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Abstract

This paper analyses the demand for petroleum products in African member countries of OPEC namely Algeria, Angola, Libya and Nigeria over the period of 1980-2007. For this purpose, econometric models based on time series data are generated for individual products so as to capture product specific factors affecting demand. In doing so, the ARDL bounds testing approach to cointegration is applied to examine the long run relationship among the variables. Four specifications such as total petroleum product demand function, gasoline demand function, diesel demand function and kerosene demand functions have been estimated. The review of trends in the consumption and real prices of the various products suggest that demand for oil products has risen fast due to fast rise in income levels of individuals in these countries as compared to price level. Furthermore, results of estimation show mixed evidence about cointegration between the variables in all the countries studied. The evidence from the estimates show that the diesel demand specification provided satisfactory results in terms of producing expected signs than other specifications. The results for the kerosene model was the least satisfactory as most of the coefficients were found with unexpected signs. Finally the overall result indicates that demand for oil products are more responsive to changes in income than the real prices, both in the short and long run. This result is consistent with the previous studies on developing countries. Finally, the policy implication for result show the need for diversification, increase refining capacity and demand management policies in these countries to promote energy efficiency, conservation as well as discourage cross border smuggling of products and encourage private investment into the oil sector.

Keywords: Petroleum product demand, ARDL procedure

Introduction

The dynamics of oil in the energy sector makes it imperative to study the nature and characteristics of demand for the oil products in these countries. Firstly, apart from being the major producers and exporters of oil in Africa, some of these countries are also becoming major consumers of oil products in Africa. Arguably, this will have significant implications for their energy security[1,] the refining industry, domestic energy and macroeconomic policies, and for the world oil market, including global oil prices as well as global emission of greenhouse gases.

Since increase in consumption of oil products in these countries is inevitable due to rising population, economic growth, urbanization and rapid industrialization; therefore, there is a need to have policies that may promote conservation and efficient energy use in these counties. More so, petroleum resources are scarce and subject to depletion, measures to deal with future demand for and supply of these products needs not to be overemphasized. Similarly, accelerated production and consumption of oil among these countries are likely to have profound effects on global warming.

The World Bank (1997), suggests that rapidly rising oil demand in the developing countries has significant implications for the petroleum industry, governments and the world oil market. Furthermore, the increasing concentration of oil demand in the developing economies could alter crude oil trade flows, requiring more oil from the Middle East. However, greater dependence on oil from the Middle East due to higher demand does not necessarily imply higher oil prices. Much will depend on trends in non-OPEC supplies, OPEC's share of the world oil market, and the pricing policies of key oil exporting countries.

In addition, energy sector, particularly, oil contributes over 60% of the foreign exchange earnings and GDP of these countries therefore, any disruptions in supply or decline in international prices of oil will have an adverse balance of payment problems in these countries. Furthermore, unlike other developing countries, the prices of oil products in these countries remain relatively low and are, to a great extent, controlled by the government. This has stimulated higher

[1] For example, Nigeria is the largest exporter of Oil and largest consumer of oil products in Africa but has to rely on imports for her domestic needs due to dearth in refining capacity and perennial crisis in oil producing area.
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consumption rates, compared with other developing countries. The pricing of oil products, however, is a major policy issue in these countries. For example, there is a debate currently going on in Nigeria is on the need to completely deregulate the downstream sector of petroleum industry to allow the prices of products determined by market forces.

Therefore, the future rise in the consumption of oil products in these countries could likely have a potential to impose a heavy burden on the economies of these countries. In particular, the investments required in the energy supply sector to meet the anticipated increase in demand for oil are likely to be enormous. This requires the ability of these countries to mobilise both domestic and foreign resources, given the high debt burden in some of those countries and decline in the level of foreign investment in energy sector due to low energy prices and domestic insecurity in some of these countries. Recently, it has been argued that the link between foreign investments and energy sector will be influenced by both energy prices (which are expected to be high) and also the size of the investor and the capacity to borrow from banking system (Sa'ad, 2010).

Therefore, the objective of this paper is to estimate demand functions for three oil products (gasoline, diesel, and kerosene) and aggregate total in four African- member countries of OPEC, namely Algeria, Angola, Libya and Nigeria from 1980 to 2008 using the Autoregressive distributed lags (ARDL)/ Bound testing approach to cointegration.

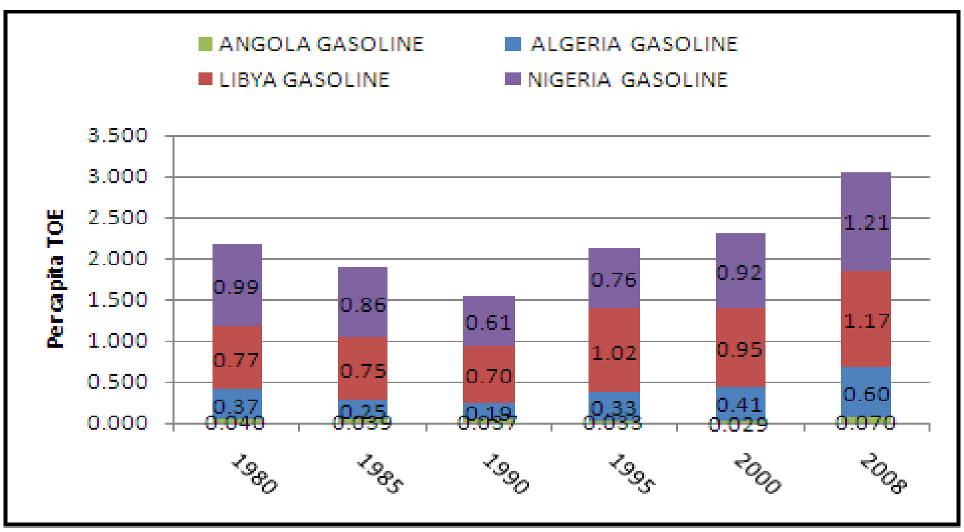
The importance of this study hardly needs emphasizing. Firstly, it is probably the earliest attempt to extend the existing literature on developing countries by expanding the geographical location of the countries to specifically study the demand for products in African member countries of OPEC. Secondly, reliable estimates of price and income elasticities are crucial in understanding the way in which oil products demand in these countries has responded to real factors such as economic growth and variations in real prices as well as structural and behavioural factors. This can guide the policy makers in pricing of oil products, designing of products mix and forecast of future demand and its likely impact on the environment. Thirdly, this study can significantly help to guide investment decisions for the various upstream and downstream activities of petroleum supply in these countries and will help in planning for an optimal product mix in these countries as well as forecast of future demand for petroleum products that are also crucial input for planners, policy makers and analysts.

The layout of this paper is as follows. Section 2 discusses the profile of oil products consumption in these countries. Section 3 reviews the previous literature on oil products demand and the methodology of the paper. Section 4 presents and interprets the empirical results and Section 5 provides the summary and conclusions from the results.

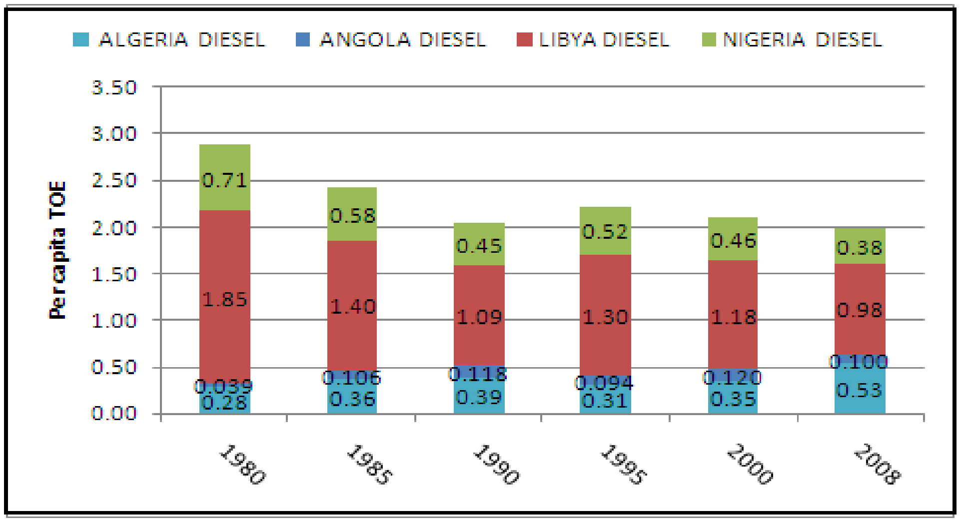
2. Evolution of Oil -product demand in Member Countries of OPEC

This part analyzed the trends in the consumption of oil petroleum products and movements in real prices of such products. From the figures, the consumption of the total and individual products increased significantly among the countries but at varied magnitudes. These differences arguably, are due to the fact that these countries are extremely heterogeneous in many dimensions, among themselves. There are major structural and policy differences in the economies of these countries; such as differences in real household's incomes, domestic pricing policies and the size of population as well as urbanization and motorization are all likely to will have a tremendous influence on the types and patterns of the products consumed in each countries.

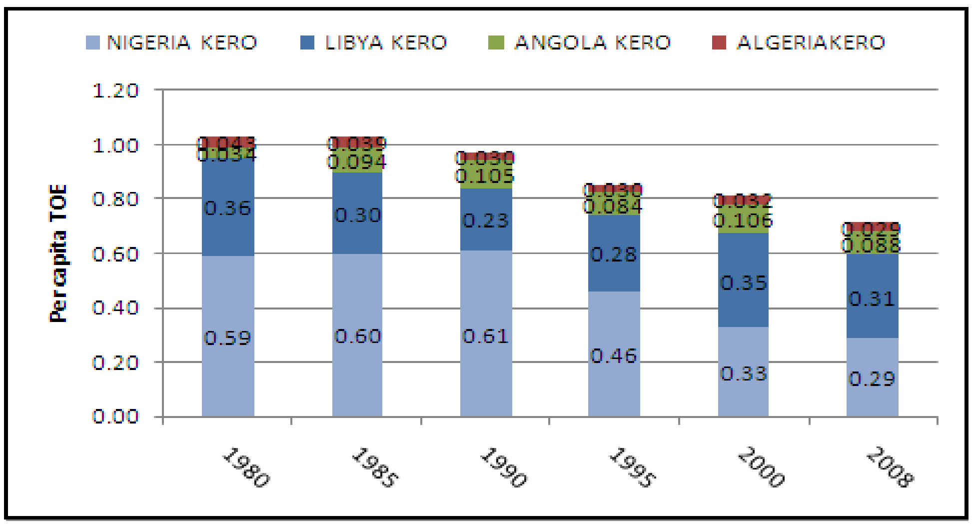
Fig 1 (a). Per capita Gasoline Consumption



(b). Per capita Diesel Consumption in TOE



(c) **Per capita Kerosene Consumption in TOE**



(d) **Per capita Total Consumption of Oil Products in TOE**

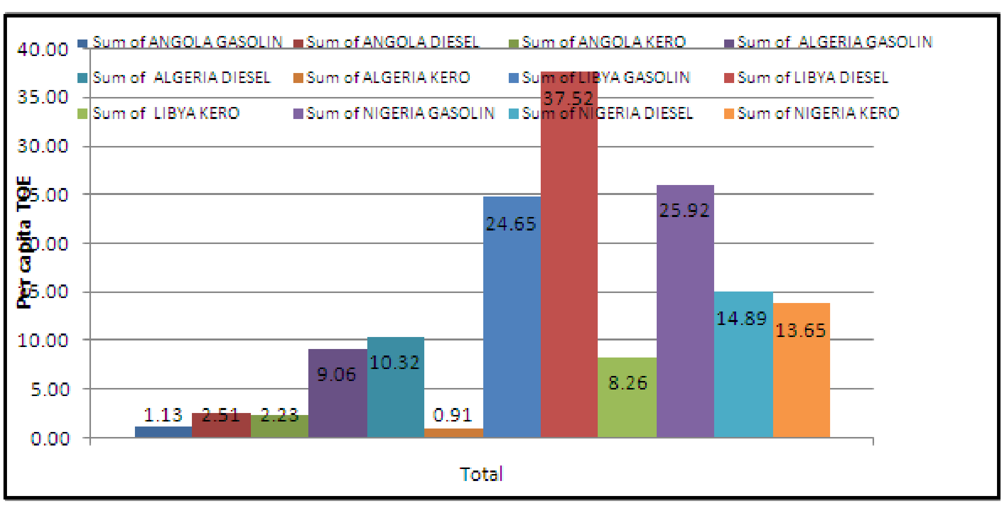


Fig 1 a-d presents the comparisons of the consumption of petroleum products (gasoline, diesel and kerosene) in Algeria, Angola Libya and Nigeria for the periods 1980, 1985, 1995, 2000 and 2008. In figure a, as can be seen, throughout the period, Nigeria and Libya recorded the highest per capita consumption of gasoline, this followed by Algeria and finally Angola. From the fig-a, in 1980, the per capita consumption of gasoline in Nigeria was 0.99toe, this slowed down to 0.61toe in 1990, however, trended upwards to a peak of 1.21toe in 2008. Similarly, the per capita consumption of gasoline in Libya was 0.77toe in 1980, this increased to 1.02toe in 1995, however, slowed down to 0.95toe in 2000, finally increased to 1.17toe in 2008.

In contrast, both Algeria and Angola recorded a modest growth of consumption during the period of study. In 1980 Algeria recorded 0.37toe per capita gasoline consumption; this fluctuated between 0.25toe and 0.60toe during the period of study. In Angola in 1980, the per capita consumption of gasoline was only 0.04toe, this progressively declined 0.03toe in 2000, however, steadily increased to reach a peak of 0.07toe in 2008.

Fig b compares per consumption of diesel in toe during the period of the study. The trends show clearly, the consumption of diesels maintained increasing trends throughout the period of study**.** Unlike the consumption of gasoline reviewed initially shows that Nigeria was leading; the trends in diesel consumption suggest that Libya recorded the highest level of consumption; this followed by Nigeria, as well as Algeria and Angola recorded the least.

Fig c shows the per capita consumption of kerosene for the countries of the study, from the trends, it is clear that Nigeria maintained the highest consumption of this product from 1980 to 1995, however, after 1995; Libya consumed more kerosene than other countries. The trend also shows that Algeria recorded lowest rate of kerosene consumption throughout the period of study.

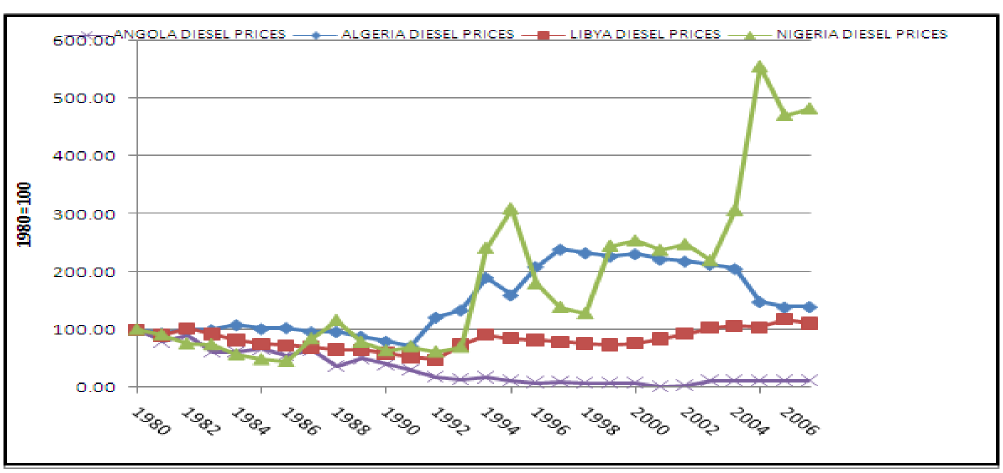
A general review of the total consumption of all the products are shown in fig. d, the trend suggest that Libya recorded the highest rate of diesel consumption, this followed by Nigeria and Algeria with Angola having the least. In contrast, the per capita consumption of gasoline suggests that Nigeria maintained a leading role, this followed by Libya, then Algeria and finally

Angola. Similarly, the per capita consumption of kerosene suggests that Nigeria recorded the highest rate this followed by Libya, then Angola and Algeria recording the least.

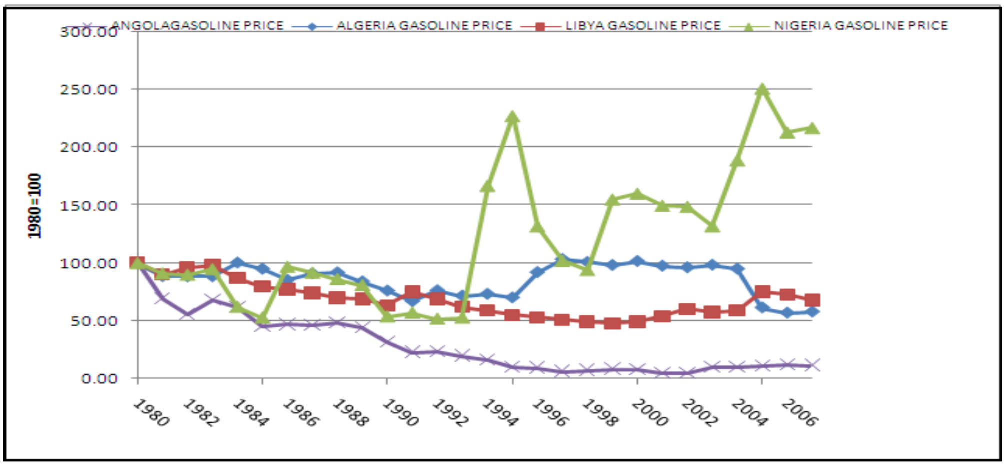
The trends in the consumption of gasoline show the influence of vehicle stocks and possible pricing policies on the consumption gasoline in these countries. It also implication for the refining capacity; for instance, from the trend, Nigeria, maintained leading position in the consumption of gasoline, while over 80 percent of the domestic consumption of that products are imported. Therefore, this trend suggests the need for expansion of refining capacity and implementation of demand management policies to promote efficiency.

The trend in the consumption of diesel probably suggest that most of the electricity generating plants in Libya use diesel, which shows the need for energy diversification and a shift towards energies like natural gas renewable like wind and solar in electricity generation in that countries. Finally, the consumption of kerosene suggests that there was a shift in consumption of kerosene to LPG in Algeria and also Angola heavily rely on biomass energy for domestic consumption. On the other hand, the high rate of kerosene in relation to diesel in Nigeria may suggest that there is substitution going on between kerosene and diesel; since one liter of diesel can buy almost four liters of kerosene. Other factors that a likely to contribute to these trends are urbanization, motorization and transition from biomass to commercial energy in households energy. Overall, the trends in the consumption suggest the need for energy diversification and increase in refining capacity particularly in Nigeria to reduce the overdependence on imported products as well as demand management policies to promote efficiency.

Fig 2 (a) Index of Real Gasoline Prices Country Comparison



(b) Index of Real Diesel Prices Country Comparison



(c) Index of Real Diesel Prices Country Comparison

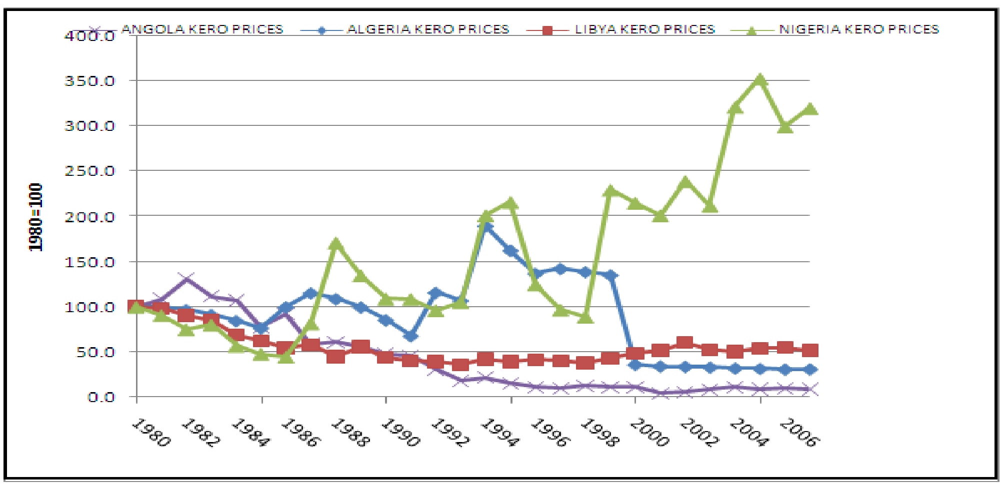


Fig. 2 a-c shows the relative movements of the real prices of petroleum products in United States dollar per tons of oil equivalents index to 1980. It can be observed from the graph that the real prices of all the products tended to be higher in Nigeria than other countries throughout the period of review[2]. Furthermore, for Libya and Angola, the trend shows that for all the three fuels, greater part of the review period their prices were relatively very love and almost flat, suggesting that changes in domestic prices were very infrequent during the period of review. This suggests that the real prices of these products were heavily subsidized in these countries.

[2] Nigeria started deregulating the prices of petroleum products since late 1980s as part of the structural adjustment programme.

From the review of the trends in consumption and movements of products prices in these countries, there is a clear cut differences in the trends of consumption and movements of real prices in all the countries and for all the prices[3]. However, it is clear that the consumption of all these products have been growing very fast and the fluctuations in the real prices were very slow. So many factors are likely to be responsible for the trend.

The World Bank (1997), argued that there is a strong positive (but not perfect) correlation between income and oil products demand in developing countries, this relationship is even stronger in OPEC than non-OPEC countries. Within OPEC, oil demand has risen even in the face of declining per capita income. This phenomenon in inconsistent with previous studies on the asymmetric responds of changes in energy consumption to income decline which shows that as incomes decline, energy consumption tends to decline. Conversely, in oil exporting countries, as income declines, oil consumption continues to increase, albeit more slowly than when income had been rising.

Similarly, as observed, domestic energy (particularly pricing) policies have a profound influence on the consumption of energy in both develop and developing countries, whereas in developed OECD countries, there are some consistent and clear policies aimed at encouraging efficiency of energy use and inflow of private investments into energy sectors. Therefore, energy and oil demand respond asymmetrically to price increases and decreases. In contrast, in developing countries, particularly, oil exporting countries governments have complex, inconsistent and distorting pricing policies. And these policies are changing over time. Some governments have subsidies[4] on most or all petroleum products. As a result, pricing policies are formulated based on political rather than economic considerations, thus, prices are heavily subsidized which encourages wastages and smuggling of products into neighboring countries. Therefore, there is a need for pricing policies that can promote efficiency in consumption, discourage cross-border smuggling of products and encourage private investment in downstream sector of the industry in all the countries.

[3] These differences can be attributed to real and structural factors discussed earlier.
[4] Due to budgetary pressures Nigerian government have begun rising prices of products at least to cover the cost. In fact, the government is considering total deregulation of oil products prices.

3. Review of Previous Studies on Oil Products Demand

The demand for oil products has already been well researched extensively. However, most studies of oil products demand focus on the industrialized developed OECD countries inspite of the growing importance of developing countries in the global supply and demand of oil (see Dahl (1986), Dahl and Sterner (1991), Bhatia (1987), and Gately (1990)). However, there are some few studies which concentrate on non-OECD developing countries such as Dunkerley and Hoch (1987); Garbacz (1989); Dahl (1994); Al-Sahlawi (1997); Chakravorty et al. (2000); Dahl and Kurtubi (2001); Akinbaode et al. (2008), Alfaris (1997), Rao and Parikh (1996), Dahmani (2001), Bhattacharyya and Blake (2009) and Iwayemi et al. (2010). Table-1 below reports the estimated price and income elasticities of demand for oil products in developing countries.

A common characteristic of oil products demand like other energy demand studies is that there is little consistency in methodology, assumptions as well as the nature of data[5] used in each study. These factors led to divergence in price and income elasticities of demand for products; this will have a profound influence on both domestic and international energy policies.

Table-1: Survey of Oil Products Demand Elasticities for Developing Countries

Year	Author	Country	Products	LR Price	LR Income
1994	Dahl, C.	Developing Countries	Oil Products	-0.16-0.34	0.85-2.2
1996	Rao and Parikh	India	Petroleum Products	-0.03 to -0.25	0.02-0.75
1997	Alfaris, A.F	GCC Countries	Oil Products	-0.11to-0.24	0.07-2.9
1997	Al-Sahalawi, M.A.	Saudi Arabia	Oil Products	-0.26 to -0.30	0.86-2.0
1998	Wohlgemuth, N	Developing Countries	Oil Products	-0.07 to-0.90	0.32-1.7
2001	Dahl and Kurtubi	Indonesia	Oil Products	-0.63 to -1.15	0.63-1.73
2001	Dahmani, A	OPEC Countries	Oil Products	N/A	N/A
2009	Bhattacharyya and	MENA Countries	Petroleum Products		
2010	Ewayemi, A. et al.	Nigeria	Petroleum Products		

The paper by Dahl (1994) was the earliest attempt to review the existing econometric studies on oil and its products demand in developing countries, the review show that the long run price and

5 Some studies for example, international market prices rather than local market prices when estimating energy consumption in developing countries.

income elasticities in the countries reviewed ranged between -0.16-0.34 for long run price and 0.85-2.2 for long run income elasticity. Two year after, Rao and Parikh (1996) studied price and income elasticities of demand for oil products in India, their result reveled long run price and income elasticities of -0.03 to -0.25, for price and 0.02-0.75 for long run income respectively. In 1997, Alfaris, estimated long run oil demand functions for GCC countries, all these counties are members of OPEC; his result also falls within the ranges of -0.11to-0.24 for long run price and 0.07-2.9 for income elasticity respectively. Similarly, Al-Sahalawi (1997) studied the demand for petroleum products in Saudi Arabia, the result of his study revealed long run price and income elasticities of -0.26-0.30 for price and 0.86-2.0 for long run income, respectively. The study by Wohlgemuth (1998) for developing countries estimated long run price elasticity between the range of -0.07 to -0.90 and long run income elasticity of 0.32-1.7, respectively. Furthermore, study by Dahl and Kurtubi (2001) for Indonesia have the largest price elasticities among all the studies reviewed, the study estimated the long run price elasticities of -0.63 -1.15, and the long run income elasticities of 0.63-1.73, respectively.

Interesting thing about all the papers reviewed, irrespective of the country and year of study, shows that in all the countries, consumption of all products are more responsive to changes in incomes than real prices, this therefore, suggest that prices are highly subsidized in those countries, therefore, there is little room for energy efficiency and conservation. Unless of there is a deliberate policy by those counties to deregulate prices, and allow market forces to determine them, otherwise, there desired objective of efficiency and conservation can hardly be achieved.

Theoretical Framework, Methodology and Data Collection

This paper uses log-linear specification which is widely used in energy demand modeling; this method also has a desirable quality of providing more robust and reliable results as compared to simple linear specification (Shahbaz, 2010). Furthermore, Dahl and Kurturbi (2004) pointed out that log-linear specifications are better than lagged endogenous models, the lagged endogenous model presents the problem of multicolinearity between lagged variable and income (Dahl, 1994). Multicolinearity makes empirical model instable due to an increase in the standard errors which reduces the explaining power of independent variables.

Following framework derives from standard consumer theory which is based on the consumer's optimization solution problem. This approach shows the key role of income and price on petroleum consumption (energy consumption) but functional structure of this approach is weak (Iwayemi et al. 2010). Even though, energy literature offers different types of specification for empirical purpose. Most of studies used lag structure such as Koyck, Partial, Adaptive and Almon following specific stock adjustment mechanism, habit persistence or adaptive expectations (Engsted and Bentzen, 2001 and Iwayemi et al. 2010). The functional form of estimable equations is being modeled as following:

$$\ln PC_t = \alpha_0 + \alpha_{PP} \ln PP_t + \alpha_Y \ln Y_t + \mu_{i1} \ldots \quad (1)$$

$$\ln GC_t = \phi_0 + \phi_{GP} \ln GP_t + \phi_Y \ln Y_t + \mu_{i2} \ldots \quad (2)$$

$$\ln DC_t = \varphi_0 + \varphi_{GP} \ln GP_t + \varphi_Y \ln Y_t + \mu_{i3} \ldots \quad (3)$$

$$\ln KC_t = \psi_0 + \psi_{KP} \ln KP_t + \psi_Y \ln Y_t + \mu_{i4} \ldots \quad (4)$$

Equations 1-4 above are functional forms showing the consumption of each products in log form is a function of real variables such as real income, real prices and deterministic trend, which capture the structural factors that are likely to affect the consumption of such products. This paper follows the ARDL bounds testing approach to cointegration developed by Pesaran et al. (2001) to examine the long run relationship between oil products demand, income and prices of oil products in case of Algeria, Angola, Libya and Nigeria. There are certain advantages of this approach. First, the short- and long- runs parameters are estimated simultaneously. Secondly, it can be applied irrespective of whether the variable are integrated of order zero i.e., *I(0)* or integrated of order one i.e. *I(1)*. Thirdly, it has better small sample properties vis-à-vis multivariate cointegration test i.e. it is more useful when sample size is small. Fourth, ARDL bounds testing approach to cointegration is free from any problem faced by traditional techniques such as Engle-Granger (1987), Philips and Hansen (1990); Johansen and Juselius (1990); Johansen (1991) and Johansen (1992) maximum likelihood ratio. The error correction method integrates the short-run dynamics with the long-run equilibrium, without losing long-run information. However, Pesaran and Shin, (1999) contented that, "*appropriate modification of the orders of ARDL model is sufficient to simultaneously correcting for residual serial correlation and problem of endogenous variables*".

There are several procedures for cointegration e.g. Engle–Granger's (EG) (1987), Johansen's (1992) maximum likelihood, Pesaran–Shin's (1999) are available but require unique order of integration for the variables to be concerned in model and Engle–Granger (1987) is not preferable in the presence of more than one cointegrating vector (Seddighi et al. 2006). While ARDL bounds testing approach to cointegration is more advanced and does not require information about integrating order of the variable as necessary condition. This shows that ARDL procedure can be applied without testing the stationarity properties of interested variables in the model. But, (Ouattara, 2004) argues that lower and upper critical bounds by Pesaran et al. (2001) are based the assumption that the variables should be stationary of order I(0) or I(1). If any series is found to be stationary at I(2) then computation of F-statistic for cointegration is not validated. Therefore, to ensure that none of the variable is stationary at $I(2)$ or higher, unit root test is necessary. In doing so, the Augmented Dickey-Fuller (ADF), unit root test has been employed to for testing unit root. The equations of unrestricted error correction methods are being modeled as follows:

Model-A: Aggregate petroleum consumption (PC), petroleum prices (PP) and income (Y):

$$\Delta \ln PC_t = \alpha_\circ + \alpha_T T + \alpha_{PP} \ln PP_{t-1} + \alpha_Y \ln Y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \ln PC_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta \ln PP_{t-j} + \sum_{l=0}^{n} \alpha_k \Delta \ln Y_{t-l} + \mu_{t1} \quad (5)$$

Model-B: Gasoline consumption (GC), gasoline prices (GP) and income (Y):

$$\Delta \ln GC_t = \beta_\circ + \beta_T T + \beta_{GC} \ln GC_{t-1} + \beta_{GP} \ln GC_{t-1} + \beta_Y \ln Y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln GC_{t-i} + \sum_{j=0}^{q} \beta_j \Delta \ln GP_{t-j} + \sum_{l=0}^{n} \beta_k \Delta \ln Y_{t-l} + \mu_{i2} \quad (6)$$

Model-C: Diesel consumption (DC), diesel prices (DP) and income (Y):

$$\Delta \ln DC_t = \delta_\circ + \delta_T T + \delta_{DC} \ln DC_{t-1} + \delta_{DP} \ln DP_{t-1} + \delta_Y \ln Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta \ln DC_{t-i} + \sum_{j=0}^{q} \delta_j \Delta \ln DP_{t-j} + \sum_{l=0}^{n} \delta_k \Delta \ln Y_{t-l} + \mu_{i3} \quad (7)$$

Model-D: Kerosene oil consumption (KC), kerosene oil prices (KP) and income (Y):

$$\Delta \ln KC_t = \varphi_\circ + \varphi_T T + \varphi_{KC} \ln KC_{t-1} + \varphi_{KP} \ln KP_{t-1} + \varphi_Y \ln Y_{t-1} + \sum_{j=0}^{q} \varphi_j \Delta \ln KC_{t-j} + \sum_{l=0}^{n} \varphi_k \Delta \ln KP_{t-l} + \sum_{n=0}^{n} \varphi_l \Delta \ln Y_{t-n} + \mu_{i4} \quad (8)$$

The ARDL bounds testing approach to cointegration depends upon the tabulated critical values by Pesaran et al. (2001) to take the decision about the existence of cointegration among the variables. In case where, long run liaison is established and F-statistic indicates which variable should be normalized. Unambiguously, the null hypothesis of no cointegration in equation-5 is $H_\circ : \alpha_{PC} = \alpha_{PP} = \alpha_Y = 0$ tested against its alternative hypothesis $H_a : \alpha_{PC} \neq \alpha_{PP} \neq \alpha_Y \neq 0$ and it is referred as $F_{PC}(PC / PP, Y)$. In equation-6, gasoline consumption is dependent variable and null hypothesis of no cointegration is $H_\circ : \beta_{GC} = \beta_{GP} = \beta_Y = 0$ against its alternative hypothesis which is $H_a : \beta_{GC} \neq \beta_{GP} \neq \beta_Y \neq 0$ and indicated as $F_{GC}(GC / GP, Y)$ for F-statistic. Hence, null hypotheses of no cointegration of equation-7 and 8 are $H_\circ : \delta_{DC} = \delta_{DP} = \delta_Y = 0$ and $H_\circ : \varphi_{KC} = \varphi_{KP} = \varphi_Y = 0$ against their alternative hypotheses $H_a : \delta_{DC} \neq \delta_{DP} \neq \delta_Y \neq 0$ and $H_a : \varphi_{KC} \neq \varphi_{KP} \neq \varphi_Y \neq 0$ respectively while referred as $F_{DC}(DC / DP, Y)$ and $F_{KC}(KC / KP, Y)$ for F-statistic respectively. Next step is to compare the calculated F-statistic with LCB (lower critical bound) and UCB (upper critical bound) by Pesaran et al. (2001). There is cointegration among the variables if calculated value of F-statistic is more than UCB. If LCB is more than computed F-statistic then hypothesis of no cointegration may be accepted. Finally, if calculated F-statistic is between lower and upper critical bounds then decision about cointegration is inconclusive. In such situation, we will have to rely on the lagged error correction term to investigate long run relationship. As, Bannerjee et al. (1998) pointed out that a highly significant error correction term is further proof of the existence of stable long run relationship. If long run relationship exists, short run behavior is investigated using error correction method (ECM) as given below in equation-9-12.

$$\Delta \ln PC_t = \alpha_{\circ 1} + \sum_{j=0}^{q} \alpha_{j1} \Delta \ln PP_{t-j} + \sum_{l=0}^{n} \alpha_k \Delta \ln Y_{t-l} + \delta_i ECM_{t-1} + \mu_{i1} \ldots (9)$$

$$\Delta \ln GC_t = \beta_{\circ 1} + \sum_{j=0}^{q} \beta_{j1} \Delta \ln GP_{t-j} + \sum_{l=0}^{n} \beta_{k1} \Delta \ln Y_{t-l} + \delta_j ECM_{t-1} + \mu_{i2} \ldots (10)$$

$$\Delta \ln DC_t = \delta_{\circ 1} + \sum_{j=0}^{q} \delta_j \Delta \ln DP_{t-j} + \sum_{l=0}^{n} \delta_k \Delta \ln Y_{t-l} + \alpha_i ECM_{t-1} + \mu_{i3} \ldots \quad (11)$$

$$\Delta \ln KC_t = \varphi_{\circ 1} + \sum_{l=0}^{n} \varphi_{k1} \Delta \ln KP_{t-l} + \sum_{n=0}^{n} \varphi_{l1} \Delta \ln Y_{t-n} + \delta_i ECM_{t-1} + \mu_{i4} \ldots (12)$$

The lagged residual term or error term (ECM_{t-1}) in equation-9-12 indicates the changes in dependant variable. These changes are not only due to the two levels of disequilibrium in the cointegration association but also in the other explanatory variables which points to the convergence of the dependant variable from short to long run equilibrium relationship (Masih and Masih, 1996). In such situation, the error correction term causes the dependent variable to converge to the long span of time for stable equilibrium caused by the variations in the independent variables.

Annual data for the aggregate total products consumption, gasoline, and diesel and kerosene consumption are their real prices for the period 1980 to 2008 are sourced from OPEC annual reviews (various editions). Data for the real income are sourced from the International Energy Agency, Beyond 2020, Energy Statistics and Balances 2010 edition.

Per capita real income is the GDP at 1980 constant prices (billions of local currency) divided by the annual population. The per capita final oil products consumption (gasoline, diesel and kerosene) in tons of oil equivalent consumed by various sectors in the countries of study during the period of this study was divided by the annual population. The index of the weighted average of real petroleum products prices are the nominal prices of diesel and gasoline and kerosene in local currency per ton of oil equivalent deflated by the GDP implicit deflator and indexed to 1980 as the base year.

4. Results Interpretations

The results are reported in Table-2. In Algeria, all the variables do have unit root problem at level but stationary at their 1st differenced form while in case of Angola, $\ln DC_t$ is integrated of I(0) at 1% level of significance and other variables are stationary at I(1) and same case is Libya as $\ln GC_t$ is stationary at I(0) at 10% level of significance. Finally, $\ln PC_t$, $\ln PP_t$, $\ln DP_t$, $\ln KC_t$, $\ln KP_t$ and $\ln GP_t$ are integrated of I(0) order and rest are stationary at I(1) integrating order.

Table-2: Unit Root Estimation

Variables	ADF at Level		ADF at 1st Difference	
	T-Statistic	Prob-Value	T-Statistic	Prob-Value
Algeria				
$\ln PC_t$	-2.04	0.553	-8.670*	0.000
$\ln PP_t$	-0.98	0.930	-5.261*	0.001
$\ln GC_t$	-1.57	0.776	-9.850*	0.000
$\ln GP_t$	-1.76	0.693	-3.671**	0.043
$\ln DC_t$	-1.30	0.864	-3.313***	0.095
$\ln DP_t$	-0.97	0.931	-5.066*	0.002
$\ln KC_t$	-2.42	0.362	-4.211**	0.014
$\ln KP_t$	-1.59	0.770	-5.209*	0.001
$\ln Y_t$	-2.34	0.400	-4.895*	0.003
Angola				
$\ln PC_t$	-2.62	0.276	-3.983**	0.023
$\ln PP_t$	-0.97	0.929	-5.031*	0.002
$\ln GC_t$	-0.87	0.943	-5.695*	0.000
$\ln GP_t$	-1.00	0.926	-4.259*	0.012
$\ln DC_t$	-4.71	0.005*	-4.838*	0.003
$\ln DP_t$	-2.10	0.519	-5.082*	0.002
$\ln KC_t$	-2.21	0.463	-3.991**	0.022
$\ln KP_t$	-1.52	0.795	-4.198**	0.014
$\ln Y_t$	-1.10	0.909	-3.310***	0.086
Libya				
$\ln PC_t$	-1.65	0.744	-4.154**	0.016
$\ln PP_t$	-0.91	0.939	-3.892**	0.027

$\ln GC_t$	-3.29	0.0905***	-3.624**	0.048
$\ln GP_t$	-0.74	0.958	-4.743*	0.004
$\ln DC_t$	-3.01	0.149	-4.207**	0.014
$\ln DP_t$	-2.02	0.563	-4.250**	0.013
$\ln KC_t$	-1.90	0.624	-7.259*	0.000
$\ln KP_t$	-1.61	0.760	-3.629**	0.047
$\ln Y_t$	-1.81	0.667	-5.581*	0.000
Nigeria				
$\ln PC_t$	-3.55	0.053***	-7.201*	0.000
$\ln PP_t$	-4.48	0.007*	-5.387*	0.001
$\ln GC_t$	-2.33	0.401	-5.745*	0.000
$\ln GP_t$	-3.75	0.035**	-5.089*	0.002
$\ln DC_t$	-2.85	0.191	-4.375*	0.010
$\ln DP_t$	-4.29	0.011**	-5.350*	0.001
$\ln KC_t$	-3.62	0.047**	-5.169*	0.001
$\ln KP_t$	-4.58	0.006*	-4.705*	0.004
$\ln Y_t$	-1.98	0.577	-4.710*	0.004

It is noted that unique order of integration in Algeria and mixed order of integration in Angola, Libya and Nigeria lead us to apply the ARDL bounds testing approach to cointegration to analyse long run relationship between the said variables in African countries of OPEC. After confirming the order of integration, we estimate the UECM cointegration to select the lag length[6]. We use the Akaike's Information Criterion (AIC) to determine the optimal lag order[7]. Narayan (2005) argue that the critical values from Pesaran et al. (2001) are inappropriate for small sample. Given that the small sample ($T = 27$), we apply the critical values for small sample from the procedure developed by Narayan (2005) for Pesaran et al. (2001). The UECM cointegration results show that the calculated F-statistics 13.1514, (11.5130), 9.8506 are exceed critical values at the 1 percent level of significance when $\ln PC_t$, $(\ln GC_t), \ln KC_t$ are dependent variables showing cointegration between the variables in said models in case of Algeria. This shows that there is long run relationship between petroleum, gasoline and kerosene demand functions.

No long run relationship is found in diesel demand function as critical value is less than lower critical bounds at 1%, (5%), 10% level of significance respectively. In the case of Angola, no

[6] For more details see Feridun and Shahbaz (2010) and Shahbaz et al. (2010c)
[7] Results of lag length selection are not reported due lack of space but available upon request from authors.

cointegration is found in any petroleum demand function at any level of significance that indicates no long run relation is found among the variables for said petroleum demand functions. The ARDL bounds testing approach to cointegration analysis indicates no cointegration for gasoline demand function indicating no long run relationship between gasoline consumption, gasoline price and income in case of Libyan economy. The empirical results show cointegration for petroleum, diesel and kerosene demand functions at 10% and 5% respectively over the study period. Lastly, cointegration is found at 10%, 5% and 1% level of significance respectively, when $\ln PC_t$, $\ln GC_t$ and $\ln DC_t$ are response variables suggesting long run relationship for the said variables in the estimated models.

Table-3: ARDL Bounds Testing Approach to Cointegration

Dependent Variable	Country	ARDL bounds testing to cointegration F-Statistic	Adjusted-R^2
	Algeria		
$\ln PC_t$		13.1514*	0.8016
$\ln GC_t$		11.5130*	0.7758
$\ln DC_t$		1.5825	0.3442
$\ln KC_t$		9.8506*	0.6608
	Angola		
$\ln PC_t$		2.2348	-0.0515
$\ln GC_t$		2.6219	0.4197
$\ln DC_t$		2.4240	-0.0025
$\ln KC_t$		2.3199	0.0667
	Libya		
$\ln PC_t$		6.3518***	0.6124
$\ln GC_t$		2.3212	0.0831
$\ln DC_t$		7.8304**	0.5920
$\ln KC_t$		6.0822**	0.8494

Nigeria		
$\ln PC_t$	5.2715***	0.3511
$\ln GC_t$	7.1297**	0.5050
$\ln DC_t$	13.530*	0.7063
$\ln KC_t$	4.2400	0.4044

Note: The lower and upper critical bounds are 7.593, 8.350 at 1%; 5.377, 5.963 at 5% and 4.427, 4.957 at 10% by Narayan (2005) from Table CI (V), page-1989. * (**), *** show cointegration among the variables at 1%, (5%), 10%.

After discussing cointegration results for long run, next turn is to discuss the long- and short-runs income and price elasticities over the study period i.e. 1980-2007. We have divided our analysis in four parts: (i) average petroleum demand function, (ii) gasoline oil demand function, (iii) diesel demand function and kerosene oil demand function respectively. Petroleum demand function results both long and short run are reported in Table-4.

The empirical results reveal that in case of Algeria and Nigeria income has positive and significant impact of average petroleum consumption. This shows with an increase in income demand for petroleum is increased suggesting that petroleum shows characteristic of normal good for long run Nigeria and, for long run and short run in case of Algeria. In the rest such as Angola and Libya countries impact is negative but insignificant. This shows that petroleum is considered an inferior good in long run. Our findings regarding Nigerian economy are consistent with the findings of Iwayemi et al. (2010) both long run and short run. The impact of petroleum prices is negative and significant on petroleum demand in Nigeria (also for short run). In long run (short run) impact of petroleum price is positive and insignificant in case of Algeria, this might not be unconnected with the fact that kerosene is an inferior product in that country because of the shift from kerosene to natural gas in most Algerian households.

Table-4: Aggregate Petroleum Consumption Analysis

Countries	Long Run Analysis				Short Run Analysis				
	$Constant$	$\ln Y_t$	$\ln PP_t$	$Trend$	$Constant$	$\ln Y_t$	$\ln PP_t$	ECM_{t-1}	$F-statistic$
Algeria	-1.6762	0.6101	0.1001[a]	0.0099	0.0017	0.9347	-0.2386	-0.9030	5.8041*
	(-1.7568)***	(1.9351)***	(0.5649)	(2.0356)**	(0.0533)	(1.7345)***	(-1.3408)	(-2.3443)**	
Angola	-2.3283	-0.1447[a]	0.0975[a]	0.0338	0.0332	0.1799	-0.2185	-0.3617	1.9737
	(-4.3405)*	(-0.4272)	(0.6569)	(2.3282)**	(0.7721)	(0.3553)	(-0.7019)	(-2.3806)**	
Libya	-0.9296	-0.3307[a]	0.6565[a]	-0.0080	-0.0076	-0.0659	0.0435 [a]	-0.2742	1.1539
	(-1.0446)	(-1.3714)	(2.3178)**	(-1.9498)***	(-0.4025)	(-0.2630)[a]	(0.1666)	(-2.3858)**	
Nigeria	-0.0206	0.5513	-0.0642	-0.0087	-0.0008	0.1467	-0.1694	-0.5988	3.8854**
	(0.0493)	(2.3982)**	(-0.9992)	(-2.1462)**	(-0.0473)	(0.4065)	(-2.6538)**	(-2.9602)*	

Note: *, ** and *** indicate significance at 1%, 5% and 10% while [a] means unexpected sign.

In case of Libya, the affect of petroleum prices is positive and statistically significant and same inference is for the short run but impact is insignificant. The impact of petroleum prices is positive and it is insignificant but negative in short run although insignificant. The trend variable has positive affect on petroleum consumption in Algeria and Angola while negative impact is also found in Libya and Nigeria respectively. The short run adjustment to long run convergence can be seen from coefficients of lagged error term which are -0.9030, -0.3617, -0.2742 and -0.5988 in Algeria, Angola, Libya and Nigeria respectively. The significance of lagged residual terms is further proof of established cointegration in Algeria, Libya and Nigeria. The significant lagged error term in case of Angola confirmed that there is cointegration showing long run relation between petroleum demand, income and petroleum prices[8]. The results of gasoline oil demand function are reported in Table-5.

[8] We could attain cointegration for said variables as we compared our calculated F-statistic with upper critical bound generated by Pesaran et al. (2001)

The impact of income on gasoline is positive in Libya and Nigeria at 10% level of significance but insignificant impact of income on gasoline demand for Algerian economy. It implies that gasoline is considered as normal good in Libya and Nigeria. In case of Angola, impact of income on gasoline demand is negative and statistically insignificant. These findings are consistent with the evidence view by Bhattacharyya and Blake (2009). The effect of rise in income on gasoline demand is positive but it is statistically insignificant in case of Algeria in long run this probably suggests that gasoline is highly subsidized in Algeria. The hike in prices of gasoline has positive impact on gasoline demand in case of Algeria and Angola but effect in negative but insignificant in Libya and Nigeria. The trend variable raises demand for gasoline significantly in Angola, Libya and Nigeria but insignificant in case of Algeria. The short run analysis reveals that the effect of income is positive and significant at 10% only in Nigeria while price hike in gasoline will affect demand for gasoline negatively but it is statically insignificant. Further, it is concluded on basis of short run analysis that rise in price of gasoline affects gasoline demand positively in case of Angola and Libya but significance is not found in Algerian economy. The lagged error terms are significant having negative signs only for Algeria[9] and Nigeria[10].

[9] It established cointegration between gasoline demand, income and gasoline prices.
[10] It confirmed the established cointegration between the said variables.

Table-5: Gasoline Consumption Analysis

Countries	Long Run Analysis				Short Run Analysis				
	$Cons\tan$	$\ln Y_t$	$\ln GP_t$	$Trend$	$Cons\tan t$	$\ln Y_t$	$\ln GP_t$	ECM_{t-1}	$F-statistic$
Algeria	-12.2158	1.0154	2.1564[a]	0.0096	-0.0336	0.8721	1.1661[a]	-0.15924	26.1836*
	(-2.8458)*	(0.7654)	(2.6568)**	(0.4818)	(-0.2979)	(0.4002)	(1.2086)	(-8.7894)*	
Angola	-5.9411	-0.1115[a]	0.5816[a]	0.0695	0.0387	0.1404	0.2464[a]	-0.2025	2.4501***
	(-17.5884)*	(-0.4594)	(5.9329)*	(7.4035)*	(1.2187)	(0.3500)	(1.8782)***	(-1.2905)	
Libya	-1.1285	0.3652	-0.0557	0.0235	0.0198	0.0724	0.2412[a]	-0.0924	0.8595
	(-2.0328)**	(1.7226)***	(-0.3131)	(5.5817)*	(1.6152)	(0.5669)	(2.5422)**	(-0.8884)	
Nigeria	-1.4220	0.6006	-0.0078	0.0082	0.0063	0.6267	-0.0119	-0.4953	2.4416***
	(-2.1639)**	(1.7640)***	(-0.0088)	(1.6843)***	(0.2375)	(1.7300)***	(-0.1022)	(-2.0104)***	

Note: *, ** and *** indicate significance at 1%, 5% and 10% while [a] means unexpected sign.

The Table-6 reports results for diesel demand function. The empirical evidence indicates that the income is positively and significantly associated with the demand of diesel in Nigeria but it is insignificant for Algerian economy. In case of Algeria, findings are consistent with the analysis of Bhattacharyya and Blake (2009). The rise in income has inverse and insignificant affect on diesel consumption in Angola and Libya. The sign of price elasticity on diesel demand is according to theory and it is significant at 1% level of significance in case of Algeria. The effect of trend variable is positive and statistically significant in Algeria but it is negative and significant in case of Libya and Nigeria. In short run analysis, impact of income is positive but statistically insignificant in Algeria but inverse and insignificant effect of income is found on diesel demand in Nigeria. The diesel prices has negative affect on diesel demand in case of Algeria and findings are contradictory with Bhattacharyya and Blake (2009) who found positive impact of diesel prices on diesel consumption.

Table-6: Diesel Consumption Analysis

Countries	Long Run Analysis				Short Run Analysis				
	$Constant$	$\ln Y_t$	$\ln DP_t$	$Trend$	$Constant$	$\ln Y_t$	$\ln DP_t$	ECM_{t-1}	$F-statistic$
Algeria	0.6334 (2.0212)***	0.0379 (0.2558)	-0.4202 (-7.3555)*	0.0261 (8.4600)*	0.0241 (2.2762)**	0.2061 (1.0752)	-0.2001 (-4.2654)*	-0.1250 (-2.2522)**	3.7373**
Angola	-2.6785 (-4.4487)*	-0.1842[a] (-0.3561)	-0.0220 (-0.1406)	0.0245 (1.3646)	0.0333 (0.6789)	-0.1296[a] (-0.2294)	-0.0308 (-0.2980)	-0.3089 (-2.1891)**	1.6151
Libya	-0.6360 (-0.7746)	-0.1820[a] (-0.4646)	0.4058[a] (1.5706)	-0.0315 (-2.6889)**	-0.0211 (-0.6805)	-0.0389[a] (-0.0953)	-0.3232 (-1.2329)	-0.3054 (-2.007)***	2.5492***
Nigeria	-1.9686 (-2.8414)*	1.0026 (2.5361)**	-0.0780 (-0.8685)	-0.0237 (-3.1847)*	-0.0056 (-0.2167)	-0.6789[a] (-1.1893)	-0.2727 (-3.4033)*	-0.6722 (-3.7112)*	5.7702*

Note: *, ** and *** indicate significance at 1%, 5% and 10% while [a] means unexpected sign.

Table-7: Kerosene Consumption Analysis

Countries	Long Run Analysis				Short Run Analysis				
	$Constant$	$\ln Y_t$	$\ln KP_t$	$Trend$	$Constant$	$\ln Y_t$	$\ln KP_t$	ECM_{t-1}	$F-statistic$
Algeria	-2.8636 (-10.1254)*	0.1613 (0.9987)	-0.1260 (-3.5506)*	-0.0150 (-5.6978)*	-0.0131 (-0.9963)	-0.4514[a] (-1.5549)	-0.0488 (-1.1497)	-0.3874 (-2.9906)*	3.9683**
Angola	-2.8173 (-2.5369)*	-0.2236 (-0.3995)	-0.0118 (-0.0461)	0.0253 (0.8065)	0.0131 (0.2632)	0.2951 (0.5149)	-0.3305 (-1.9469)***	-0.3530 (-2.4289)**	2.8998***
Libya	-2.6725 (-7.4335)*	-0.5339[a] (-2.4066)*	0.6942[a] (5.7489)*	-0.0017 (-0.4221)	0.0080 (0.5079)	-0.2281[a] (-1.8534)***	0.7967[a] (13.3542)*	-0.1938 (-1.8287)***	29.3843*
Nigeria	1.1535 (2.1348)**	-0.4584[a] (-1.5693)	-0.1154 (-1.4427)	-0.0297 (-5.6948)*	-0.0216 (-1.0453)	0.0972 (0.2342)	-0.1642 (-1.6090)	-0.1463 (-1.2291)	1.2783

Note: *, ** and *** indicate significance at 1%, 5% and 10% while [a] means unexpected sign.

In case of Libya and Angola, income and prices diesel have negative affect on diesel demand in short run and same inference can be drawn for Nigeria. The signs of lagged error term are negative and statically significant indicating cointegration in Algeria and Angola while confirming established cointegration for Libya and Nigeria.

Finally, kerosene oil demand analysis is reported in Table-7. The results show that kerosene is inferior good in Libya while impact of kerosene prices is positive. This empirical evidence is consistent with the findings of Bhattacharyya and Blake (2009), Chakravorty et al. (2000) and Dahl (1994) who reported that in less income countries, kerosene is considered as normal good for cooking and lighten only because kerosene oil is a substitute for cheaper fuels. As income rises, kerosene becomes an inferior good as compared to other sources of energy such as LPG, natural gas and electricity etc. In case of Nigeria, the impact of income and prices of kerosene oil is positive and negative but it is statistically insignificant. The trend variable is negatively linked kerosene demand in long run in Algerian and Nigerian economies. The significance of lagged error terms with negative sign further confirmed established cointegration in Algeria and Libya while in case of Angola; it established cointegration for kerosene oil demand function. In case of Nigeria, no cointegration was established both ARDL and ECM analysis.

5. Conclusion and Policy Implications

The present paper explores the price and income elasticities for petroleum products demand in African OPEC member economies namely, Algeria, Angola, Libya and Nigeria. The log-linear speciation of petroleum products demand such as average petroleum, gasoline, diesel and kerosene has been used over the period of 1980-2007. The ARDL bound testing approach to cointegration is applied to examine long run relationship among the variables. ADF unit root test is applied to detect the order of integration of running variables in the empirical models.

The empirical analysis has provided mixed results in four countries. It is hard to interpret them but diesel demand specification is relatively than other petroleum products specifications.. Anyhow, petroleum demand function shows that petroleum is considered a normal good in Nigeria and Algerian economies but not in rest countries namely Libya and Angola. Petroleum prices are inversely associated with petroleum consumption in Angola and Nigeria but positively linked with petroleum demand in case of Libya.

In gasoline demand analysis reveals that gasoline is normal good in Angola and Nigeria and rise in prices of gasoline decline its demand in case of Angola. The results of diesel demand indicates positive impact of impact of an increase in income diesel consumption in Algeria, Libya and Nigeria while diesel price hike affects diesel demand negatively and significantly in Angola and Nigeria. Surprisingly, in kerosene analysis, kerosene oil is considered as an inferior good in Algeria, Libya and Nigeria while rise in prices kerosene oil does not affect kerosene demand in Libya but negative linked with demand of kerosene in Angola and Nigeria.

The policy implication for result show the need for diversification, increase refining capacity and demand management policies in these countries to promote energy efficiency, conservation as well as discourage cross border smuggling of products and encourage private investment into the oil sector.

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