Adj. R^2	0.45	0.57	0.68

4.5. Parameter stability test

One of the aims of this study is to examine whether the estimated long-run relationship between the gasoline demand and its determinants in Nigeria really exhibits the desired property of structural stability over time. Hence, there is need to investigate how stable the parameters are. In order to further strengthen the robustness of our analysis, this study applies two different parameter stability tests, namely the Hansen and Quandt-Andrews breakpoints test for one or more unknown structural breakpoint(s). Since the estimation periods for our study cover the fairly volatile period, consequently, it is important to check whether the models (hence, parameters) under estimation are really stable over these periods. Basically, Hansen (1992) proposes three tests (Lc, MeanF, and SupF) for parameter instability based on the full modified statistics.[4] Our aim specifically is to examine how stable the parameters are, thus the study is interested primarily in the Lc statistics. 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 gasoline function 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.

Table 6. Hansen Parameter Instability Test

	Stochastic	Deterministic	Excluded	
Lc statistic	Trends (m)	Trends (k)	Trends (p2)	Prob.*
0.056113	2	0	0	> 0.2

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 7. Quandt-Andrews Unknown Breakpoint

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

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

[4] 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)

5. Policy Relevance and Conclusion

The primary goals of the paper center on investigating the cointgration status of gasoline demand model with a special focus on structural breaks/regime shifts, parameter stability and alternative model specification. Hence, the study estimates gasoline demand function for Nigeria from 1977 to 2008 with special emphases on alternative model specification, structural breaks and parameter stability. Specifically, demand function for gasoline is estimated under two different models.

The main finding as revealed in this study is that in the energy (gasoline) functions, price and income elasticity estimates are inelastic both in the long and short run. Meanwhile, the findings from the Price-Income Interaction Parameter Model show that the responsiveness of consumers to price changes tends to increase as income increases over time. There are evidences of structural breaks in the cointegration in the gasoline demand model. Also, the result from parameter tests reveals that price and income elasticity estimates are stable. 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 gasoline demand function in Nigeria. Also, the structural breakpoints as identified in the results seem to match clearly with the corresponding critical economic incidents in Nigeria. 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.

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