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Modeling Petroleum Product Demand in Nigeria Using Structural Time Series Model (STSM) Approach[1]

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ABSTRACT: In this paper, the demand function for five major petroleum products consume in Nigeria namely gasoline, diesel, kerosene, fuel oil, liquefied petroleum gas (LPG) and aggregate was estimated using Structural Time Series Models (STSMs) which accounts for structural changes in energy demand estimation. STSMs incorporate stochastic rather than deterministic trend which is more general and therefore argued to be more appropriate in this study. The results suggest that the demand for petroleum products in Nigeria is both price and income inelastic and the underlying demand trends were generally stochastic in nature. LPG has relatively higher elasticities than the rest of the petroleum products, namely kerosene, gasoline, diesel and fuel oil.

Keywords: Petroleum Product; demand; STSM; Stochastic Trend
JEL Classifications: C32; Q43; Q47

1. Introduction

Petroleum products are key inputs vital for the growth and transformation of any economy. They are in fact, inputs in every product that is produced and every service accomplished in today's modern world. Thus, understanding the nature of their demand including key drivers is necessary to plan consumption that is consistent with long term growth objectives. Since the first oil price shocks of early 1970s, there has been increasing attention on oil demand studies, with a view to generating accurate demand parameters for planning, projections and policy formulation. Various modeling and estimation techniques have been employed to understand the relationship between oil consumption and other economic variables especially price and income. These include Static Models, Partial Adjustment Models (PAMs), Autoregressive Distributive Lags (ARDLs) Models, Cointegration and Error Correction Models (ECMs) as well as Structural Time Series Models (STSMs). The choice of appropriate technique to model oil demand is useful for accurate projections of future consumption levels.

Recent studies on energy demand focus on cointegration technique which has the beauty of capturing both long-run and short-run dynamics in a single stationary model (see for example Dahl and Kurtubi, 2001; De Vita et al., 2006; Iwayemi et al., 2009). The technique however ignores structural changes which are important features of energy demand particularly for developing countries such as Nigeria. Bhattacharyya and Timilsina (2010) argued that energy demand models for developing countries which ignore structural changes or informal and traditional economic activities are unable to truly reflect such country's condition. This is because declining role of traditional energy has important implication for energy demand due to changes in life style, consumer choices and fuel mix and socio-demographic and environmental factors which are not easily measured.

It is further argued that over reliance on cointegration without due consideration to structural changes has the potential of significant bias in price and income elasticities (Hunt et al., 2003a;

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Adeyemi and Hunt, 2007; Adebisi, 2010). Whereas most energy demand models ignore this important feature or at best, attempted to capture structural change with a deterministic time trend, the STSMs permits a more flexible approach of modelling Underlying Energy Demand Trend (UEDT) which can reveal the true pattern of changes in economic structure over time. STSM fits an ARDL framework and further decomposes a set of time series into unobservable components but having meaningful economic interpretation (mainly trend, seasonal and irregular components).This study therefore attempt to model petroleum product demand in Nigeria using the STSM approach. Generally few empirical studies were carried on energy demand using econometric modeling to estimate elasticities for Nigeria despites its prominence as the largest oil producer in Africa and one of the major consumer of petroleum products (Iwayemi et al., 2009). Most recent studies relating to energy demand on Nigeria heavily relied on cointegration technique (see for example (Iwayemi et al., 2009; Omisakin et al., 2012; Nwosa and Ajibola, 2013).

This paper is divided into six sections. Section 2 presents an overview of the Nigerian downstream petroleum sector. Review of relevant literature is presented in Section 3 while Section 4 discusses in detail the data and Empirical Methodology and Section 5 presents the main results of the estimation and Section 6 presents the conclusion and policy implication of the study.

2. An Overview of the Nigerian Downstream Petroleum Sector

The petroleum industry is one of the important sectors of the Nigerian economy, both as a source of foreign exchange earnings and supplier of various refined petroleum products for domestic consumption. Oil resources account for 91% of foreign exchange earnings, 83% of government revenue and 30% of the GDP (CBN, 2009). Nigeria is ranked 10th in the world in terms of oil reserve and 9th in terms of gas with a proved reserve estimates of 37.2 billion barrel and 186.9 trillion cubic feet respectively (BP Statistical Review, 2011). Annual average crude oil and condensate production stood at 2.37 mbd and about 6.6 bcf of natural gas (NNPC, 2011).

Petroleum products dominate fossil energy consumption mix in Nigeria. In the recent years, socioeconomic, technological and demographic developments have resulted into increased demand of petroleum products. These products account for 78% of fossil-based fuel consumption, followed by electricity (13%) and natural gas (9%) (IEA, 2011). Until recently, the prices of most petroleum products in Nigeria were heavily subsidized and the major supplier of these products is the state owned company – Nigerian National Petroleum Corporation (NNPC). This has several implications for the government. First is the increase local demand and therefore fiscal cost of subsidy. Second is decrease export revenue.

Nigeria has four (4) refineries – all owned by NNPC. They are Portharcourt I & II, Warri and Kaduna Refinery with a combined capacity of 445,000 b/d. The refineries have not reached full production capacity due to operational failures and sabotage mainly on crude pipeline feeding the refineries.

Increasing domestic demand coupled with poor performance of domestic refineries prompted the Nigerian government to commence liberalization and deregulation of the downstream oil sub sector. Petroleum product consumption in 2009 is estimated at 8.81 million tonnes, out of which over 70% was imported due to rising demand and the poor state of the domestic refineries (CBN, 2009).

Figure 1 shows trend in petroleum product consumption in Nigeria for the period 1978 – 2010. It can be observed that between 1990 and 2000, there were significant fluctuations in petroleum product consumption, particularly gasoline, diesel and kerosene. Marked drop in consumption in 1990 and 1998 were as a result of unprecedented scarcity.

Rising cost of subsidy and poor management of product supply by the government have caused severe fuel crisis between the years 1990 to 2000. The government made several attempts to increase product prices and deregulate the fuel market, which was always greeted with massive protests by the civil society and the general public.

Figure 1. Trends in Petroleum Products Consumption ('000 Tons) in Nigeria (1978 – 2010)

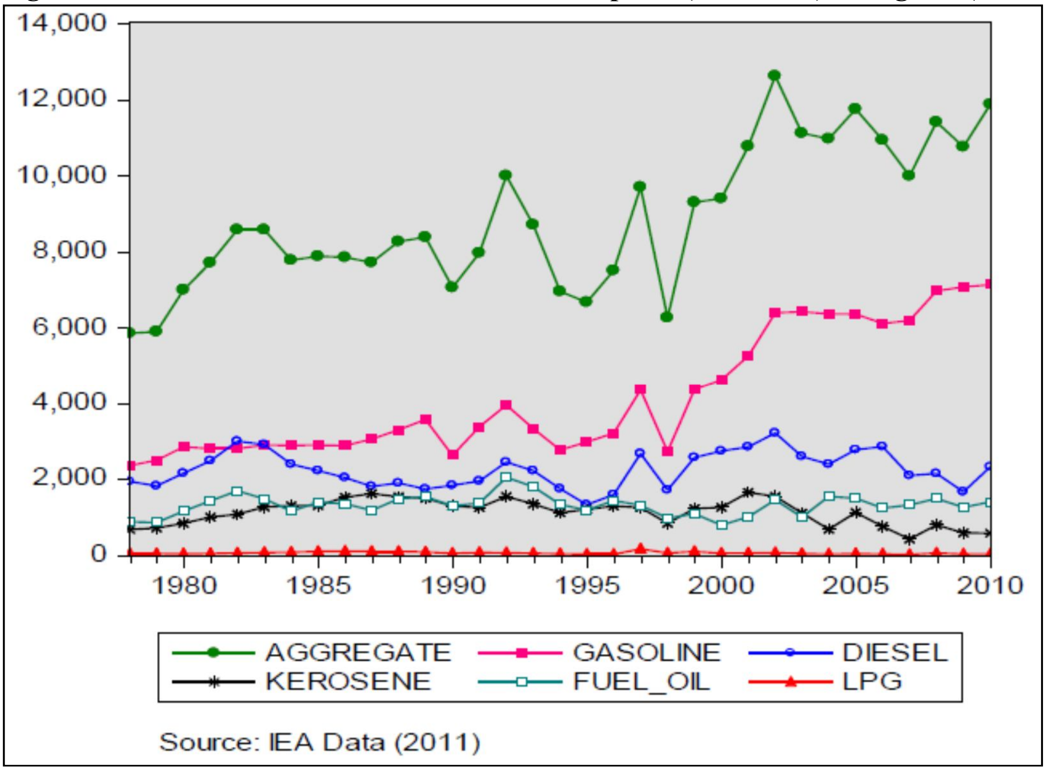
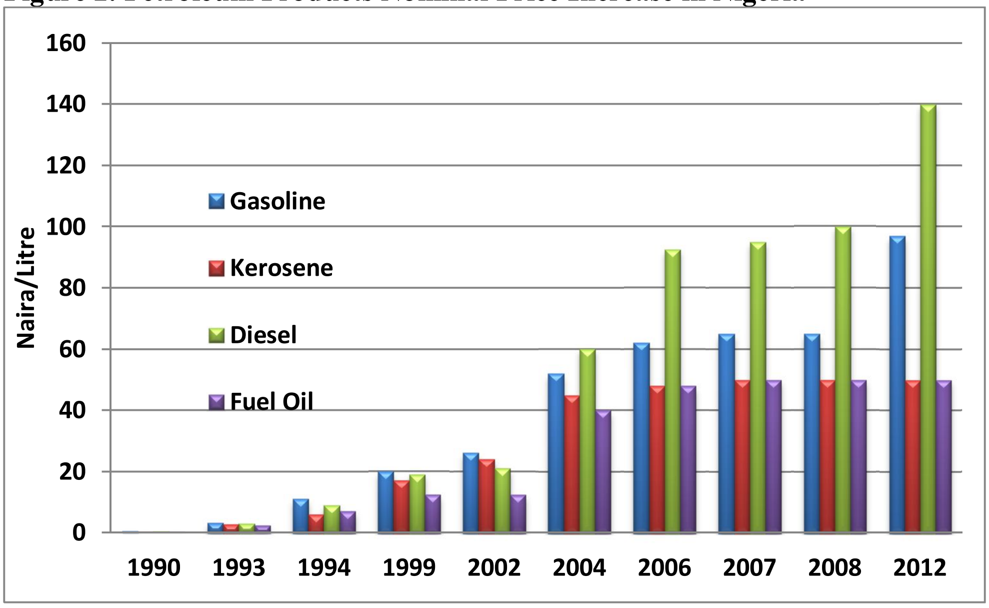


Figure 2. Petroleum Products Nominal Price Increase in Nigeria*



*Note: Diesel Price was fully deregulated since 2004.

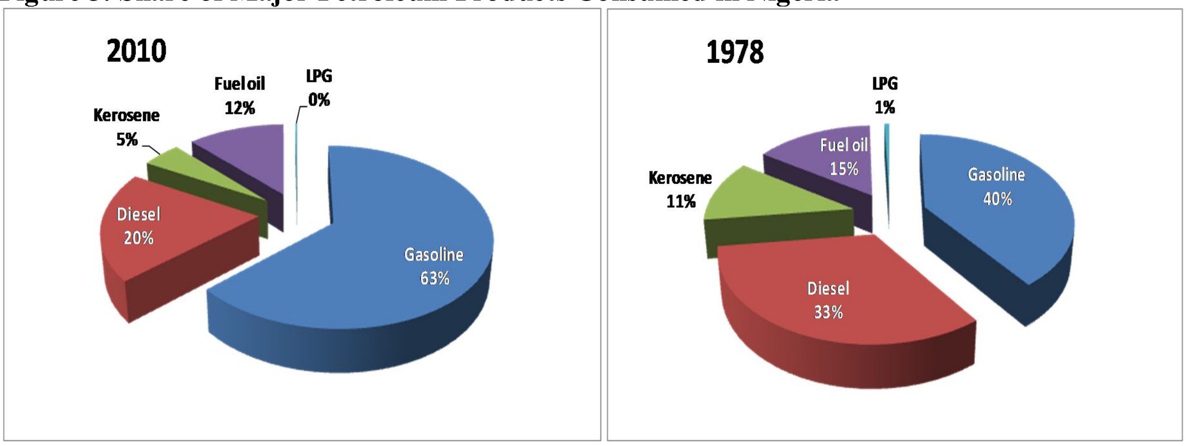
Until 1993, the prices of gasoline, kerosene and diesel were ₦0.7, ₦0.5 and ₦0.55 per litres respectively; these were subsequently increased to ₦3.25, ₦2.75 and ₦3.0 per litre of gasoline, kerosene and diesel respectively. The new prices remain untenable for the government and in 1994 they were reviewed upward to ₦11 per litre of gasoline, ₦6.0 per litre of kerosene and ₦9.0 per litre of diesel. Subsequent price increases were made on a nearly annual basis upto2008 (see Figure 2). The most recent price increase was in January 2012 where price of gasoline was increased from ₦65 to ₦143 per litre which attracted nationwide strike action. In order to calm the protest, the government had to review the price of gasoline from ₦143 to ₦97 per litre. Government officials claimed that subsidy constitutes a huge fiscal cost and there is therefore the need to withdraw subsidy in order to make funds available for social and infrastructural development.

Table 1. Yearly Average Consumption Growth and Share of Petroleum Product in Nigeria

	Yearly Average Growth Rate of Petroleum Product Consumption (%)							*Share (%)*	
Product	***1979-1983***	***1984-1988***	***1989-1993***	***1994-1998***	***1999-2003***	***2004-2008***	***1979-2010***	***1978***	***2010***
Gasoline	*4.3*	*2.7*	*2.4*	*-0.7*	*20.4*	*1.8*	*5.1*	*40*	*64*
Diesel	*9.1*	*-8.0*	*4.0*	*1.3*	*11.0*	*-2.6*	*2.8*	*33*	*20*
Kerosene	*13.7*	*4.3*	*-1.8*	*-7.7*	*9.3*	*8.1*	*3.2*	*11.4*	*4.8*
Fuel oil	*12.6*	*1.7*	*6.3*	*-10.2*	*5.2*	*10.9*	*4*	*15*	*12*
LPG	*16.4*	*7.5*	*-11.7*	*222*	*7.5*	*127*	*56.3*	*0.6*	*0.2*
Aggregate	*8.2*	*-0.6*	*2.2*	*-3.6*	*13.9*	*0.4*	*3.4*	*100*	*100*

Table 1 presents five (5) year average consumption growth of major petroleum products in Nigeria. Rapid consumption growth particularly for gasoline is noticeable in the last 10 years. Key factor for increased gasoline consumption is the increasing number of vehicles and generators that are gasoline powered. Diesel growth was negative over the period 2004 – 2008. This could be as a result of complete removal of subsidy on diesel since 2004 which lowers demand. Growth in kerosene consumption was negative over the periods 1989 – 1993 and 1994 – 1998 due to supply scarcity. Kerosene price is still heavily subsidized by the government. Official price remains ₦50 per litre since 2004 while the current border price is about ₦140 per litre. This situation has caused local scarcity as only the state owned company – NNPC supplies kerosene.

Figure 3. Share of Major Petroleum Products Consumed in Nigeria



Growth in aggregate petroleum product consumption is driven mostly by gasoline which is the dominant fuel in the petroleum product mix. Gasoline share of total product consumed increased from 40% in 1978 to 64% in 2010 while average annual growth rate was 20.4% for the period 1999 – 2003 as compared to 13.9% for aggregate products over the same period. Similarly, average gasoline consumption growth for the past 31 years (1979 – 2010) was 5.1% compared to 3.4% for the aggregate. Recent rise in LPG consumption growth is as a result of government policy aimed at boosting domestic supply of LPG. The government is concerned over the poor penetration of LPG as a cooking fuel for Nigerian households. LPG share of fossil based fuels consumption declined from 0.6% in 1978 to 0.2% in 2010 (see Figure 3).

3. Review of Related Literature

3.1 Rationale for Modelling Energy Demand using Structural Time Series Model (STSM)

Energy demand is influenced by both economic and non-economic factors. The major economic factors are price, income and energy efficiency. Non-economic factors may include tastes, preferences, policy and structural changes whose changes are usually non-linear and stochastic over time. Thus, the use of linear and deterministic trend to capture the influence of non-economic factors in demand modeling may not be appropriate. According to Hunt et al (2003b), the underlying energy demand trend (UEDT) will be affected for instance, by change in economic structure from manufacturing to a service sector there by affecting total energy demand. This change is not induced by change in output or prices, but rather switches to a sector with different level of energy intensity.

Thus if UEDT is not included or modelled properly, these changes will be forced to be picked up by the income and price variables leading to bias in income and price elasticities.

In the past, energy demand modellers usually ignore these factors or at most, approximated by a linear deterministic time trend which assumes that the underlying trend is fixed over time (Hunt and Ninomiya, 2003). The Structural Time Series Model (STSM) developed by Harvey (1989) permits a more general and flexible approach of modelling the trend component of time varying economic variables such as energy demand. It therefore allows for the estimation of non-linear Underlying Energy Demand Trend (UEDT) which can be negative, positive or zero as time changes. Moreover, the use of simple deterministic trend is not ruled out in the STSM, instead, it becomes a limiting case that is admissible only if statistically accepted by the data (see Harvey, 1989; Harvey and Shephard, 1993; Hunt and Ninomiya, 2003, Dimitropoulos et al., 2005, Adeyemi and Hunt, 2007, Pedregal et al., 2009; Broadstock and Hunt, 2010).

STSM decomposes a set of time series into unobservable components but having meaningful economic interpretation (mainly trend, seasonal and irregular components). A simple STSM is therefore a regression model in which the explanatory variables are a function of time and the parameters are time-varying (Harvey and Shephard, 1993). This important attributes of the STSM and its compatibility with ARDL models makes it a useful tool in estimating UEDT. The merit of the ARDL model is that it can be applied irrespective of the order of integration among the variables.

3.2 Review of energy demand studies with UEDT

A number of studies on energy demand have estimated UEDT using various techniques such as STSM, OLS with deterministic trend and non-linear OLS with time dummies. There seem to be increasing popularity of the STSM in combination with ARDL in estimating UEDT (see for example Hunt and Ninomiya, 2003; Dimitropoulos et al., 2005; Ahmadian et al., 2007; Pedregal et al., 2009; Broadstock and Hunt, 2010). Just as the STSM is, a more general and flexible method of estimating trend in energy demand, the ARDL is also a more general and dynamic specification in contrast to PAM and static models. The STSM is consistent with the UEDT and ARDL specification which permits a more flexible approach to modelling the trend components. Table 2 presents some selected energy demand studies with UEDT.

For example, Hunt and Ninomiya (2003) used STSM with ARDL specification to estimate transport oil demand in UK and Japan. Their estimated long-run elasticities of income and price for UK were 0.801 and -0.23 respectively while that of Japan were 1.080 and -0.083 for income and price respectively. The UEDT were found to be non-linear for both countries with periods where it is both upward and downward sloping. Dimitropoulos et al. (2005) also confirmed the presence of non-linear stochastic trends in UK UEDT due to technical change and other exogenous factors driving energy demand. Their long-run elasticities for the whole economy with respect to income and price were reported as 0.583 and -0.133 respectively, while those of residential, manufacturing and transport sectors ranges between 0.807 to 0.304 and -0.232 to -0.113 for income and price respectively. Broadstock and Hunt (2010) attempted to quantify the impact of exogenous non-economic factors on oil demand in the UK transport sector by including fuel efficiency variable in addition to price and income among the determinants of energy demand in an UEDT framework. Broadstock and Hunt (2010) argued that since income, price and efficiency variables account for economic factors, the UEDT in their specification captures purely the effect of exogenous non-economic factors in driving energy demand. Their estimated elasticities for income, price and fuel efficiency were reported as 0.6, -0.1 and 0.3 respectively. The study indicates the presence of a stochastic rather than deterministic trend in UK transport energy demand.

Most of the studies on energy demand and particularly those employing STSM to estimate UEDT were conducted on OECD countries with only few on the developing countries, such as Ahmadian et al. (2007) on Iran and Amarawickra and Hunt (2008) on Sri Lanka and most recently Ackah and Adu (2014) on Ghana. Ackah and Adu (2014) examined the effect of productivity, economic and non-economic factors on gasoline demand in Ghana using STSM. Both price and income were found to be inelastic in the short run and only income is elastic in the long run while productivity was negatively related to gasoline consumption. Iwayemi et al. (2009) estimated long run elasticities of petroleum product demand for Nigeria using multivariate cointegration approach which ignores structural or technical changes in their estimation.

Table 2. Selected Studies on Energy Demand with UEDT

Author(s)	Scope/sector	Country	Modelling technique	Treatment of trend	Type of data & period	Estimated LR elasticities
Hunt and Ninomiya (2003)	Transport/oil	UK and Japan	STSM; ARDL	Stochastic trend	Quarterly data 1972Q1-1995Q4	Price= -0.08 to -0.12 Income= 0.08 to 1.08
Griffin and Schulman (2005)	Whole economy/oil	16 OECD countries	Non-linear OLS applied to panel data	Stochastic trend through time dummies	Annual data 1961 - 1999	Price= -0.044 to -0.093 Income=0.367 to 0.408
Dimitropoulos *et al.* (2005)	Sectors/whole economy/energy	UK	STSM; ARDL	Stochastic trend	Annual data 1960 - 1999	Price= -0.2 Income=0.7
Adeyemi and Hunt (2007)	Industrial/ aggregate energy	15 OECD countries	Non-linear OLS in panel data context	Asymmetric price/time dummies	Annual data 1962 - 2003	Price=-0.30 to -0.68 Income=0.70
Ahmadian et al. (2007)	Whole Economy/ gasoline	Iran	STSM;ARDL	Stochastic trend	Annual data 1968 - 2002	Price= -0.63 to -0.74 Income=1.25
Amarawickra and Hunt (2008)	Whole economy/ electricity	Sri Lanka	EG, FMOLS, STSM;ARDL	Stochastic trend	Annual 1960 - 2007	Price= 0 to -0.006 Income=1.0 to 2.0
Pedregal et al. (2009)	sectoral /oil products	Spain	STSM;ARDL	Stochastic trend	Monthly Jan 1984 – Dec 2006	Price= -0.013 to -0.238 Income=0.441 to 1.581
Broadstock and Hunt (2010)	Transport/oil	UK	STSM;ARDL	Stochastic trend	Annual 1960 - 2007	Price=-0.19 Income=0.53 to 0.57
Ackah and Adu (2014)	Transport/Gasoline	Ghana	STSM	Stochastic Trend	Annual 1971 - 2010	Price=-0.065 Income=5.129 TFP=-2.935

Omisakin et al. (2012) test possibility of structural breaks/regime shifts and parameter instability in the gasoline demand function in Nigeria using Gregory-Hansen structural break cointegration approach. The study confirms the presence of cointegration relationship and structural break points in 1978, 1979 and 1980. Income and price terms were inelastic in both short and long run. The study offers little explanation on those structural breaks. Adeyemi and Hunt (2007) argued that over reliance on cointegration without due consideration to technical changes has the potential of significant bias in price and income elasticities of demand. Therefore energy demand models for developing countries such as Nigeria will be unable to truly reflect the countries conditions if it ignores structural changes. This is because of the important implication of the declining role of traditional energy for demand, due to changes in life style, consumer choices and socio-demographic and environmental changes which are difficult to measure in practice (Battacharyya and Timilsina, 2010). This further justifies the inclusion of a stochastic trend in estimation of long-run energy demand models (see Hunt and Ninomiya, 2003; Ahmadian, et al., 2007; Hunt and Broadstock, 2010 and Adebisi, 2010

4. Empirical Methodology and Data Description

The Structural Time Series Model (STSM) developed by Harvey (1989), and employed by Hunt and Ninomiya (2003), Ahmadian et al. (2007) and Pedregal et al. (2009) was employed to estimate the demand function for the various petroleum products in Nigeria. The model allows for the estimation of a stochastic rather than deterministic trend which is important when estimating price elasticity of demand as discussed by Hunt and Ninomiya (2003a). The significance of inclusion of the trend variable in the estimation of energy demand for developing countries has been emphasized by Bhattacharyya and Timilsina (2010). The underlying trend would be affected by economic and technological structural changes. As the economic structure changes, the role of informal economy and traditional energy declines, thus impacting on the choice of technology and fuel mix. In addition, changes in tastes, preferences and demographic factors are difficult to measure and therefore necessitating the inclusion of a stochastic trend in estimating long-run oil products demand (Ahmadian et al., 2007; Broadstock and Hunt, 2010).

The long-run petroleum products demand is derived with the assumption that there exists a long-run (LR) equilibrium demand relationship between individual petroleum products consumption, level of economic activity and real price of the corresponding product represented as:

$$Q_i = f(Y, P_i, \mu_i) \tag{1}$$

Where Q_i is the net inland consumption of petroleum product i in million tons, Y is Real GDP in Million Naira and P_i is Real Price of petroleum product i while μ_i is the corresponding underlying energy demand trend (UEDT).

Equation (1) can be estimated econometrically, using conventional log-linear static model with a constant and a deterministic trend as:

$$q_{it} = \delta_0 + \theta t + \psi_1 y_{it} + \varphi_1 p_{it} + \varepsilon_{it} \qquad \varepsilon_{it} \sim \mathrm{NID}\left(0, \delta_{i\varepsilon}^2\right) \tag{2}$$

Where $q_{it} = Ln(Q_{it});\ y_{it} = Ln(Q_{it})\ and\ p_{it} = Ln(P_{it});\ \psi_1 and\ \varphi_1$ represent LR Income and price elasticities respectively and ε_{it} is the random white noise.

The conventional dynamic ARDL specification with a constant δ_0 and a deterministic time trend θt is:

$$q_{it} = \delta_0 + \theta t + \delta_1 q_{it} + \cdots + \delta_n q_{it-n} + \psi_1 y_{it} + \cdots + \psi_n y_{it-n} + \varphi_1 p_{it} + \cdots + \varphi_n p_{it-n} + \varepsilon_{it} \qquad \varepsilon_{it} \sim \mathrm{NID}\left(0, \delta_{i\varepsilon}^2\right) \tag{3}$$

To determine the LR elasticities, assume LR equilibrium:

$$q_{it}^* = q_{it} = q_{it-1} = q_{it-2} = \cdots \tag{4a}$$

$$y_{it}^* = y_{it} = y_{it-1} = y_{it-2} = \cdots \tag{4b}$$

$$p_{it}^* = p_{it} = p_{it-1} = p_{it-2} = \cdots \tag{4c}$$

$$q_{it}^* = \delta_0 + \theta t + \delta_1 q_{it}^* + \cdots + \delta_n q_{it}^* + \psi_1 y_{it}^* \ldots + \psi_n y_{it}^* \delta_1 + \varphi_1 p_{it}^* + \cdots + \varphi_1 p_{it}^* \tag{5}$$

Rearranging and solving for q_{it}^* we obtained:

$$q_{it}^* = \frac{\delta_0}{(1 - \delta_1 - \cdots - \delta_n)} + \frac{\theta t}{(1 - \delta_1 - \cdots - \delta_n)} + \frac{(\psi_1 + \cdots + \psi_n)}{(1 - \delta_1 - \cdots - \delta_n)} + \frac{(\varphi_1 + \cdots + \varphi_n)}{(1 - \delta_1 - \cdots - \delta_n)} \tag{6}$$

Therefore:

$$\widehat{\text{Ȩ}}_y^{LR} = \frac{(\hat{\psi}_1 + \cdots + \hat{\psi}_n)}{(1 - \hat{\delta}_1 - \cdots - \hat{\delta}_n)}$$

and

$$\widehat{\text{Ȩ}}_p^{LR} = \frac{(\hat{\varphi}_1 + \cdots + \hat{\varphi}_n)}{(1 - \hat{\delta}_1 - \cdots - \hat{\delta}_n)}$$

Where $\widehat{\text{Ȩ}}_y^{LR}$ and $\widehat{\text{Ȩ}}_p^{LR}$ are estimates of long-run elasticites of income and price respectively.

The limiting case for the ARDL model is where the dynamic lagged terms $q, y\ and\ p$ all equal to zero, hence the model reverts to static case (2)

4.1 ARDL formulation in STSM

As mentioned earlier, the STSM is a more general and flexible formulation in that it allows for a stochastic UEDT. In the STSM setting, equation (3) is cast into a state space form, with the constant and deterministic trend term $\delta_0 + \theta t$ replaced by a stochastic trend μ_{it}

$$q_{it} = \mu_{it} + \delta_1 q_{it} + \cdots + \delta_n q_{it-n} + \psi_1 y_{it} + \cdots + \psi_n y_{it-n} + \varphi_1 p_{it} + \cdots + \varphi_n p_{it-n} + \varepsilon_{it} \qquad \varepsilon_{it} \sim \mathrm{NID}\left(0, \delta_{i\varepsilon}^2\right) \tag{7}$$

Following Harvey (1989), Hunt and Ninomiya (2003), the trend component μ_{it} is assumed to have the following stochastic properties:

$$\mu_{it} = \mu_{it-1} + \beta_{it-1} + \eta_{it} \qquad \eta_{it} \sim \mathrm{NID}\left(0, \delta_{i\eta}^2\right) \tag{8}$$

$$\beta_{it} = \beta_{it-1} + \xi_{it} \qquad \xi_{it} \sim \mathrm{NID}\left(0, \delta_{i\xi}^2\right) \tag{9}$$

The trend is characterized by a level μ_{it} and a slope β_{it}. The shape of the trend depends on the variances $\delta_{i\eta}^2$ and $\delta_{i\xi}^2$ known as hyper-parameters. The most restrictive form of the model occurs when both $\delta_{i\eta}^2 and\ \delta_{i\xi}^2$ are equal to zero, in which case the model collapses to equation (3) with a constant and a deterministic linear trend and therefore can be estimated using conventional regression OLS.

4.2 Estimation of the STSM

The estimated equations consist of (7), (8) and (9). All the stochastic terms are assumed to be independent and mutually uncorrelated with each other. The hyper parameters $\delta^2_{i\varepsilon}, \delta^2_{i\eta}$ and $\delta^2_{i\xi}$ determine the basic structure of the model. The hyper parameters together with the other parameters in the model were estimated by a combination of maximum likelihood and Kalman filter technique over the period 1978 – 2007, sparing the last three years (2008 – 2010) for prediction failure test. The optimal estimates of the trend components over the period 1978 – 2007 are further calculated by smooth algorithm of the Kalman filter. In order to evaluate the model, the equation residuals were calculated. The residuals include the conventional white noise and three auxiliary residuals namely the smoothed estimate of the equation disturbance (known as irregular residual), the smoothed estimate of the level disturbances (known as the level residuals) and smoothed estimate of the slope disturbances (known as the slope residuals). The model was estimated with the aid of software STAMP (Structural Time Series Analyser, Modeller and Predictor) Version 8.2 (Koopmans et al., 2009).

4.3 Data Description

Annual time series data spanning the period 1978 to 2010 was collected from the following sources. The choice of data source for a particular variable depends on the availability of complete series and data consistency. Net annual inland consumption of the targeted petroleum products namely; gasoline, kerosene, diesel, fuel oil and Liquefied Petroleum Gas (LPG) were obtained from the online data base of International Energy Agency (IEA). Domestic price series of the listed petroleum products was obtained from Annual Statistical Bulletins of the state-own oil company – NNPC (various issues). Real GDP and Consumer Price Index (CPI) for oil products were obtained from the Annual Statistical Bulletins of the Central Bank of Nigeria (CBN). The price deflator was used to deflate the individual product prices.

5. Estimation Results & Discussion

In line with procedure discussed in the literature and more specifically in the methodology, the UEDT model was estimated in an STSM/ARDL framework using Kalman filter procedure with the aid of software STAMP 8.2 (Koopmans et al., 2009). Following the general to specific approach, the ARDL specification with a lag of four for each of the five petroleum products was initially estimated and gradually deleting the insignificant variables in accordance with economic intuition and statistical criteria and ensuring that the preferred models passed series of diagnostic tests, including normality, heteroscedasticity, multicollinearity, autocorrelation, hyper-parameter tests among others. Furthermore, the preferred models were re-estimated imposing zero restrictions on non-zero hyper-parameters and a likelihood ratio (LR) test was conducted on the stochastic versus deterministic model specification. (see Appendix I for detail).

5.1 Gasoline

Based on statistical and economic criteria, the preferred model for gasoline demand is the static case with no dynamic term. The estimated long-run elasticities for gasoline demand were 0.11 and -0.23 for income and price respectively. The income elasticity is relatively lower than the one reported in Iwayemi et al. (2010) and Omisakin et al (2012) whose estimates of income and price elasticities were 0.747 and -0.055 and 0.714 and -0.015 respectively, although they did not include a trend term in their specification.

<u>Gasoline Equation</u>

$$q_{it} = 0.106y_t - 0.225p_t$$
$$\mathbf{(2.13)}^{**} \quad \mathbf{(3.05)}^{***}$$

Hyperparameters: $\delta^2_{i\varepsilon} = 0.00569572$; $\delta^2_{i\eta} = 0.00378948$; $\delta^2_{i\xi} = 0.0000006187$

Note*: *Figures in Parantheses are the t − statistics*; *** *and* ** *indicates significance at* 1% *and* 5% *level respectively

The result indicates that gasoline demand is both price and income inelastic and underlying demand trend is stochastic, that is both level (Figure 4a) and slope (Figure 4b) are stochastic. The likelihood ratio (LR) test (see Appendix I) implies that imposing restriction of a deterministic trend (in which both level and slope in the trend are fixed) is rejected. It can be seen clearly in Figures 4a and 4b that the underlying trend is non-linear but generally upward sloping. Since 1981, the trend level was rising gradually and becomes much steeper from 1999 onward. One possible reason for the rapid increase in the demand trend since 1999 could be attributed to changing taste and fashion among the Nigerian populace as represented by the purchase of more private cars that are mostly gasoline powered. Another reason might be the growing number of small electricity generating sets among average income earners due to low and erratic power supply in Nigeria. Though gasoline is largely consumed in the transport sector in Nigeria, additional demand for household and small businesses power supply and the smuggling of cheap gasoline to neighbouring countries where it is sold at higher prices might be responsible for the much steeper trend in gasoline consumption in recent years.

Figure 4a. Gasoline Trend Level

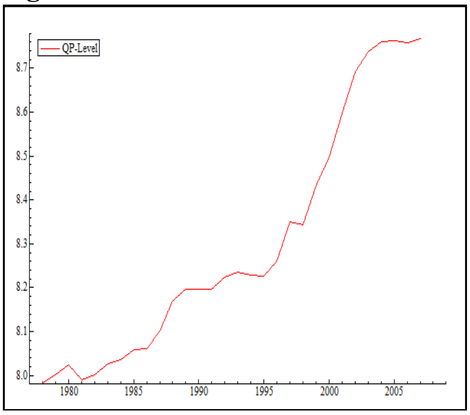
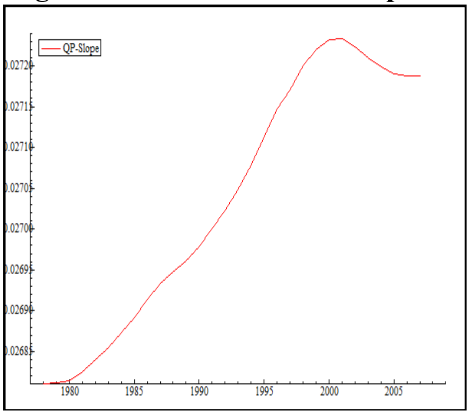


Figure 4b. Gasoline Trend Slope



5.2 Diesel

The preferred model for diesel supports a dynamic price term with long-run estimates of income and price elasticites of 0.17 and -0.30 respectively. The elasticity estimates were not far away from the estimates of Iwayemi et al (2010). It further confirms their findings that diesel demand responds more to price changes than real income.

Diesel Equation

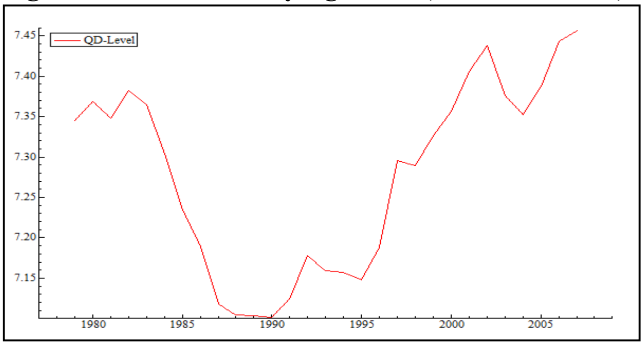
$$q_{it} = 0.174y_t - 0.296p_{t-1}$$
$$\mathbf{(2.54)^{**} \quad (3.44)^{***}}$$

Hyperparameters: $\delta^2_{i\varepsilon} = 0.0115113;\ \delta^2_{i\eta} = 0.0063216;\ \delta^2_{i\xi} = 0$

Note*: *Figures in Parantheses are the t – statistics*; *** *and* * * *indicates significance at* 1% *and* 5% *level respectively

Diesel demand trend was found to be local level type (see figure 5) where there is no slope term but variation in the trend comes through the level. The diesel demand trend is therefore characterised by a stochastic level and fixed slope. The trend indicates a drastic irregular pattern, reaching its lowest level around 1990 and gradually rises in an irregular fashion. The reasons for the falling and low level of diesel trend since the early 1980s up to mid-1990s are mainly due to scarcity and changing taste among the populace as most cars are gasoline powered except heavy trucks and certain class of vehicles. However since 1995, diesel trend is upward sloping indicating increasing consumption. This could be attributed to rising demand from manufacturing industries since nearly all the manufacturing firms have diesel generators as power supply back up in response to epileptic power supply from state-owned monopoly, Power Holding Company of Nigeria (PHCN). Iwayemi et al (2009) noted that in addition to manufacturing firms, mobile telecommunication service providers make use of diesel to power their installations thereby contributing to the rise in demand. Furthermore, government offices, corporate bodies and rich households – all make use of diesel powered generators to supplement the PHCN epileptic power supply.

Figure 5. Diesel underlying trend (stochastic level)



5.3 Kerosene

Both income and price terms were statistically significant and the coefficient of determination is 0.83, an indication that 83% of variation in kerosene demand in Nigeria is explained by the model. The preferred model supports no dynamic term with estimated long-run income and price elasticities of 0.10 and -0.20 respectively. In comparison, Iwayemi et al (2010) estimates were 0.625 and -0.115 for income and price respectively. The differences were much larger in the case of income elasticities.

Kerosene Equation

$$q_{it} = 0.096y_t - 0.179p_t$$
$$(\mathbf{1.77})^{*} \quad (\mathbf{3.05})^{***}$$

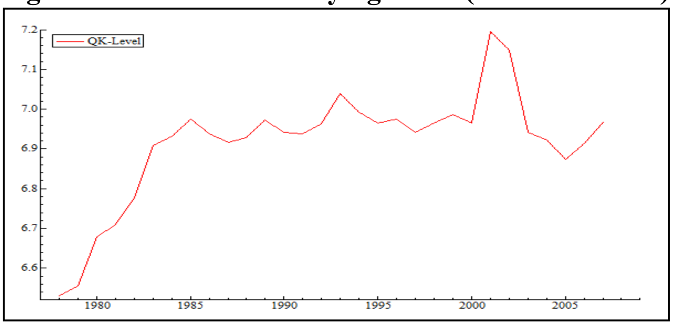
Hyperparameters: $\delta_{i\varepsilon}^2 = 0.00101062$; $\delta_{i\eta}^2 = 0.0077123$; $\delta_{i\xi}^2 = 0$

***Note*: *Figures in Parantheses are the t − statistics*; *** *and* ***

**** indicates significance at 1% and 5% level respectively***

The kerosene demand trend was found to be local trend type, having a stochastic level and a fixed slope. The trend was much steeper between the period 1978 and 1985, flattens thereafter, rose further in 2000 reaching its peak around 2002 and continue to fall thereafter (see Figure 6). The falling trend of kerosene in recent years could be attributed to increasing scarcity and higher price faced by final consumers. Kerosene is basically used for domestic heating and lighting purposes in Nigeria. Though the official pump price of kerosene is still ₦50.00 per litre, however consumers in most cases pay more than double this amount due to increasing scarcity. Government officials blame the growing scarcity on marketers who divert the product to Aviation Turbine Kerosene – ATK market which is deregulated, thereby reaping additional profit.

Figure 6. Kerosene underlying trend (stochastic level)



5.4 Fuel oil

The long-run fitted model for fuel oil demand is also the static case with no dynamic term. Income and price terms were statistically significant at 1% and 5% respectively and the coefficient of determination is 58%. The model also passed all the diagnostic tests conducted including prediction failure test. Demand elasticities for income and price were 0.27 and -0.18 respectively. No estimates of fuel oil elasticities were reported in Iwayemi et al (2010) because of data limitations. Fuel oil demand is driven by a local level underlying trend, having stochastic level and fixed slope.

Fuel oil Equation

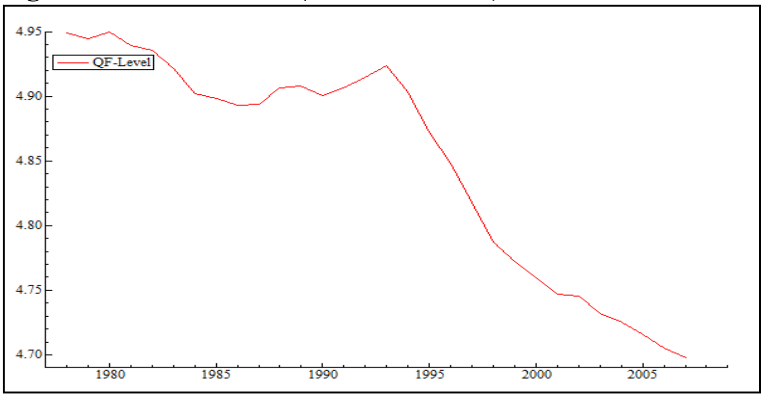
$$q_{it} = 0.268y_t - 0.184p_t$$
$$(\mathbf{4.01})^{***} \quad (\mathbf{2.66})^{**}$$

$$\textbf{Hyperparameters}: \delta_{i\varepsilon}^2 = 0.0158999;\ \delta_{i\eta}^2 = 0.0014942;\ \delta_{i\xi}^2 = 0$$

***Note*: Figures in Parantheses are the t − statistics; *** and ** indicates significance at 1% and 5% level respectively**

LR test reject deterministic restriction at 5% hence a model with local level is upheld similar to the kerosene and diesel case (see Appendix1). However, unlike kerosene and diesel, fuel oil trend level is persistently downward sloping with a sharp decline in demand trend since mid-1990s (see Figure 7). This could be attributed to the slowdown of manufacturing sector since late 1970s. Average manufacturing capacity utilization dropped from 78.8% in 1978 to 38.3% in 1985 and reached its lowest ebb (29.3%) in 1995. Recent trend however shows gradual recovery of industrial capacity utilization reaching 55.7% in 2005 and 53.8% in 2008 (CBN, 2011). Another possible reason for the decline fuel oil trend could be a shift from fuel oil to natural gas power generation by some large manufacturing industries.

Figure 7. Fuel oil trend (stochastic level)



5.5 Liquefied Petroleum Gas (LPG)

The preferred LPG equation supports a dynamic term for both income and price which are statistically significant at 5%. All measures of goodness-of-fit recorded impressive score and the residual diagnostic tests upheld normality, homoscedasticity and serial independence.

LPG Equation

$$q_{it} = 0.636y_{t-1} - 0.579p_{t-2}$$
$$(\mathbf{2.18})^{**} \quad (\mathbf{2.26})^{**}$$

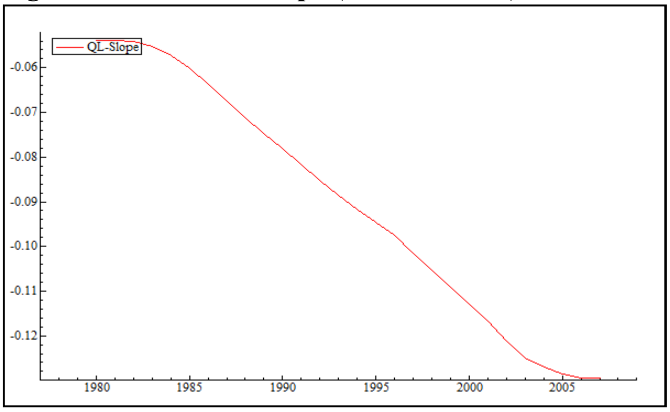
$$\textbf{Hyperparameters}: \delta_{i\varepsilon}^2 = 0.327716;\ \delta_{i\eta}^2 = 0;\ \delta_{i\xi}^2 = 0.0025326$$

***Note*: Figures in Parantheses are the t − statistics; *** and ** indicates significance at 1% and 5% level respectively**

The estimated long-run income and price elasticities were 0.64 and -0.58 respectively. No LPG elasticities were reported in Iwayemi et al (2010) due to data limitation. In comparison to diesel and petrol, LPG elasticities were relatively higher for both income and price. This seems plausible because as consumers' income increase, they tend to move away from inferior cooking products such as kerosene and biomass, which are the common cooking energy sources in Nigeria. While the relatively higher price elasticity indicates consumers' switch to alternatives such as kerosene and biomass (firewood) as LPG price increases. Trend type for the model indicates a smooth trend, having fixed level and stochastic slope. The trend slope is downward indicating declining LPG consumption (see Figure 8). According to a World Bank (2004) study on LPG improvement in Nigeria, per capita LPG consumption remain abysmally low (0.5 kg) below the West African average of 3.7 kg. The declining was attributed to a number of factors which impacted negatively on LPG demand growth. These include acute supply shortages especially the last 15 years, arbitrary and extremely volatile pricing and the availability of cheaper and subsidized substitutes[2].

[2] LPG supply in Nigeria comes from two primary sources: by-product of petroleum refineries and by-product of natural gas processing. Since the last two decades, supply from the refineries is very limited due to general operating problems. Although the country's natural gas processing facilities produce large volume of LPG designed for export market, there is limited access to domestic market due to infrastructure limitations. This is

Figure 8. LPG trend slope (smooth trend)



6. Conclusion and Policy Implications

Petroleum products are key inputs vital for the growth and transformation of any economy. They are in fact, inputs in every product that is produced and every service accomplished in today's modern world. Thus, understanding the nature of their demand including key drivers is necessary to plan consumption that is consistent with long term growth objectives. At the centre of sustainable energy planning for any country is appropriate pricing policy. Nigeria is a developing country that is endowed with petroleum resource which has been the main source of revenue and foreign exchange for the government. At the same time, like other oil producing countries, the domestic prices of petroleum products are highly subsidized which has contributed to rapid growth in domestic demand. The result has been a decrease in export revenues and rising cost of subsidy, which has become a serious fiscal policy concern for the government. In this study, the demand functions for five (5) major petroleum products consumed in Nigeria, namely; gasoline, kerosene, diesel, fuel oil and Liquefied Petroleum Gas were estimated with a view to obtaining price and income elasticities and to unravel their respective underlying demand trends.

Various techniques have been used in the literature to model energy demand; Static Models, Partial Adjustment Models (PAM), Autoregressive Distributive Lags (ARDL) Models, Cointegration and Error Correction Models (ECM) as well as Structural Time Series Models (STSMs). The choice of appropriate technique to estimate energy demand functions underlines the need to generate robust elasticities for analysis, forecasting and decision making.

Recent studies on energy demand focus on cointegration technique which has the beauty of capturing both long-run and short-run dynamics in a single stationary model. The technique however ignores structural changes which are important features of energy demand particularly for developing countries such as Nigeria. It is argued that over reliance on cointegration without due consideration to structural changes has the potential of significant bias in price and income elasticities. Whereas most energy demand models ignore this important feature or at best, attempted to capture structural change with a deterministic time trend, the STSMs permits a more flexible approach of modelling Underlying Energy Demand Trend (UEDT) which can reveal the true pattern of changes in economic structure over time. STSM fits an ARDL framework and further decomposes a set of time series into unobservable components but having meaningful economic interpretation (mainly trend, seasonal and irregular components). This study therefore used the STSM to model the demand trend for five different petroleum products that are widely consumed in Nigeria. The model was estimated using a combination of maximum likelihood procedure and Kalman filtering technique with the aid of STAMP 8.2 software.

The preferred models were chosen based on economic intuition, econometric and statistical criteria. Impulse dummies were used in some cases to control for outliers in the sample. The preferred models passed series of diagnostic test, including normality, heteroscedasticity, multicollinearity, autocorrelation and hyper-parameter tests. All the demand models were price and income inelastic and

also a major setback to the LPG import scheme embarked by PPMC and subsequently other marketers as a means of increasing domestic supply.

fall within the range reported in the literature but generally in the lower bounds. This is probably due to inappropriate capture of the trend component in many previous studies which might have caused some upward bias in their price and income elasticities. The long-run price and income elasticities obtained in this study using STSM were (0.11 and -0.23), (0.17 and -0.30) and (0.10 and -0.20) for gasoline, diesel and kerosene respectively while that of fuel oil and liquefied petroleum gas (LPG) were (0.27 and -0.18) and (0.64 and -0.58) respectively. In line with *a priori* expectation, none of the models have a deterministic linear trend, which is the limiting case in the STSM formulation. Furthermore, Likelihood ratio test on the hyper-parameters reject the restriction of a deterministic trend. The nature of gasoline underlying demand trend is stochastic, that is having a stochastic level and a stochastic slope while that of LPG is a smooth trend, having fixed level but stochastic slope. The remaining models; including diesel, kerosene and fuel oil and all have local level trend that is having stochastic level and fixed slope. The shapes of these trends reveal some interesting developments that have affected demand over the sample period.

The findings of this study have important policy implications. Firstly, low price elasticities of demand for all the petroleum products present a taxable base for the government to be exploited in the future especially when the downstream petroleum product market is fully deregulated. Thus if government wants to raise more revenue, more tax should be charged on petroleum products. On the other hand, since higher prices will have little impact on demand due to low price elasticities, if government wants to restrain domestic consumption, policies such as high tax on private vehicles might be necessary. This will be consistent with pro poor policies of income distribution since most owners of private vehicles fall in the high income group.

Finally, the analysis presented in this study was based on individual petroleum products. Future studies on sectoral basis including residential, industrial, transport and service sector and on regional basis (rural/urban) could provide better information for policy consideration, particularly in designing appropriate mitigation strategies on the proposed subsidy withdrawal on gasoline and kerosene.

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Appendix I: Full Parameter Estimate Results of Nigeria Petroleum Product Demand Using STSM

Dependent Variable: Petroleum product Demand		**Sample: 1978 – 2010**			
Product Type	**Gasoline**	**Diesel**	**Kerosene**	**Fuel oil**	**LPG**
Estimated coefficient					
y	0.106** (2.13)	0.174**(2.54)	0.096* (1.77)	0.268***(4.01)	—
y_{t-1}	—	—	—	—	0.636**(2.18)
y_{t-2}	—	—	—	—	—
p	-0.225***(3.05)	—	-0.179***(3.05)	-0.184** (2.66)	—
p_{t-1}	—	-0.296**(3.44)		—	—
p_{t-2}	—		—	—	-0.579**(2.26)
Long-run elasticities					
Income	0.11	0.17	0.10	0.27	0.64
Price	-0.23	-0.30	-0.20	-0.18	-0.58
Hyper parameters					
Irregular($\boldsymbol{\delta^2_{i\varepsilon}}$)	0.00569572	0.0115113	0.00101062	0.0158999	0.327716
Level ($\boldsymbol{\delta^2_{i\eta}}$)	0.00378948	0.0063216	0.0077123	0.0014942	0
Slope ($\boldsymbol{\delta^2_{i\xi}}$)	0.0000006187	0	0	0	0.00025326
Nature of trend	***Stochastic trend***	***Local level***	***Local level***	***Local level***	***Smooth trend***
Interventions	1990	—	1998	1992, 2000	1995
Goodness-of-fit					
p.e.v	0.010641	0.020605		0.017466	0.34581
p.e.v/m.d^2	1.20	1.32		1.22	1.17
R^2	0.92	0.65	0.83	0.71	0.71
R^2_d	0.62	0.53	0.70	0.72	0.58
AIC	-4.14	-3.55	-4.43	-3.26	-0.66
Residual Diagnostics					
Std. Error	0.10315	0.14354	0.089581	0.15277	0.58806
Normality	1.57	3.69	2.57	2.84	3.59
Skewness	0.81	2.68	1.33	1.11	0.014
Kurtosis	0.011	0.66	3.36	0.29	0.31
H(8)	1.85	1.92	3.26	0.45	H(7) 7.74
r(1)	-0.161	-0.0079	-0.094	0.03	-0.34
r(2)	0.145	-0.084	-0.282	0.13	-0.11
r(3)	-0.109	-0.021	-0.007	0.11	0.027
DW	2.15	1.97	1.92	1.90	2.50
Q(q, q-p)	5.30	4.95	5.62	1.79	3.56
Auxiliary Residuals					
Irregular					
Normality (B-S)	1.87	1.83	1.75	2.10	1.09
Skewness	0.50	1.67	0.12	2.07	0.46
Kurtosis	1.37	0.15	1.63	0.03	0.63
Level					
Normality (B-S)	1.01	0.17	1.59	1.20	n/a
Skewness	0.00012	0.16	0.03	0.30	n/a
Kurtosis	1.02	0.01	1.56	0.90	n/a
Slope					
Normality (B-S)	4.40	n/a	n/a	n/a	4.86
Skewness	4.30	n/a	n/a	n/a	4.20
Kurtosis	0.15	n/a	n/a	n/a	0.63
Prediction test 2007-2010					
Failure	0.58	3.19	1.09	2.32	3.81
Cusum t(3)	0.57	0.27	0.55	0.58	1.42
LR test	**29.51*** **	**15.83***	**10.78***	**7.3***	**12***

Notes: Model estimation and standard error (in parentheses) are from STAMP software 8.2; *, **, *** Denotes significance at 10%, 5% and 1% level respectively; impulse dummies were included in gasoline model(1990), kerosene (1998), fuel oil (1992, 2000), LPG(1995) and Aggregate oil products (1990, 1998); Prediction Error Variance (p.e.v.), prediction error mean deviation (p.ev/m.d^2)and the Coefficients of Determination R^2 and R^2_d) all are measures of goodness-of-fit; Normality (corrected Bowman–Shenton), kurtosis and skewness are error normality statistics, approximately distributed as $\chi^2_{(2)}$, $\chi^2_{(1)}$ and $\chi^2_{(1)}$ respectively; H(8) is the test for heteroscedasticity, approximately distributed as F(8, 8); r(1), r(2) and r(3) are the serial correlation coefficients at the 1st 2nd and 3th lag respectively ; DW is the Durbin Watson Statistic; Q(q,q-p) is the Box–Ljung Q-statistic based on the first n residuals autocorrelation; distributed as $\chi^2_{(n,1)}$; failure is a prediction failure statistic distributed as $\chi^2_{(3)}$; Cusum is cumulative sum stability statistic distributed as the student t-distribution; LR represents likelihood ratio tests on the sample specification after imposing zero restrictions on non-zero hyper parameters.