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Imperatives for Modelling and Forecasting Petroleum Products Demand for Nigeria

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Abstract

Modelling and forecasting petroleum products demand is a key input for energy use planning and policy formulation. This paper employs the Structural Time Series Model to estimate and forecast demand for two key petroleum products – gasoline and diesel in Nigeria. The STSM can account for structural changes in an economy through the underlying energy demand trend. STSM incorporate stochastic rather than deterministic trend which is more general and therefore argued to be more appropriate in this study. The result suggests that the demand for petroleum products in Nigeria is both price and income inelastic and fall within the range reported in the literature while the underlying demand trends were generally stochastic in nature. The demand models were forecast under three scenarios; reference case, low and high demand. The reference or base scenario describes the future based on current economic and policy environment, that is, without any specific policy shock. Under the reference case scenario, gasoline and diesel demand were forecast to reach 45.3 and 8.03 million litre per day in 2030 representing demand increase of 42% and 66% for gasoline and diesel respectively in the next fifteen years. This presents a significant challenge towards attaining self-sufficiency in meeting Nigeria's petroleum products demands through local refining. There is therefore urgent need for the government to revamp existing refineries and encourage private investors to build new ones in order to reduce dependence on product imports.

Keywords: Petroleum Product; Demand Forecast, STSMs; Stochastic Trend.

JEL Classifications: C32; C53; Q43; Q47.

1. Introduction and Related Literature

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 currently account for 78% of fossil fuel consumption, followed by electricity (13%) and natural gas (9%) (IEA, 2011).

Nigeria's rising population and economic growth implies that demand for petroleum products especially gasoline and diesel will continue to rise. Over the last three decades, gasoline consumption in Nigeria increased from an average of 10.4 million litre per day in 1980 to 31.2 million litre per day in 2013. Gasoline share of Petroleum products consumption increased from 42% in 1980 to 68% in 2013 while that of diesel decreased from 27% to 11% over the same period (NNPC, 2014). The two however are the most important petroleum products consumed in Nigeria.

Since the first oil price shock of 1973, there has been increasing attention on energy demand modelling with a view to understanding the nature of the demand including key drivers. This is essential in generating accurate demand parameters for planning, projections and policy formulation. The task is challenging especially in developing countries where necessary data, appropriate models and required institutions are lacking. Thus, projected energy demand often deviates from actual demands due to limitations in data, model structure or inappropriate assumptions (Bhattacharyya and Timilsina, 2009; 2010). Though this problem is more serious in developing countries, even industrialized countries where necessary data and tools are available often face significant challenges in producing accurate energy demand forecast. For instance, in a review of energy demand forecasts in the United States, Craig et al. (2002) show that most of the forecasts overestimated the demand by 100%. The poor estimates were attributed to model complexity and inappropriate assumptions. Consequently, decisions based on such forecasts are less likely to produce the desired results. Armstrong (2001) observed that simple models sometimes yield results as accurate as more complicated techniques.

There are various methods used in energy demand forecasting which are broadly divided into two; engineering (end-use) approach and econometric models. The end-use approach is based on the impact of energy usage patterns of different devices/systems in the overall energy consumption in a disaggregated approach[1]. Despite its richness, data intensive nature of the technique limits its application especially in developing countries. Furthermore, (Bhattacharyya and Timilsina, 2010) argued that technologically explicit representation of the energy system, has continued to suffer from aphorism. Thus, most energy demand modelers apply traditional econometric model with focus on price and income elasticities to forecast energy demand. Range of econometric techniques used in estimating energy demand model in the literature 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). There is need for an understanding of the approaches and their relevance in different contexts. This is especially true for developing countries where the quality of information is poor and the future may not just follow the same trajectory as in the past due to structural changes and economic transition.

Recent studies on energy demand focus on co-integration 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; Omisakin et al., 2012; Nwosa and Ajibola, 2013). 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 in practice. Hunt et al. (2003a), Adeyemi and Hunt (2007) and Adebisi (2010) also noted that over reliance on co-integration without due consideration to structural changes has the potential of significant bias in price and income elasticities which are key elements in a demand forecast.

Most of the studies relating to energy demand in Nigeria heavily relied on co-integration technique (Iwayemi et al., 2009; Omisakin et al., 2012; Saad and Shahbaz, 2012; Nwosa and Ajibola, 2013). These studies ignore the structural change over time or at best, attempt to capture the effect through the use of a linear deterministic time trend. 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. 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).

Further details on modelling petroleum products demand in Nigeria using STSM approach may be found in Abdullahi (2014). Building on Abdullahi (2014), this paper focuses on estimating and forecasting demand for gasoline and diesel in Nigeria up to 2030. The choice of gasoline and diesel is due to relative reliability of available data and their significance as the dominantly consumed petroleum products in Nigeria. The paper is organized as follows. Section 2 describes some stylized facts about energy and the Nigerian economy. Section 3 presents the data and methodological approach. Section 4 presents estimate results and comparison of demand elasticities with other studies. Section 5 presents forecast scenarios and discussions on the forecast assumptions and forecast results. Finally, Section 6 comments the main conclusions and policy implications of our analysis.

[1] See Bhattachariya and Timilsina (2009) for more detail on end-use energy demand models and its typology.

2. Stylized Facts on the Nigerian Economy and Petroleum Products Demand

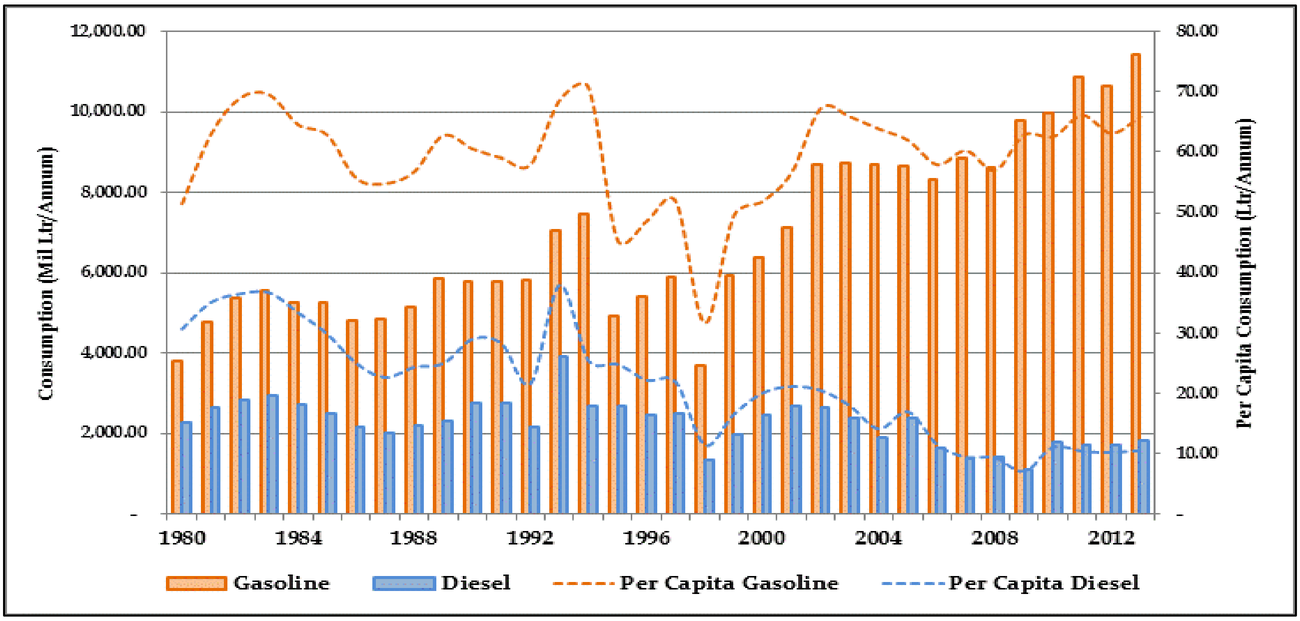
Nigeria has maintained its impressive growth over the past decade with an estimated 7.4% growth of real gross domestic product (GDP) in 2013, up from 6.6% in 2012 and 5.09% in 2011. This growth rate is higher than the sub-Saharan Africa level of 4.0% and 4.2% in 2012 and 2013 respectively, Africa Development Bank (ADB, 2014); World Bank, (2015). The performance of the economy continues to be underpinned by favourable improvements in the non-oil sector – agriculture, trade and services continue to be the main drivers of non-oil sector growth. Recent rebasing of Nigerian GDP puts the economy as the largest in Africa with a GDP estimate of about $510 billion (Kale, 2014). Key contributors to the GDP include Services (43%), Agriculture (22%), oil and gas (14%), Industry (11%) and Telecommunication (9%). The oil sector growth performance was not as impressive with 3.4%, -2.3% and 5.3% estimated growth rates in 2011, 2012 and 2013, respectively. Growth of the oil sector was hampered throughout 2013 by supply disruptions arising from oil theft and pipeline vandalism, and by weak investment in upstream oil and gas activities (Africa Development Bank, 2014).

Despite recent decline in oil sector growth, the industry remains the crucial sector 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 89% of foreign exchange earnings according to National Bureau of Statistics (NBS, 2012). Nigeria is ranked 10^{th} in the world in terms of oil reserve and 9^{th} in terms of gas with a proved reserve estimates of 37.1 billion barrel and 179.4 trillion cubic feet respectively (BP Statistical Review, 2014). Annual average crude oil and condensate production stood at 2.2 mbd and about 6.37 bcf of natural gas representing a decline of 6% and 10% respectively compared to 2012 (NNPC, 2013).

Petroleum products dominate fossil-based fuel consumption in the Nigeria accounting for about 78%, followed by electricity (13%) and natural gas (9%), International Energy Agency (IEA, 2011). Available data with NNPC indicates that about 70% of the products consumed are imported due to low domestic refining capacity. Nigeria has four (4) refineries – all owned by the Federal Government and operated by the state-owned oil and gas company – 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. Average capacity utilization of the four refineries was about 30% in 2013.

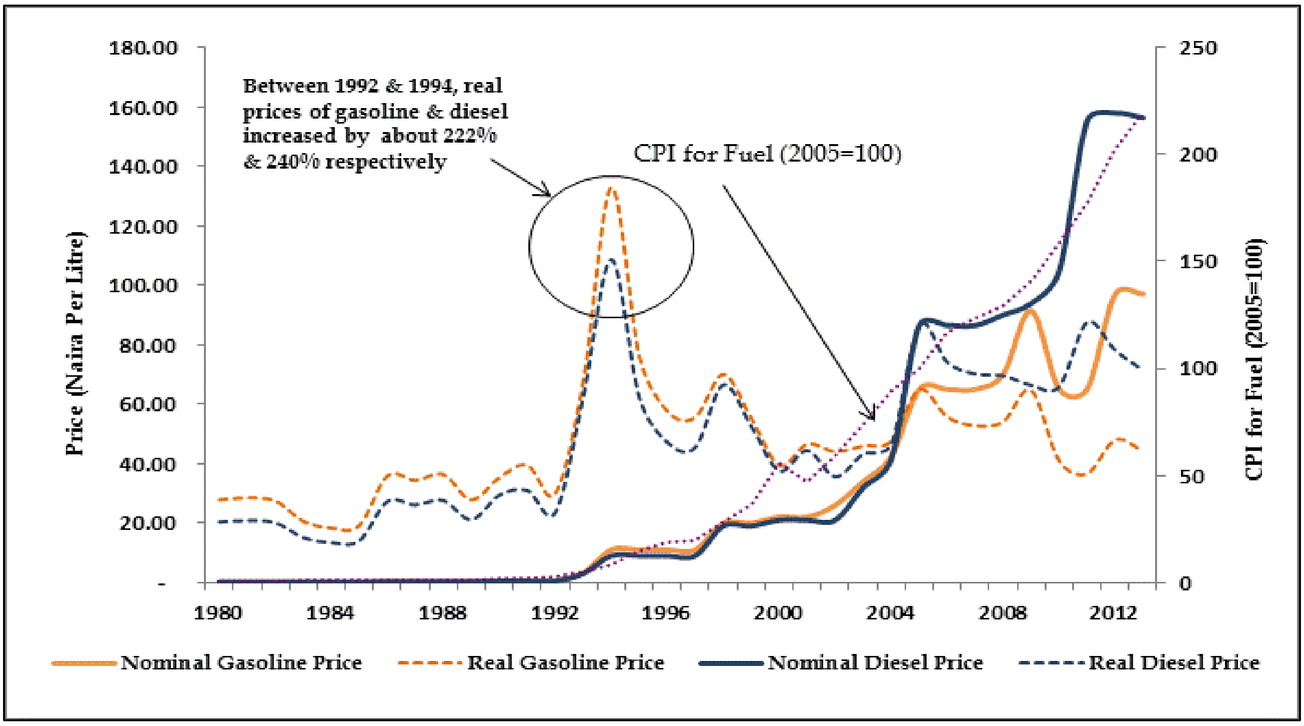
Over the last three decades, population and economic growth have resulted to increase in petroleum products consumption especially gasoline. Nigeria's population increased from 73.7 million in 1980 to 173.7 million in 2013, an increase of about 100 million in 34 years representing an average population growth rate of 2.63%. Similarly, real GDP (at constant 1990 prices) growth rate averaged 4.8% over the same period. Real GDP increased from N205.2 million in 1980 to N950 billion in 2013. Aggregate and per capita gasoline consumption responded favorably to increase in real per capita GDP while that of diesel seems to have slightly decreased due to policy related factors.

Figure 1: Historical Gasoline and Diesel Consumption in Nigeria



Until recently, the prices of petroleum products consumed in Nigeria were heavily subsidized. In an attempt to reduce the fiscal cost of subsidy on petroleum products, successive governments have periodically increased the price of petroleum products. The first remarkable price increase was recorded in 1993. Government increased the prices of gasoline, kerosene and diesel from ₦0.7, ₦0.5 and ₦0.55 per litres respectively to ₦3.25, ₦2.75 and ₦3.0 per litre of gasoline, kerosene and diesel respectively. These represents real price increase of 222% and 240% for gasoline and diesel respectively (see figure 2). Under officially administered price, diesel price was traditionally below that of gasoline until its price was fully deregulated in 2004. Since then, real price of diesel has remained higher than that of gasoline which is still regulated by the government (see figure 2). Higher diesel price might be another reason for the decline per capita consumption of diesel in recent years.

Figure 2: Nominal Versus Real Prices of Gasoline & Diesel in Nigeria



Gasoline share of Petroleum products consumption increased from 42% in 1980 to 68% in 2013 while that of diesel decreased from 27% to 11% over the same period. Growth in aggregate petroleum product consumption is driven mostly by gasoline which is the dominant fuel in the petroleum product mix. Average annual growth rate of gasoline demand was 5.1% between 1980 and 2010 compared to 3.4% for aggregate petroleum products (Abdullahi, 2014). Major driver to gasoline consumption is the dominance of road transportation over other transport mode and the increasing number of private cars which are mostly gasoline powered. There seems to be no comprehensive data on the number of vehicles in Nigeria. The Federal Road Safety Commission of Nigeria (FRSC) authority gave an estimate of 7 million in 2007[2]; the World Health Organization (WHO, 2014) indicated 12.54 million as the number of registered vehicles in Nigeria in 2011. Future trajectory of demand will be influenced by other factors such as the on-going power sector privatization and the impending deregulation of the petroleum products market.

3. METHODOLOGY

3.1 Gasoline and Diesel Demand Function.

Following Abdullahi (2014)[3], the demand function for gasoline and diesel in Nigeria is derived with the assumption that there exists a long-run (LR) equilibrium relationship between gasoline and diesel consumption, level of economic activity and real price of the corresponding product represented as:

$$E_i = f(Y, P_i, \mu_i) \qquad (1)$$

E_i = Per capita consumption of gasoline or diesel in litres/annum,

[2] Federal Road Safety Commission of Nigeria estimate as reported by Leadership National Daily of November, 16, 2007.

[3]Whereas Abdullahi (2014) used aggregate consumption as the dependent variable, this study uses per capita consumption as the dependent variable. Similarly, Real Per capita GDP is used as one of the explanatory variable as opposed to real aggregate GDP in Abdullahi (2014). This transformation eliminates the influence of population growth on the UEDT.

$Y =$ Real Per capita GDP (Naira)

$P_i =$ Real Price of gasoline or diesel

$\mu_i =$ Corresponding underlying energy (gasoline or diesel) demand trend (UEDT).

A log-linear explicit specification of equation (1) is as follows:

$$\ln E_{it} = \mu_{it} + \alpha \ln Y_{it} + \beta \ln P_{it} + \varepsilon_{it} \qquad \varepsilon_{it} \sim \mathrm{NID}\,(0, \delta^2_{i\varepsilon}) \qquad (2)$$

Where α and β are the static elasticities of income and price respectively

A more general dynamic and flexible formulation is the Autoregressive Distributive Lag (ARDL) representation of the STSM model as:

$$\ln E_t = \mu_t + \sum_{j=1}^{p} \gamma_j \ln E_{t-j} \sum_{j=0}^{q} \alpha_j \ln Y_{t-j} + \sum_{j=0}^{q} \beta_j \ln P_{t-j} + \varepsilon_t \qquad \varepsilon_t \sim \mathrm{NID}\,(0, \delta^2_{\varepsilon}) \qquad (3)$$

The long-run income and price elastisticities are λ_Y and λ_P where $\lambda_Y = \sum \alpha_j / 1 - \sum \gamma_j$ and $\lambda_P = \sum \beta_j / 1 - \sum \gamma_j$. The limiting case for the ARDL model is where the dynamic lagged terms E, Y and P all equal to zero; hence the model reverts to static case, equation (2).

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

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \qquad \eta_t \sim \mathrm{NID}\,(0, \delta^2_{\eta}) \qquad (4)$$

$$\beta_t = \beta_{t-1} + \xi_t \qquad \xi_t \sim \mathrm{NID}\,(0, \delta^2_{\xi}) \qquad (5)$$

The trend is characterized by a level μ_t and a slope β_t. The shape of the trend depends on the variances δ^2_η and δ^2_ξ known as hyper-parameters. The most restrictive form of the model occurs when both $\delta^2_\eta$and δ^2_ξ 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.

3.2 Data Description

The data set includes annual gasoline and diesel consumption, prices, and real gross domestic product spanning 1980 to 2013. The nominal prices were converted to real prices using the consumer price index (CPI) for energy in Nigeria over the same period (1980 – 2013). Per capita estimates of gasoline and diesel consumption and real GDP were obtained by dividing the corresponding aggregates with the national population estimates. All variables were converted to logarithms. 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 while the population figures were obtained from the National Population Commission (NPC) and the National Bureau of Statistics (NBS).

3.3 Estimation of the Model

The estimated equations consist of the ARDL version (3) and the trend equations (4) and (5). All the stochastic terms are assumed to be independent and mutually uncorrelated with each other. The hyper parameters $\delta^2_\varepsilon, \delta^2_\eta$ and δ^2_ξ 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.

Following the general to specific approach, the ARDL specification with a lag of three for both gasoline and diesel model 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. The model was estimated with the aid of software STAMP (Structural Time Series Analyser, Modeller and Predictor) Version 8.2 (Koopmans et al., 2009). The preferred models were then used to generate the forecast for gasoline and diesel demand in Nigeria up to 2030.

4. Results and Discussion

4.1 Demand Model Estimates

4.1.1 Gasoline

As stated in Section 3.2, the best model was selected based on statistical and economic criteria. Impulse (irregular) dummies included in 1993, 1994 and 1998 were significant suggesting outliers which would have affected the normal property of the irregular residual if not controlled. The inclusion of the impulse dummies was informed based on both a priori and statistical grounds. The price hike of 1993/94 (see Figure 2) was accompanied by supply boom which ease access across the country thus raising consumption over the period (see Figure 3). The preferred model for gasoline demand is the static case with no dynamic term. The models passed series of diagnostic tests, including normality, heteroscedasticity, multicollinearity, autocorrelation, hyper-parameter tests among others. The results are presented in Table I. The estimated long-run elasticities for gasoline demand were 0.619 and -0.133 for income and price respectively. The result indicates that gasoline demand is both price and income inelastic and underlying demand trend is local level that is, the level is stochastic while the slope is fixed. The likelihood ratio (LR) test implies that imposing restriction of a deterministic trend (in which both level and slope in the trend are fixed) is rejected. Gasoline underlying demand trend is non-linear but generally upward sloping. Since 1981, the trend level was rising gradually and becomes much steeper from 1999 onward. Economic boom and the attendant purchase of luxury cars might be the reason for the rising gasoline trend. Another possible reason for the rising demand is the growing number of small electricity generating sets among average income earners due to low and erratic power supply. Though gasoline is largely consumed in the transport sector in Nigeria, additional demand for household and small businesses for 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.

Table I: Full Parameter Estimate Results of Gasoline & Diesel Demand Model[4]		
Dependent Variable: gasoline and Diesel Demand Sample: 1980 – 2013Dependent V0 – 203		
Estimated coefficient	Gasoline	Diesel
y	0.619** (p=0.0166)	—
p	-0.133** (p=0.023)	
p_{t-1}	—	-0.208** (p=0.011)
Long-run elasticities		
Income	0.619	—
Price	-0.133	-0.208
Hyper parameters		
Irregular($\delta^2_{i\varepsilon}$)	0.0000	0.00207653
Level (δ^2_{in})	0.00456015	0.0145074
Slope ($\delta^2_{i\xi}$)	0.000000	0.000000
Nature of trend	Local Level	Local Level
Interventions	93,94,98 (irregular)	1998(irregular),1993,2010 (Level)
Goodness-of-fit		
p.e.v	0.0036222	0.015178

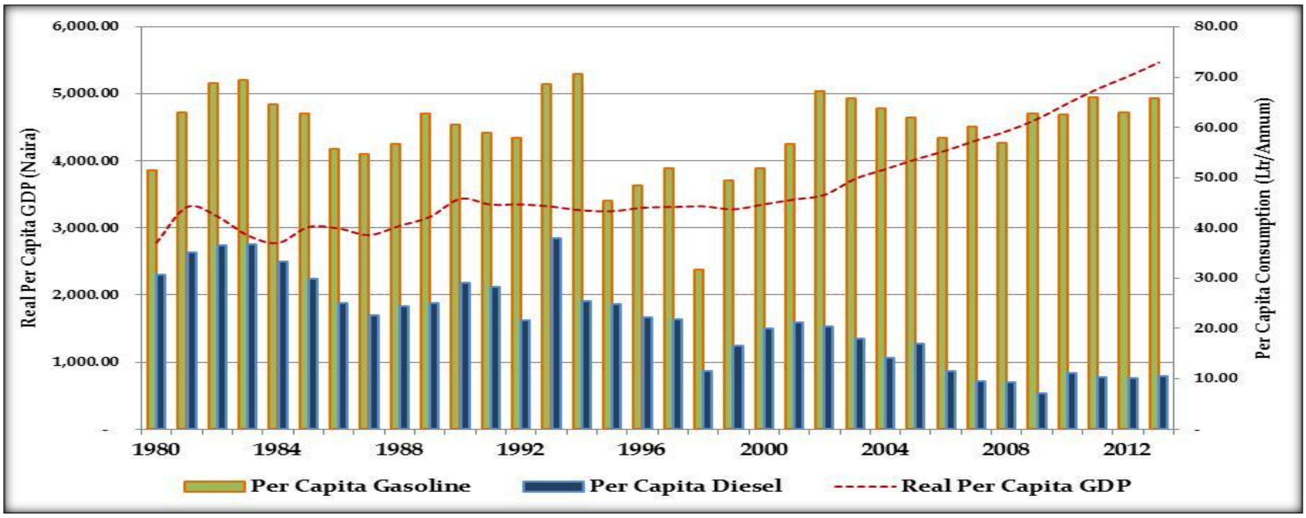
[4] Model estimation and standard error (in parentheses) are from STAMP software 8.2; *, **, *** Denotes significance at 10%, 5% and 1% level respectively; impulse dummies were included in gasoline model (1993,94,98 &2011) and Level dummy in 2010. Diesel Impulse dummy in 1998, level dummies in 1993 & 2010); 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.

p.e.v/m.d^2	0.002771	0.013573
R^2	0.876	0.94
R^2_d	0.881	0.77
AIC	-5.150	-3.7619
Residual Diagnostics		
Std. Error	0.060184	0.12320
Normality	1.7582	3.4898
Skewness	0.536	0.040093
Excess Kurtosis	0.0422	-1.3168
H(9)	0.98236	1.4304
r(1)	-0.12723^{NS}	-0.073767^{NS}
r(2)	-0.09549^{NS}	0.096438^{NS}
r(3)	-0.2251^{NS}	0.050266^{NS}
DW	2.2354	2.1025
Q(q, q-p)	3.1097	5.8604
Auxiliary Residuals		
Irregular: Normality (B-S)	1.216	0.36759
Skewness	1.154	0.026243
Kurtosis	0.062	0.34135
Level: Normality (B-S)	2.901	1.9013
Skewness	2.8382	0.00643
Kurtosis	0.0628	1.8949
Slope: Normality (B-S)	6.2601	2.1875
Skewness	0.3802	1.9201
Kurtosis	6.6403	0.2674
Prediction test 2011 – 2013		
Failure	0.2962	0.9650
Cusum t(3)	-0.011	-0.8020
LR test	16.69***	15.91***

4.1.2 Diesel

Similar to the gasoline case, intervention was included but in this case in 1998 (irregular) 1993, 2010 (level dummies) and were found to be statistically significant. The preferred model supports a dynamic price term while the income variable is statistically insignificant. This suggests that per capita diesel demand is insensitive to increase in real per capita GDP over the sample period. Both aggregate and per capita diesel consumption has dropped while aggregate and real per capita GDP increased over the period 1980 to 2013 as shown in Figure 3. The decline could be attributed to several factors. Key is the persistent diesel supply shortage prior to its price deregulation in 2004. As noted by Iwayemi et al (2009), diesel supply was inadequate in the Nigerian market. Whereas the official price was fixed at ₦21 per litre in 2000 and ₦32 per liter in 2003, the price paid by consumers doubled that amount. Secondly, changing taste among the populace as most cars are gasoline powered except heavy trucks and certain class of vehicles. Thirdly, higher price of diesel after deregulation as compared to subsidized gasoline and kerosene. In the last ten years, diesel price was much higher than that of gasoline. For instance, nominal price of gasoline was ₦65 per litre in 2005 as compared to ₦87 per litre for diesel. In 2013, the official price of gasoline was ₦97 per litre while diesel market price averaged about ₦160 per litre.

Figure 3: Per Capita GDP Vs Per Capita Gasoline & Diesel Consumption in Nigeria



Under officially administered price, diesel price was traditionally below that of gasoline until its price was fully deregulated in 2004. Since then, real price of diesel has remained higher than that of gasoline which is still regulated by the government (see figure 2). Higher diesel price might be another reason for the decline per capita consumption of diesel in recent years. Thus, the preferred diesel demand model presented in Table I is driven primarily by price and the stochastic trend parameters as real income changes appears less influential in the model. The long run price elasticity was -0.208. The preferred model also passed series of diagnostic tests (see Table 1). The underlying demand trend for diesel indicates a local trend type that is having a stochastic level and a fixed slope. The demand is trending downward since the 1980s albeit a stochastic manner due to the combination of factors outlined above.

4.2 Comparison of Demand Elasticities with Other Studies

The price and income elasticities of demand obtained in this study were compared with those of previous studies on Nigeria. The comparison is presented in Table II. All the studies presented in the table affirmed that gasoline and diesel demand in Nigeria are price and income inelastic (<1) that is, a unit increase/decrease in income or price will lead to less than proportionate increase/decrease in demand for gasoline or diesel. The elasticities range between 0.01 and 0.99 for income and -0.01 and -0.99 for price. The most striking difference is the negative income elasticity and positive price elasticity for diesel reported by Iwayemi et al (2010), which is contrary to a priori expectation. This was attributed to the persistent scarcity of diesel supply in the Nigerian market, with consumers paying more than double the official price prior to diesel price deregulation in 2004. The income coefficient of diesel demand is insignificant in this study and therefore its elasticity is not reported due to the reasons outlined in section 4.1.2.

Table II: Comparison of Gasoline and Diesel Demand Elasticites in Nigeria

Author(s)	Petroleum Product	Elasticities		Modelling technique	Data Coverage	Comment
		Income	Price			
Iwayemi et al. (2010)	Gasoline	0.747	-0.055	Cointegration	1977 to 2006	Demand Inelastic. Diesel coefficients contrary to a priori expectation
	Diesel	-0.100	0.108			
Saad & Shahbaz (2012)	Gasoline	0.601	-0.078	Cointegration with Linear deterministic trend	1980 to 2007	Demand Inelastic
	Diesel	1.003	-0.078			
Omisakin et al. (2012)	Gasoline	0.511 to 0.714	-0.015 to -0.104	Cointegration with Structural breaks	1977 to 2008	Demand Inelastic. Study limited to gasoline only
	Diesel	NIL	NIL			
This Study	Gasoline	0.619	-0.133	Structural Time Series Model (STSM)	1980 to 2013	Demand Inelastic. Diesel demand insensitive to income
	Diesel	–	-0.208			

5. Demand Forecast

The preferred demand model reported in this study was used to forecast gasoline and diesel demand in Nigeria up to 2030. In order to drive the forecasts, assumptions are required for population growth, real GDP and real energy price changes. These assumptions were discussed in Section 5.1.

5.1 Forecast Assumptions/Scenarios

Three scenarios were considered for the future path of demand and its associated drivers namely reference case, low and high case scenario. The reference scenario is the most probable outcome based on available information, hence a business as usual forecast. The low and high case scenarios were the lower and the upper bound from the reference case for the future path of the key drivers of demand and the resultant demand forecast. The key drivers of future demand are population, real GDP and real prices of the petroleum products (Amarawickrama and Hunt, 2008; Suleiman, 2013). Both the demand model and forecast were constructed on per capita basis, hence assumption about future population growth is required to obtain aggregate demand of these products in litre per day, which is the standard for reporting petroleum products demand. The population projection was obtained from National Bureau of Statistics which is based on National Population Commission (NPC) estimates of population growth rates (based on three scenarios; low, medium and high) in Nigeria (see Table III). A major driver of oil consumption in the mid-term is economic growth represented by the real GDP although other factors such as technology and government policies may have significant impact in the long-term (Suleiman, 2013). Similarly, three scenarios were constructed for real per capita GDP growth. The reference case is the long term average real per capita GDP growth rate over the sample period i.e 1980 – 2013[5]. The high growth scenario is 1% more than the base case and the low growth scenario is 1 less than the base case. Gasoline price is still regulated by the government while diesel price was deregulated since 2004. Government control makes it difficult to predict the future changes in gasoline price. Historically, annual real price changes averaged 6.4% over the period 1980 to 2013. This long term average is therefore assumed as the reference case scenario for future changes in real gasoline price. On the other hand, diesel price was fully deregulated since 2004. Post deregulation, the market price of diesel in real terms hovered between ₦66 per litre and ₦86 per litre and averaged ₦74 per litre. Over this period, real annual price increase averaged 1.54%. This is expected to slow down especially given the current decline in international crude oil prices. A modest 1% per annum price change is therefore assumed as the reference case scenario.

Table III: Forecast Scenarios/Assumptions

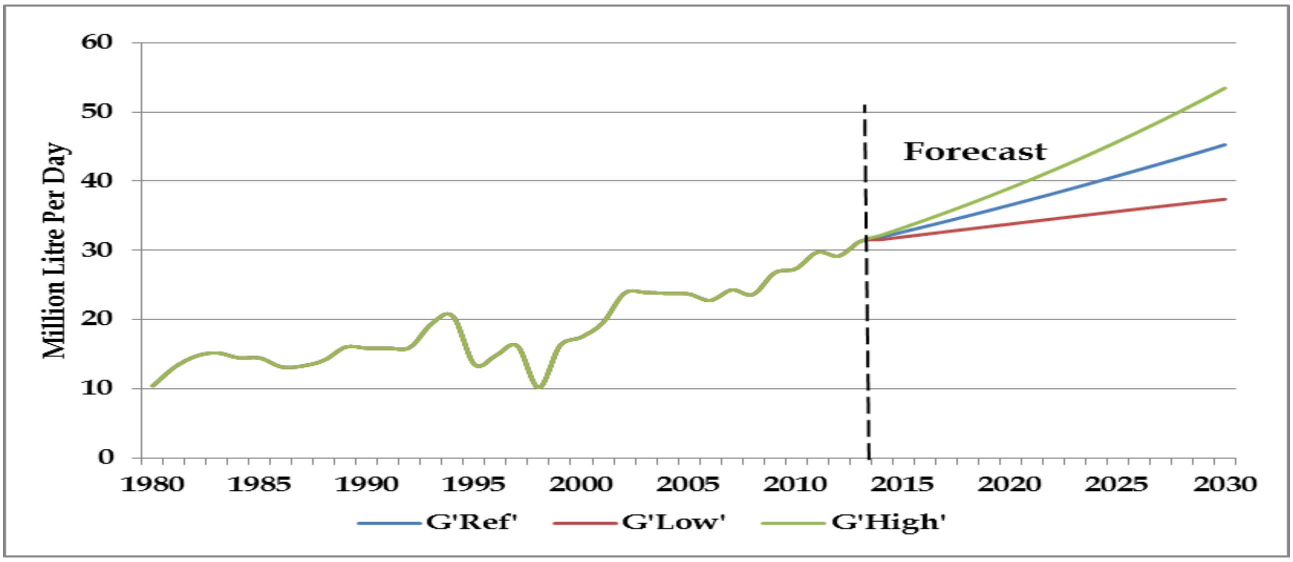
	Forecast Scenarios (%)		
Variable	Reference	Low	High
Population	2.80	1.47	3.04
Real Per Cap GDP	2.18	1.18	3.18
Real Prices of Gasoline	6.4	4.4	8.4
Real Prices of Diesel	1.0	0.5	2.0

5.2 Forecast Result

The scenario assumptions in Table III were applied on the estimated demand models in Table I to drive the forecast. Gasoline demand forecast is shown in Figure 4 while detail figures are presented in Appendix – Table IV. Under the reference case scenario, gasoline demand was forecast to reach 31.9, 36.6 & 45.3 million litre per day in 2014, 2020 and 2030 respectively. This implies that in the next fifteen years, assuming business as usual (reference case); gasoline demand in Nigeria will increase by about 42%. The reference forecast is compared to the 'high' and 'low' scenarios. Demand in the high case scenario is 18% higher than the base case and that of the low case scenario is about 21% less than the base case in 2030. This shows the uncertainty of longer term demand forecasts due to variation in assumptions under the three scenarios.

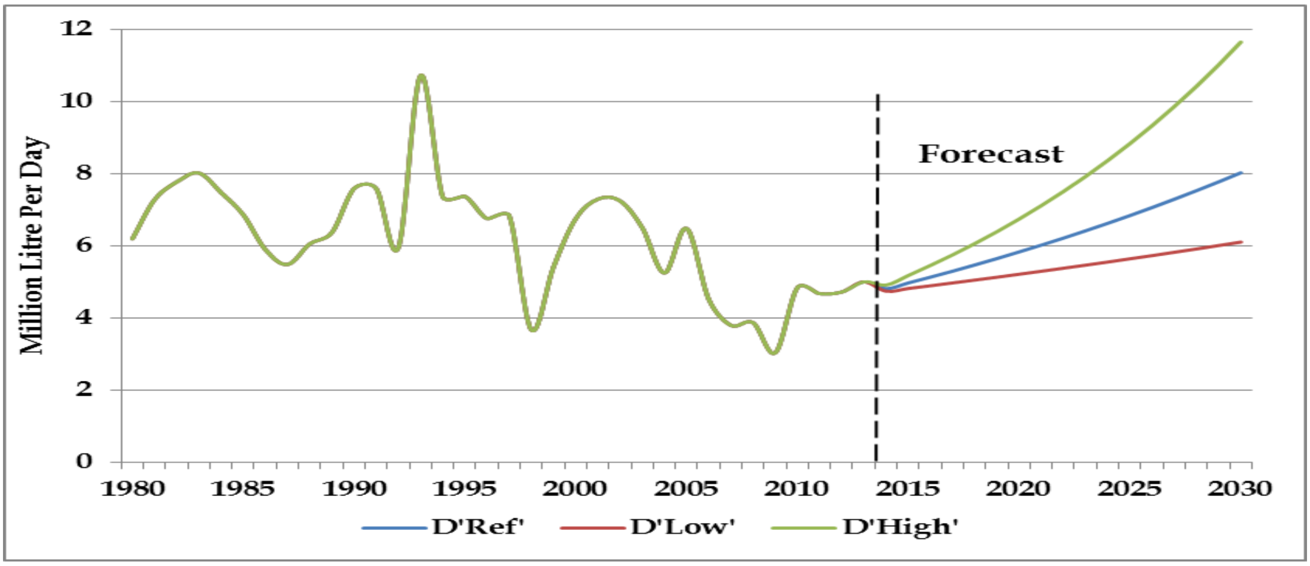
[5] Over the period 1980 to 2013, Nigeria's real GDP growth averaged 4.87% while real Per capita GDP growth rate averaged 2.18%. This average was used as the reference case for future growth of real per capita GDP. Since the model was estimated on per capita basis, the forecast was first conducted on per capita basis and then escalated with the future population growth to obtain the national demand forecast.

Figure 4: Gasoline Demand Forecast



Similarly, the reference case scenario projection for diesel indicates a significant increase in demand by about 67% in the next fifteen years. Diesel demand was forecast to reach 4.82, 5.83 and 8.03 million litre per day in 2014, 2020 and 2030 respectively (see Table V in Appendices). In comparison with the low and high case scenario, the reference case is 31% higher than the low case and 45% less than the high case in 2030. According to Isa et al (2013), about 20% of current consumption of petroleum products especially diesel is for captive electricity generation in the household and service sectors. Thus if grid electricity supply improves, the actual demand for petroleum products in the future especially diesel might be less than the projected values in this study.

Figure 5: Diesel Demand Forecast



5.3 Forecast Comparison

The reference scenario forecast in this study was compared with that of other studies on petroleum products demand in Nigeria. The forecast in this study seems to be in tandem with that of Wood Mackenzie (2014) for both gasoline and diesel demand especially in the next ten years. There is however large discrepancy between this study and forecast by Energy Commission of Nigeria (ECN, 2012). For instance, the reference case gasoline and diesel demand projection of 32.7 million litre per day and 4.97 million litre per day respectively in 2015 is significantly lower than ECN projection of 58.1 million litre per day and 23.3 million litre per day for gasoline and diesel respectively (see Figures 6 and 7). The discrepancies could be attributed to difference in methodology and assumptions on the future growth rate of key drivers of demand especially GDP and population. It is highly unlikely that Nigeria's gasoline and diesel demand will increase by about 100% within two years as envisaged by ECN (2012). We therefore expect future trajectory of petroleum products demand to be close to what is projected in this study.

Figure 6: Comparison of Gasoline Demand Projections (Reference Scenario)

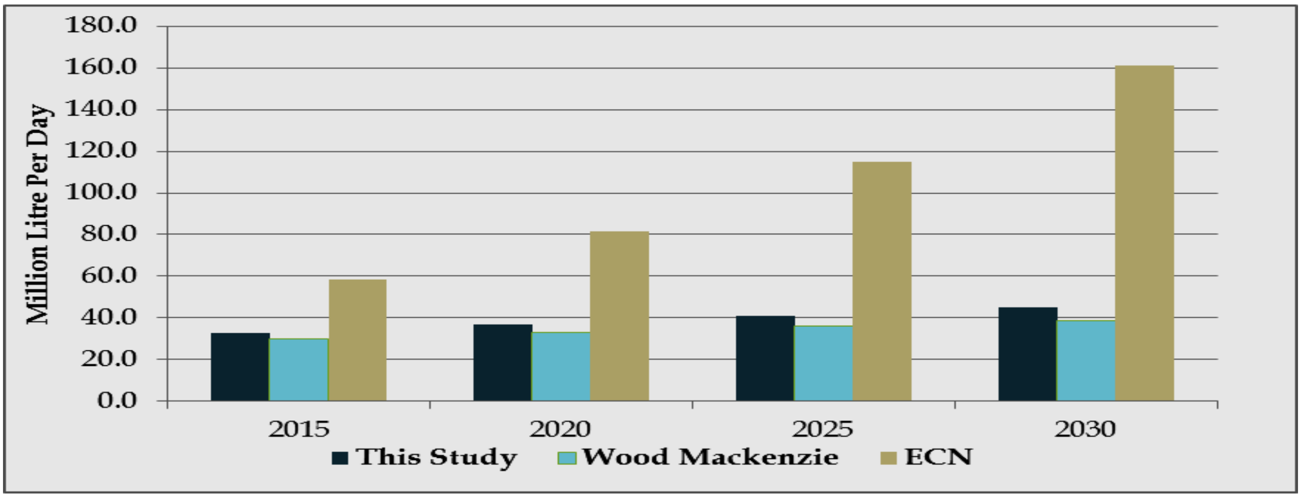
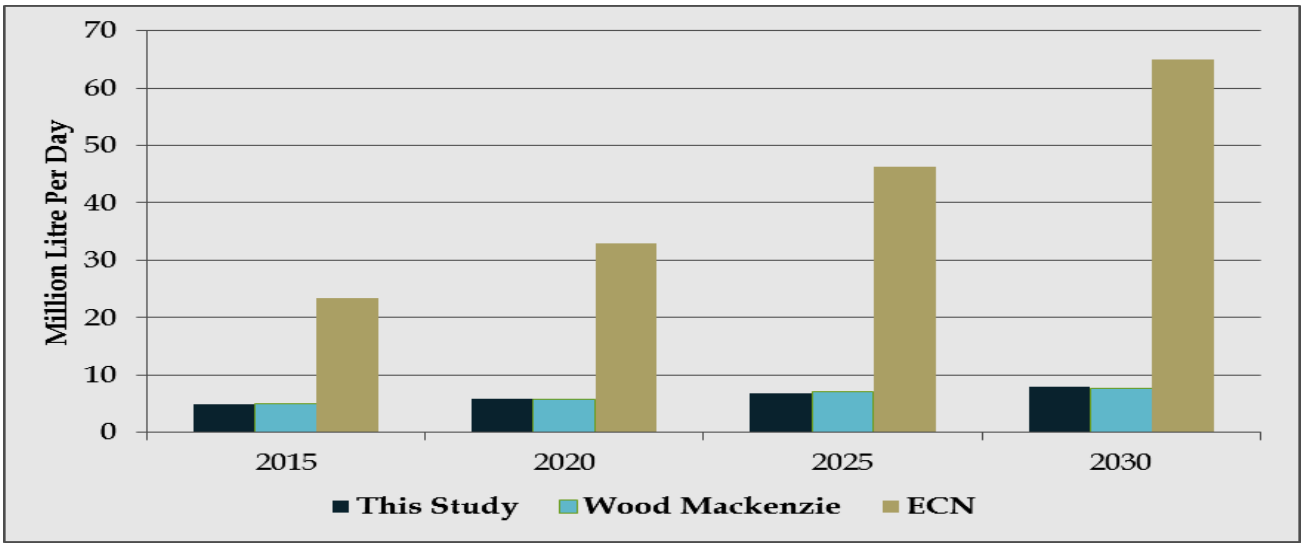


Figure 7: Comparison of Diesel Demand Projections (Reference Scenario)



6. Conclusion and Policy Implication

Modelling and forecasting petroleum products demand is a key input for energy use planning and policy formulation. This paper employs the Structural Time Series Model to estimate and forecast demand for two key petroleum products – gasoline and diesel in Nigeria. The preferred models were chosen based on economic intuition, econometric and statistical criteria. The models passed series of diagnostic test, including normality, heteroscedasticity, multicollinearity, autocorrelation and hyper-parameter tests. The models indicate a stochastic demand trends for both gasoline and diesel. Likelihood ratio test on the hyper-parameters further reject the restriction of a deterministic trend. The estimated demand models for gasoline and diesel were price and income inelastic and fall within the range reported in the literature.

The inelastic demand revealed in this study has important policy implications. Low price elasticities of demand for gasoline and diesel 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 these 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.

The demand models were forecast under three scenarios; reference case, low and high demand. The reference or base scenario describes the future based on current economic and policy environment, that is, without any specific policy shock. Under the reference case scenario, gasoline and diesel demand were forecast to reach 45.3 and 8.03 million litre per day in 2030 representing demand increase of 42% and 66% for gasoline and diesel respectively in the next fifteen years. This presents a significant challenge towards attaining self-sufficiency in meeting Nigeria's petroleum products demands through local refining. Already, there exist a huge gap between current petroleum products demand and local refinery output. The last fifteen years indicates a rising trend in import share of gasoline and diesel consumption reaching 90% and 44% respectively in 2013. With 30% average capacity utilization, the four local refineries (with combined capacity of 445 kilo barrels per day) barely meet 10% of local demand. Unless pragmatic policies are put in place to build new and revamp existing refineries, Nigeria will virtually continue to depend on imports in meeting its future petroleum products demand. The situation can improve especially if the existing refineries are revamped while the new proposed refineries are actualized. At present, there are about ten (10) proposals to establish new refineries in Nigeria which are all at initial project phase ranging from discussion, planning and feasibility stage. The combined capacity of the proposed refineries is about 1,560,000 barrels per day. The most likely to be commissioned in 2018 is the Dangote Refinery with a capacity of 400,000 barrels per day. Even though several others had proposed completion date as far back as 2013, not much has been achieved in terms of execution. Thus, given current demand trends, Nigeria is likely to continue to import gasoline up to 2022 even if 50% of the proposed new capacities are realized. There is therefore urgent need for the government to encourage private investors to build more refineries in order to reduce dependence on product imports.

Finally one may posit that the deployment of monthly and quarterly data rather than annual could elicit interesting results that would have account for seasonality. Furthermore, as opposed to aggregate demand, disaggregate data on sectoral demand such as residential, industrial, transport and services could provide sector specific demand forecast and therefore yield better information for policy consideration, particularly in designing appropriate policies such as taxes or subsidies targeted at specific sectors of the economy.

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APPENDICES

Table IV: Gasoline Demand Forecast (Million Litre Per Day)			
Year	**G'Ref'**	**G'Low'**	**G'High'**
2014	31.9	31.6	32.2
2015	32.7	31.9	33.3
2016	33.4	32.3	34.3
2017	34.2	32.7	35.5
2018	35.0	33.1	36.6
2019	35.8	33.4	37.8
2020	36.6	33.8	39.0
2021	37.4	34.2	40.3
2022	38.2	34.5	41.6
2023	39.0	34.9	42.9
2024	39.9	35.3	44.3
2025	40.8	35.6	45.7
2026	41.6	36.0	47.2
2027	42.5	36.3	48.7
2028	43.4	36.7	50.2
2029	44.3	37.0	51.8
2030	45.3	37.4	53.4

Table V: Diesel Demand Forecast (Million Litre Per Day)			
Year	**D'Ref'**	**D'Low'**	**D'High'**
2014	4.82	4.74	4.91
2015	4.97	4.82	5.18
2016	5.13	4.89	5.46
2017	5.30	4.97	5.75
2018	5.47	5.05	6.06
2019	5.65	5.13	6.40
2020	5.83	5.21	6.75
2021	6.02	5.30	7.12
2022	6.22	5.38	7.51
2023	6.42	5.47	7.93
2024	6.63	5.55	8.37
2025	6.84	5.64	8.84
2026	7.07	5.73	9.34
2027	7.30	5.82	9.87
2028	7.53	5.92	10.43
2029	7.78	6.01	11.03
2030	8.03	6.11	11.66