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THE DEMAND FOR RESIDENTIAL ELECTRICITY IN NIGERIA

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This paper examines the residential demand for electricity in Nigeria as a function of real gross domestic product per capita, price of electricity, and price of a substitute between 1970 to 2007. The bounds testing approach used to cointegration within an autoregressive distributed framework, suggested by Pesaran et al. (2001). In the long run, we found that income and the price of substitute emerges as the main determinant of electricity demand in Nigeria, while electricity price is insignificant. The relationship among the variables is stable and significant.

I. Introduction

Despite Nigeria's vast wealth of oil, majority of the populace have no access to uninterrupted supply of electricity. Nigeria has a generating capacity of approximately 5,900 megawatts (MW) of the installed electricity. However, power outages are frequent and the power sector operates well below its estimated capacity. A fundamental reason offered is the low generating capacity of the Nigerian power sector relative to its installed capacity. Consequently, the sector had to undergo some reforms to increase power generation and distribution. These reforms include setting up the National Electricity Regulatory Commission (NERC), unbundling of Power Holding Company of Nigeria (PHCN) and entry of Independent Power Producers (IPP), among others. These reforms are expected to increase power generation, transmission, distribution and residential electricity supply, in Nigeria.

Although, much explanation has been offered on the supply of electricity in Nigeria quite a little is known about the determinants of residential electricity demand. The quest for more accurate estimates of important electricity demand parameters viz., short- and long-run price and income elasticities are critically important in the projection of future electricity demand. Further understanding electricity demand dynamics through improved and robust estimates of electricity demand parameters, are essential for more informed and successful electricity sector policy decision making and implementation. The major objective of this paper is to develop and test an econometric model to identify the main economic fundamentals that influence the behavior of electricity consumption in Nigeria. The present endeavor is the first of its kind to empirically analyze the residential electricity demand for Nigeria.

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The empirical analysis is for the period 1970–2006, employing annual data. Income and price sensitivity of both the long- and the short-run demand for electricity are examined. The present study makes a methodological contribution to the literature on electricity demand, employing bounds testing approach to cointegration, developed by Pesaran et al. (2001), within an autoregressive distributed lag (ARDL) framework, to test for a long-run level relationship in the demand for residential electricity. The sequence of the study is clear. Section II presents a brief overview of the literature while the model on which the theory is predicated is discussed in Section III. The bounds testing approach to cointegration is the focus of Section IV. The empirical results are presented in Section V. Section VI summarizes and concludes the study.

II. Review of the Literature

Most of the studies on determinants of residential electricity demand functions have focused on developed countries. There are studies for Canada [Bernard et al. 1996)], the United States [Houthakker et al. (1974), Houthakker (1980), Hsing (1994), Silk and Joust (1997)], Mexico [(Chang and Martinez-Combo (2003) and the United Kingdom [(Dodgson et al. (1990), Henley and Peirson (1999), Clements and Madlener (1999)]. For Asia–Pacific countries, such as Australia, India and Taiwan [Narayan and Smyth (2005), Filippini and Pachauri (2004), Holtedahl and Joutz (2005)], European countries, such as Greece, Norway, Cyprus and Switzerland [Donatos and Mergos (1991), Ettestol (2002), Zachariadis and Pashourtidou (2006), Filippini (1999)] in G7 countries [Narayan et al. (2007)] and countries in the Middle East [Al-Faris (2002), Beenstock et al. (1999); Eltony and Hosque (1996), Nasr et al. (2000)]. There is a paucity of research on electricity demand in developing countries and only a few of the studies accounted for the time-series properties of electricity consumption to changes in income and relevant prices.

There is a glaring gap in Sub-Saharan Africa [except for Ziramba (2008) for South Africa and De Vita et al. (2005) for Namibia] despite the need of improved and more robust estimates of electricity demand parameters towards better electricity policy decision making and implementation. Despite the significant role of residential demand for electricity to the Nigeria economy, the controversies about appropriate pricing and the issue of IPPs coupled with the inadequate supply of electricity in the country strongly suggest that more accurate estimates of these elasticities are of paramount policy importance.

A diversity of approaches to the estimation of electricity demand can be found in the literature ranging from aggregative analysis of the relationship between electricity demand, income and prices [Narayan et al. (2007), Lin (2003), Holtedahl and Joutz, (2005)], to more detailed disaggregated analysis [Bose and Shukla (1999)] based on simultaneous modeling structure. In the most basic model, the demand for electricity has been modeled as a function of a single variable, such as real income [Dincer and Dost (1997)] or temperature [Al-Zayer and Al-Ibrahim (1996)], real income and prices [Houthakker, et al. (1974), Zachariadis and Pashourtidou (2006), Ziramba (2008)] real income, residential electricity price and price of natural gas [Narayan et al. (2007)], real income, electricity prices, population growth, structural changes in the economy and efficiency improvement [Lin (2003)], population, income, price of electricity, price of oil, urbanization, weather [Holtedahl and Joutz (2004)], real income, price of electricity and diesel (used in for captive power generation to meet the shortages), and reliability of power supply for utilities [Bose and Shukla (1999)], real income, the real price of electricity, and the variable that captures the seasonal component of the demand for electricity [Chang and Martinez-Combo, (2003)].

The studies examines the residential demand for electricity in the context of household production function theory. Studies of the empirical model of residential demand for electricity are based on household production theory which can be expressed as a function of own price, price of a substitute source of energy, real income, price of household appliances and other factors that may influence household preferences, such as temperature. In practice, most existing studies have not been able to get data on all these potential explanatory variables. Narayan and Smyth (2005) analyzed the residential demand for electricity in Australia. They estimated two models of the residential demand for electricity. Both models include income and temperature variables, but differ in their representation of the price variable. In the first model, in addition to the income and temperature variables, the prices of electricity and natural gas (a substitute source of energy) are introduced as separate variables. In the second model the specification of the price takes the relative price format. In the long run, they found that income and own prices are the most important determinants of residential electricity demand, while temperature is significant (some time) and gas prices are insignificant. In addition, the short-run elasticities are much smaller than the long-run elasticities, and the coefficients on the error-correction coefficients are small consistent with the fact that in the short-run energy appliances are fixed. Similarly, in a study of residential demand for electricity in a panel of G7 countries, Narayan et al. (2007) used similar model specifications.

III. The Theoretical Model

We adopt the commonly used modeling of electricity demand function for this study following the specification of (Houthakker, et al., 1974; Zachariadis and Pashourtidou, 2006, Narayan et al. 2007; Ziramba 2008) which postulates that electricity demand is a function of prices, real income and the price of substitutes. The long run electricity demand function for Nigeria is therefore specified as:

$$LEC = \alpha_0 + \alpha_1 LY + \alpha_2 LEP + \alpha_3 LPK + \varepsilon \tag{1}$$

where LEC is the natural log of the per capita residential electric consumption (kWh per capita), LY is the natural log of real per capita income; LEP is the natural log of the real residential electricity price (kobo/kWh); and LPK is the natural log of the real pump price of kerosene (kobo) and ε is a random error, which is assumed to be white noise, normally and identically distributed. The nominal prices are deflated by the consumer price index.

Income is considered to be an important determinant for electricity consumption in the literature (Bose and Shukla, 1999; Chang and Martinez-Chombo, 2003; Holtedahl and Joutz, 2004; Narayan and Smyth, 2005; Narayan et al., 2007; Ziramba, 2008). Economic growth and its impact on living standards is the main driving force of electricity consumption growth. Therefore, higher real per capita income will increase purchases of electrical equipment and hence increase electricity demand. Nevertheless, an increase in the price of residential electricity will cause the residential electricity demand to fall.

Economic theory suggests that electricity purchases will depend on the prices of substitutes: natural gas and petroleum products (Holtedahl and Joutz, 2004). In the case of Nigeria, the independent influences of diesel and gasoline prices may be rather small because a sizeable number of people in Nigeria do not have access to power generating set to provide electricity when there is power outage. The choice of natural gas is also not appropriate in this case because its consumption is comparatively small and also concentrated among the urban rich. Therefore, we make use of price of kerosene as our measure of alternative price of electricity. This is because kerosene is generally used by households for cooking (alternative for electric cooker) and lightning (kerosene powered lanterns) in the absence of power supply. Since kerosene is a substitute for electricity, an increase in the price of kerosene is expected to generate an increase in the consumption of electricity. Consequently, we expect α_1, and α_3 to be positive and α_2 to be negative.

IV. Empirical Approach and Data

Pesaran et al. (2001) developed an Auto-Regressive Distributed Lag (ARDL) bounds testing approach for testing the existence of a cointegration relationship. The bound testing approach has certain econometric advantages in comparison to other single cointegration procedures [Engle and Granger (1987), Johansen (1988), Johansen and Juselius (1990)]. Firstly, endogeneity problems and inability to test hypotheses on the estimated coefficients in the long-run associated with the Engle-Granger (1987) method are avoided. Secondly, the long and short-run parameters of the model in question are estimated simultaneously. Thirdly, the econometric methodology is relieved of the burden of establishing the order of integration amongst the variables and of pre-testing for unit roots.

The ARDL approach to test the existence of a long-run relationship between the variables in levels is applicable, irrespective of whether the underlying regressors are purely I(0), purely I(1), or fractionally integrated. Finally, as argued in Narayan and Smith (2005), the small sample properties of the bounds testing approach are far superior to that of multivariate cointegration [Halicioglu (2007)]. The approach, therefore, modifies the Auto-Regressive Distributed Lag (ARDL) framework while overcoming the inadequacies associated with the presence of a mixture of I(0) and I(1) regressors in a Johansen-type framework. A-priori we expect electricity to be significantly influenced by income, price, and the price of substitutes.

The ARDL representation of electricity consumption, real income, electricity price, and price of kerosene can be constructed as:

$$\begin{aligned}\Delta LEC_t = {} & \alpha_0 + \sum_{i=1}^{Q} \alpha_{1i}\, \Delta LEC_{t-i} + \sum_{i=0}^{Q} \alpha_{2i}\, \Delta LY_{t-1} + \sum_{i=0}^{Q} \alpha_{3i}\, \Delta LEP_{t-i} \\ & + \sum_{i=0}^{Q} \alpha_{4i}\, \Delta LPK_{t-i} + \alpha_5 LY_{t-1} + \alpha_6 LEP_{t-1} + \alpha_7 LPK_{t-1} + \mu_t \end{aligned} \tag{2}$$

where the variables are defined in equation (1). The procedure of the bounds testing approach is based on the F or Wald-statistics and is the first stage of the ARDL cointegration method. The null hypothesis is tested by considering the UECM in equation (2) while excluding the lagged variables LY_{t-1}, LEC_{t-1}, LEP_{t-1}, LPK_{t-1} based on the Wald or F-statistic. The asymptotic distribution of the F-statistic is non-standard under the null hypothesis of no cointegration relationship between the examined variables, without recourse to whether the underlying explanatory variables are purely I(0) or I(1). The null hypothesis of no cointegration (H_0:α_5=α_6=α_7=0) is therefore tested against the alternative hypothesis (H_0:$\alpha_5 \neq 0$,$\alpha_6 \neq 0$,$\alpha_7 \neq 0$). Thus, Pesaran et al. (2001) compute two sets of critical values for a given significance level. One set assumes that all variables are I(0) and the other set assumes that they are all I(1). If the computed F-statistic exceeds the upper critical bounds value, then the H0 is rejected. If the F-statistic is below the lower critical bounds value, it implies no cointegration. Lastly, if the F-statistic falls into the bounds then the test becomes inconclusive. Consequently, the order of integration for the underlying explanatory variables must be known before any conclusion can be drawn.

However, the critical values of Pesaran et al. (2001) are generated on sample sizes of 500 and 1000 observations and 20000 and 40000 replications, respectively. Narayan and Narayan (2005) argue that such critical values cannot be used for small sample sizes like the one in this study. Given the relatively small sample size in the present study (37 observations), we extract the appropriate critical values from Narayan and Smith (2005) which were generated for small sample sizes of between 30 and 80 observations. Data on electricity consumption KW per capita and real GDP per capita were sourced from the World Bank's World Development Indicators 2008 edition. The data on electricity prices was sourced from FGN (2006) "25 Years Power Projection Plan for Nigeria"[3]. Which ends at 2001. This was then updated with statistics from the Nigerian Regulatory Electricity Commission. The pump price of kerosene (DPK) was sourced from the Nigerian National Petroleum Corporation (NNPC). The empirical result was estimated with Microfit 5.0 software.

V. Empirical Results

The first step of the ARDL analysis is to test for the presence of long-run relationships (eq.1). The maximum number of lags in the ARDL was set equal to 2, since we use the annual data. The calculated F-statistics together with the critical values are reported in Table 1. The results of the bounds F-test (Table 1) imply that at 5 per cent level, the null hypothesis of no cointegration among the variables in

3 Report Prepared by the Presidential Committee on Electricity Requirement for Making Nigeria an Industrializing Country by the Year 2030, December, 2006.

equation (1) cannot be accepted. Having found a long-run relationship between electricity consumption, national income, electricity price, and the price of kerosene, the long-run elasticities was then estimated.

The impact of national income, electricity prices, and the price of kerosene on consumption of electricity was then investigated. In the ARDL estimation, a maximum of 2 lag was used (i_{max}= 2). The estimated model is based on minimizing the Schwartz Bayesian Criterion. The empirical results for the model, obtained through normalizing on the log of per capita electricity consumption (LEC) in the long run are reported in Table 2. The empirical results for the model in the short run, together with standard diagnostic tests are presented in Tables 3. The error term ECM_{t-1} in the short-run model is statistically significant with a negative sign in the short-run model, which confirms that a long-run equilibrium relationship exists between the variables. The error correction term is -0.612 which indicates that 61.2 per cent of the previous year's deviation from long-run equilibrium will be restored within one year. The short-run models pass all the standard diagnostic tests for autocorrelation, functional form, normality and heteroskedasticity.

TABLE 1

Bounds Testing for Cointegration Analysis

	Unrestricted intercept and unrestricted trend					
Panel A	Lag Structure	F-Statistic	Evidence of Cointegration			
F_{LEC}(EC/LY, LEP,LPK)	2	5.9759**	Yes			
F_{LY}(LY/LEC, LEP,LPK)	2	2.1125	No			
F_{LEP}(LEP/ LY,LEC,LPK)	2	1.9532	No			
F_{LPK}(EC/LPK, LEP,LY)	2	2.1765	No			
Panel B	1%		5%		10%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	5.604	7.172	4.036	5.304	3.374	4.512

Notes:*** Statistical significance at 1% level; ** Statistical significance at 5% level; * Statistical significance at 10% level. Critical values are obtained from Narayan (2005) for 35 observations. The number of regressors is 3.

TABLE 2

Estimated Long Run Coefficients using the ARDL Approach.
ARDL (1, 0, 0, 0) selected based on Schwarz Bayesian Criterion, 1970-2007.

Explanatory Variables	Dependent Variable is LEC
Constant	-4.7227*
	(-1.8679)
LY	0.5135*
	(1.9651)
LEP	0.1264
	(0.6319)
LPK	-0.8745*
	(-1.9121)

Notes:*** Statistical significance at 1% level; ** Statistical significance at 5% level; * Statistical significance at 10% level; Figures in parenthesis are t-ratios.

TABLE 3

Error Correction Representation for the Selected ARDL Model
ARDL(1,0,0,0) selected based on Schwarz Bayesian Criterion

Explanatory Variables	Dependent Variable is LEC
ΔLY	0.2137**
	(2.0123)
ΔLEP	0.0917
	(0.9215)
ΔLPK	-0.4421*
	(-1.8765)
ΔC	-2.1733*
	(-1.9618)
ECM(-1)	-0.6125***
	(-2.8344)
Diagnostic Statistics	
R-Square	0. 656
Adjusted R-Square	0. 613
$\chi 2_{Auto}(1)$	3.1461
$\chi 2_{Norm}(2)$	0.4123
$\chi 2_{Hetero}(1)$	2.8412
$\chi 2_{RESET}(1)$	0.1264

Notes: 1. *indicates that a coefficient is significant at the 1 percent level; **indicates that a coefficient is significant at the 5 percent level; ***indicates that a coefficient is significant at the 10 percent level.
2. Figures in parenthesis ( ) are t-ratios.

1. *Income Elasticity of demand*

Expectedly the income elasticity of demand has a positive sign and is statistically significant at 10 per cent level of significance in the long run (Table 2). Electricity consumption is income inelastic in Nigeria. The long-run elasticity is 0.513 in the ARDL model while it is 0.213 in the short run. As expected, the long-run income elasticity is larger than the short-run estimate. The results indicate that residential EC is a normal good as it increases with income. Our estimate of the long-run price elasticity of residential demand is at the lower and upper end of the range of estimates found in some of the previous studies for other countries. For example, Filippini (1999) and Ziramba (2008) found that the income elasticity of residential electricity demand for Switzerland and South Africa was 0.33 and 0.31 respectively. In addition, De Vita et al. (2006) reported an elasticity of 0.41 and 1.252 for Namibia and Bangladesh respectively. The short-run income elasticity of 0.213 was also found to be statistically significant at the 5 per cent level. This result suggests that income policies will have higher influence on residential electricity consumption over time. Nevertheless, the income elasticity reported should have been higher and could have even been greater than one under normal market conditions for a developing country like Nigeria.[4] However, the magnitude reported is low due to electricity supply restrictions. Under unrestricted conditions, with rising income in Nigeria, demand could have been higher. This supply restriction has rendered public electricity supply as standby source as many consumers who cannot afford irregular and poor quality service substitute more expensive supply alternatives to minimize the negative consequences of power supply interruptions on their day to day activities. Hence, the low value of income elasticity is reported.

2. *Own Price and Cross Price Elasticity*

The consumption of electricity in Nigeria is own price and cross price inelastic. Contrary to a-priori expectation, the own price elasticity is positive both in the short and long run. The long-run own price elasticity is 0.121, while the short-run value is 0.091. The explanation for the result is not far-fetched. The price of electricity has long been regulated in Nigeria. The price of electricity is usually fixed by the government and reviewed infrequently. A large number of citizens do not pay their electricity bills regularly and a great numbers of household have illegal electricity connection, rather than obtaining electricity from the PHCN electric meters. Hence, it is not surprising that price is playing an unimportant role in the demand for electricity in Nigeria. Also, the inadequate supply of electricity in Nigeria could be responsible for the positive coefficient.

In addition, contrary to the expected results, the cross price elasticity is negative and significant. The long run and short run cross price elasticities are -0.874 and -0.442 respectively. This implies that kerosene is complementary good with electricity rather than being a substitute good. An increase in the price of kerosene was expected to generate an increase in the consumption of electricity, however the reverse was found not to be the case. Electricity is usually not available in Nigeria and most households usually make use of kerosene for cooking and lightning due to the unreliable nature of electricity irrespective of whether there is a price increase or not.

3 For example, Pesaran et al. (1998) reported that an income elasticity of 1.252 for Bangladesh which is also a developing country such as Nigeria but is not faced with supply restrictions.

3. *Constancy of Cointegration Space*

Following Narayan and Smyth (2005), we used Pesaran and Pesaran (1997) to test for parameter stability. According to Pesaran and Pesaran (1997), short-run dynamics are essential for testing the stability of the long-run coefficients. The Pesaran and Pesaran (1997) test involves estimating the following error correction model:

$$\Delta LEC_t = \beta_0 + \sum_{i=1}^{n}\beta_{1i}\Delta LEC_{t-i} + \sum_{i=1}^{n}\beta_{2i}\Delta LY_{t-i} + \sum_{i=1}^{n}\beta_{3i}\Delta LEP_{t-i} + \sum_{i=1}^{n}\beta_{4i}\Delta LPK_{t-i} + \lambda ECM_{t-1} + \varepsilon_t \quad (3)$$

In this case, all variables are, as defined earlier, and the error-correction term is calculated from the long-run cointegrating vector, once the models have been estimated, After estimating the model the cumulative sum of recursive residuals (CUSUM) and the CUSUM of squares (CUSUMSQ) tests were applied to test for parameter constancy [Pesaran and Pesaran (1997)]. Figures 1 and 2 plot the CUSUM and CUSUM of squares statistics for Equation (3). The results clearly indicate the absence of any instability of the coefficients because the plot of the CUSUM and CUSUMSQ statistics is confined within the 5 per cent critical bounds of parameter stability.

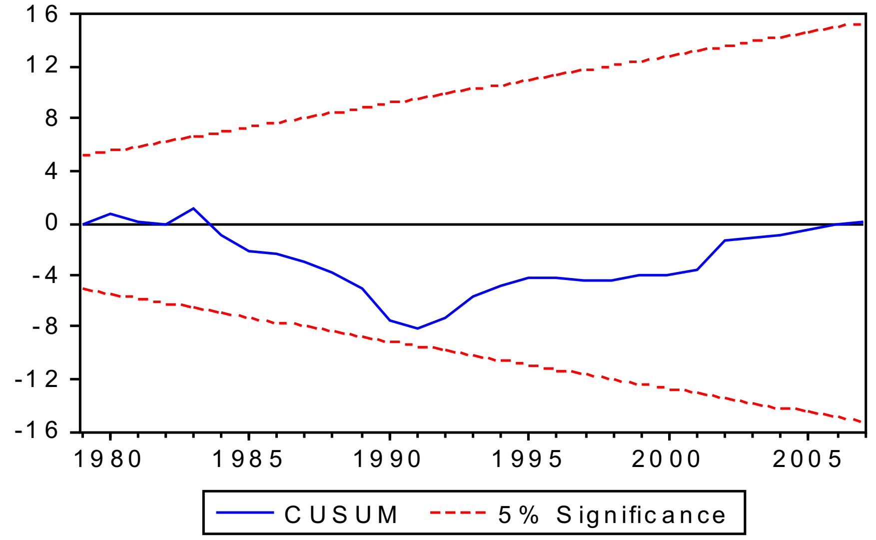

FIGURE 1

CUSUM Plots for Stability Tests

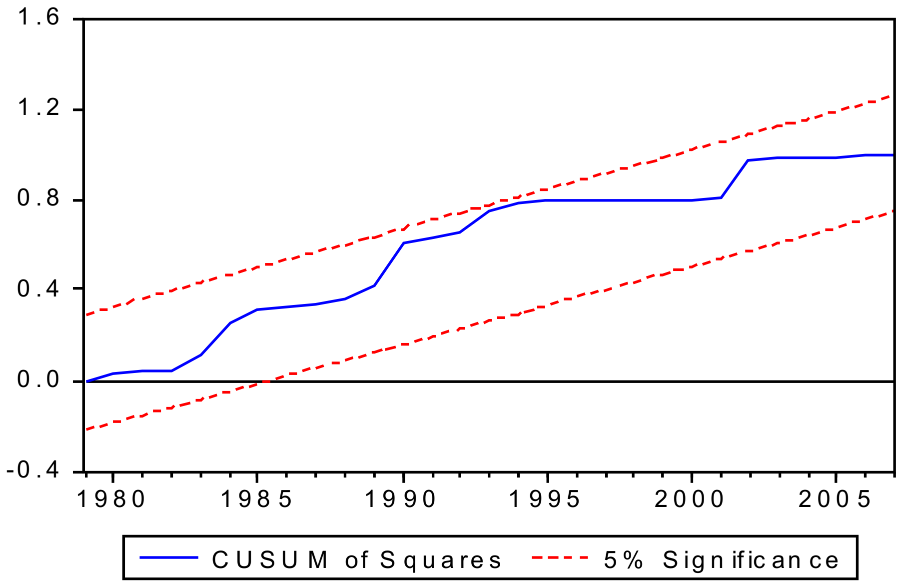

FIGURE 2

CUSUM of Squares Plots for Stability Tests

VI. Conclusions and Policy Implications

The paper examines the residential demand for electricity in Nigeria, employing annual data over the period 1970–2006. The present endeavor is the first of its kind to analyze the residential electricity demand for Nigeria. Bounds testing approach to cointegration analysis was applied to estimate residential electricity demand and to examine the issues of stability of both the long- run and the short-run residential demand for electricity. The bounds testing approach has shown to provide robust results in finite sample sizes just like in the present study [Narayan and Smyth (2005), Ziramba (2008)].

As expected the income elasticity of demand has a positive sign and is statistically significant in the short-run and in the long-run. This result indicates that residential electricity consumption is a normal good as it increases with income. The own and cross price elasticities did not have the expected negative and positive signs, while the cross price elasticity was found to be significant and the own price elasticity was found to be statistically insignificant. The stability tests performed demonstrate that the long-run residential demand for electricity in Nigeria remained stable throughout the estimation period.

Electricity demand studies have important practical implications. The results show that the estimated residential demand for electricity can be used for policy purposes, since it is stable. The finding that a stable aggregate residential electricity demand function seems to exist, would make the possible forecasting of electricity need at the national level. The estimated price and income elasticities of 0.513 and 0.126 imply that residential electricity demand in Nigeria is income and price inelastic in the long run. In addition, it shows that income and price of a substitute influence significantly the residential electricity consumption in Nigeria. Finally, the implication of the result is that an increase in residential electricity price does not induce a significant decline in residential electricity demand.

Consequently, electricity prices will have to be appropriately priced to levels that cover the cost of supply to ensure sustainable financing of power infrastructure. The new multi-year tariff scheme is an important step in bringing new capital to the electricity industry. Nevertheless, the Nigerian Electricity Regulatory Commission (NERC) should ensure that the electricity consumers are not over-burdened with high tariff charges. Though affordability should be of concern, it should no longer be used as a pretext to under-price electricity. Rather, new and well designed arrangements should be instituted to ensure affordability while maintaining the financial integrity of the sector. And, if subsidies are to be provided, it should be done in a transparent manner and fully funded by the government. Such useful information is expected to assist policy-makers in the supply of residential electricity in Nigeria.

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