Electricity Consumption in Nigeria: an Econometric Analysis

Introduction:

Energy is of strategic importance to the growth and development of any economy because of its role in industrial, commercial and agricultural activities. In recent times, the world economy has experienced one energy crisis or the other. This therefore calls for a well co-ordinated and articulate energy policy for any country that hopes to forge ahead in the path of growth. Knowledge of the determinants and pattern of energy consumption is required for appropriate energy policy formulation in Nigeria.

Electricity is an important component of the energy spectrum in Nigeria and a study of the determinants of electricity consumption is essential as a first step towards formulating an energy policy for the country. Electricity being an essential input in the development process, its abundant supply at low cost is fundamental to an industrializing economy like Nigeria's. This calls for an articulate policy on electricity to ensure an efficient utilization of this scare resource and guarantee that there is available supply to match demand and hence reduce the incidence of power failures and blackouts resulting from increasing pressure on the generating and transmission facilities of the authority responsible for the provision of electricity.

The demand by users of electricity has been growing over the last two decades and this has placed the National Electric Power Authority (NEPA) in a very precarious position. Historically, the consumption of electricity in Nigeria grew at a very rapid rate. During the period 1961/62 to 1966/67 consumption of electricity grew at an average rate of 19.7 per cent per year. As a result of the civil war which led to disruption of electricity supply to the Eastern States and imposition of a ban on street lighting[1], consumption dropped in 1967/68 by 24.8 per cent and then picked up again with annual average rate of growth being 43.5 per cent between 1968/69 to 1981. However, during this period there was a drop in consumption by an average of 8.0 per cent from the 1978/79 level between 1979 and 1980.

If one examines the historical trend of GDP, it is not difficult to link electricity consumption to economic growth. As with electricity consumption, the growth in real GDP has been very rapid. It grew at an average rate of 5.3 per cent per year between 1960/61 and 1965/66. After dropping by 4.8 per cent between 1965/66 and 1968/69, it rose continuously from 1969/70 to 1980 with an average growth rate of 9.5 per cent. Thus electricity consumption and GDP showed a positive correlation[2]. However, the extent to which demand for electricity responds to GDP cannot be easily determined by examining only the historical trends in the two variables because there are other factors which affect electricity consumption such as the stock of capital and the number of consumers, both of which display the same trend as electricity consumption and GDP. It is therefore essential to measure quantitatively the relative importance of various factors affecting electricity demand. This is particularly important from a policy stand-point.

The purpose of this study therefore is to identify the variables that influence electricity consumption, specify the correct relationships between these variables and electricity consumption and provide statistical evidence of these relationships in Nigeria. This could serve as a first step towards formulating an appropriate energy policy for Nigeria. The first part of the paper deals with the specification of the two models employed while part two presents and discusses the results of the regression analysis. The third and final part contains the conclusions.

PART I

The Models:

Since electricty is both an intermediate (producer) good and a consumer good, the determinants of its consumption is considered in two blocks viz: the final consumption block and the production block. The variables under the final consumption block are operative mostly in the Residential Consumption model since consumption of electricity for residential purposes are mainly in the form of final consumption. On the otherhand electricity consumption in the industrial sector is mainly in the form of an intermediate producer good.

Residential Consumption:

The major variables considered under the final consumption block are; Income, lagged value of electricity consumed and number of electricity consumers. The function for the residential sector could be specified as:

$$C_t = d + B_1 Y_t + B_2 C_{t-1} + \lambda NC_t + \gamma DMV_t$$

Since the logarithmic Koyck model is used to characterise the dynamic demand structure, the long-run consumption function could be specified as;

$$\ln C_t = d + B_1 \ln Y_t + B_2 \ln C_{t-1} + \lambda \ln NC_t + \gamma DMV_t$$

where

C_t = Electricity consumed in the residential sector.
Y_t = GDP at constant factor cost.
C_{t-1} = lagged value of electricity consumed in the residential sector.
NC_t = Number of electricity consumers in the residential sector.
DMV_t = Dummy variable with 1 for war years and 0 for others.
$_t$ = refers to time.

[1]See Central Bank of Nigeria Annual Report 1968 page 23.
[2]Schatzl observed a Bresvias-Pearson coefficient of correlation of 0.9565 between energy consumption and GDP in Nigeria for the period 1950 to 1963.

Industrial/Commercial Consumption:

In this sector, electricity is used generally for operating machines/equipments and chemcial processes (that is, as an input in the production process) and for premises illumination and cooling (that is as a final consumption good). So in specifying the function for the Industrial/Commercial sector, we have to include variables like capital stock and Industrial Production in addition to the variables identified in the residential sector's model.

To derive the relationship between capital stock, the output of the firm (Industrial production) and energy (electricity) consumption, we will use the production function. The basic theory underlying this approach is that firms determine their demands for factors of production in the long run by choosing the factor combination that maximizes their profits (or minimizes costs) subject to the technological constraint – the production function. We shall derive this relationship using the cobb-Douglas function because of the ease (mathematically speaking) of handling functions of this type.

Assuming that long-run equilibrium output is related to labour, capital and energy by the following relationship:

$$X^* = A(K^*)^a (L^*)^b (E^*)^c \quad \text{.......(1)}$$

where

X^* = expected longrun equilibrium output
K^* = desired longrun equilibrium capital stock
L^* = expected longrun equilibrium labour input
E^* = desired longrun equilibrium energy input
A = Scale factor
a = elasticity of output to capital
b = elasticity of output to labour
c = elasticity of output to energy
$A, a, b, c > 0$

If firms decide on factor input by minimizing the cost of producing the desired output, the objective function would be;

$$\alpha L^* + \beta K^* + \lambda E^* \quad \text{.......(2)}$$

subject to the technological constraint in equation (1) where α, β and λ are the expected unit costs of labour, capital and energy respectively.

Hence we have;

$$\text{Min } V = \alpha L^* + \beta K^* + \lambda E^* - \mu[X^* - A(K^*)^a (L^*)^b (e^*)^c]$$

where μ is the langrange multiplier.

The first order condition for optimization requires that[3]

$$\frac{\delta V}{\delta L^*} = \alpha - \mu b[A(K^*)^a (E^*)^c (L^*)^{b-1}] = 0$$

$$= \alpha - \frac{ub[A(K^*)^a (L^*)^b (E^*)^c]}{L^*} = 0$$

Using equation (1) then

$$\frac{\delta V}{\delta L^*} = \alpha - \frac{\mu b X^*}{L^*} = 0 \quad \text{.......(3)}$$

Similarly

$$\frac{\delta V}{\delta K^*} = \beta - \frac{\mu a X^*}{K^*} = 0 \quad \text{.......(4)}$$

$$\frac{\delta V}{\delta E^*} = \lambda - \frac{\mu c X^*}{E^*} = 0 \quad \text{.......(5)}$$

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[3]See Handerson and Quandt: *Microeconomic Theory: A Mathematical Approach* Chapter 4 for details of this approach.

and

$$\frac{\delta V}{\delta \mu} = X^* - A(K^*)^a (L^*)^b (E^*)^c = 0 \quad \text{.......(6)}$$

From (3) to (5)

$$\frac{\alpha}{\beta} = \frac{b}{a} \cdot \frac{K^*}{L^*} \quad \text{.......(7)}$$

$$\frac{\alpha}{\lambda} = \frac{b}{c} \cdot \frac{E^*}{L^*} \quad \text{.......(8)}$$

$$\frac{\beta}{\lambda} = \frac{a}{c} \cdot \frac{E^*}{K^*} \quad \text{.......(9)}$$

Hence from (7) and (8)

$$K^* = \left(\frac{a}{b}\right) \left(\frac{\alpha}{\beta}\right) L^* \quad \text{.......(10)}$$

$$E^* = \left(\frac{c}{b}\right) \left(\frac{\alpha}{\lambda}\right) L^* \quad \text{.......(11)}$$

Using equations (10), (11) and (6) we arrive at

$$X^* = A[(^a/_b)(^\alpha/_\beta) L^*]^a (L^*)^b \left[\left(\frac{c}{b}\right) \left(\frac{\alpha}{\lambda}\right) L^*\right]^c \quad \text{.......(12)}$$

Using (12), (9) and (8), E^* may be isolated thus:

$$E^* = \left[A^{-1} \left(\frac{c}{b}\right)^b \left(\frac{c}{a}\right)\right]^{1/(a+b+c)} (X^*)^{1/(a+b+c)} \left(\frac{\alpha}{\lambda}\right)^{b/(a+b+c)} \left(\beta/\lambda\right)^{9/(a+b+c)} \quad \text{.......(13)}$$

From equations (10) and (11)

$$\frac{K^*}{E^*} = \left(\frac{a}{\beta}\right) \left(\frac{\lambda}{c}\right) \quad \text{.......(14)}$$

Expressing E^* as a function of K^* using (14) we have;

$$E^* = K^* \left[\left(\frac{a}{c}\right) \left(\frac{\beta}{\lambda}\right)\right] \quad \text{.......(15)}$$

Equations (13) and (15) show that energy input (electricity) is a function of the output of the firm (Industrial production) and capital stock.

Combining this result with the final consumption block, we specify the function for the Industrial/Commercial Sector as;

$$C_t = \alpha + \beta_1\gamma_t + \beta_2C_{t-1} + \beta_3I_t + \beta_4ID_t + \beta_5NC_t + \beta_6DMV_t$$

Similarly, the long-run function could be specified as;

$$l_nC_t = \alpha + \beta_1\gamma_t + \beta_2l_nC_{t-1} + \beta_3l_nI_t + \beta_4l_nID_t + \beta_5l_nNC_t + \beta_6DMV_t$$

Where

C_t = Electricity consumed in the Industrial/Commercial sector
Y_t = GDP in period $_t$ at constant factor cost
C_{t-1} = lagged value of electricity consumed in the Industrial/Commercial sector
I_t = Capital stock in period $_t$
ID_t = Industrial production in period $_t$
NC_t = Number of electricity consumers in the Industrial/Commercial sector in period $_t$
DMV_t = Dummy Variable with 1 for war years and 0 for others

The inclusion of the lagged values of electricity consumed is to take into account effects of consumers inertia and nostalgia by assuming that some consumption of electricity is habitual and that the habits persist from one year to the other.

The coefficient of C_{t-1}, that is, β_2 is the lag coefficient; while $1-\beta_2$ is called the speed of adjustment of the model. The rationale for including NC_t, that is, the number of electricity consumers is obvious, since it is expected that the larger the number of consuming units, ceteris paribus, the greater would be the amount of electricity consumed.

Data:

These functions were tested with statistics for electricity sales to the Residential and Industrial/Commercial Sectors for the period 1961/62 to 1981. The figures for GDP used are based on a 1977/78 constant factor cost. Industrial production was approximated with the Index of Industrial production with 1977/78 = 100. Since figures for capital stock were not available in a continuous series from 1960 to 1981, we had to use the figures for investments in machineries and equipments as a proxy for this. The short comings of some of the data are obvious. For instance figures for electricity sales represent what was consumed based on available supply. Potential (desired) consumption is likely to be higher than this because over the years in Nigeria, electricity demand had always outstripped its supply[4]. But in the present situation, the sales figures are the "second best" figures available. In view of the fact that figures of capital stock and value added by industries are not readily available in a continuous series for the period under study, the proxies we have used are to the best of our knowledge reasonable and acceptable. The figures for electricity consumption and number of consumers were derived from NEPA's Ten-Year Operational Statistics 1961/62-1970/71 and 1972-1981. Figures for the index of Industrial production were derived from FOS publications while figures for Investment in Machineries and Equipment were obtained from CBN publications and files. Finally, figures for Gross Domestic Product at current factor costs are from FOS, Economic Indicators and Nigerian Gross Domestic and Allied Macro-Aggregates, April 1982. These figures were then converted to constant factor cost by deflating them with the appropriate GDP deflators.

II

Regression Results:

The results of the tests are presented in tables 1 and 2 below. Only the logarithmic koyck equations were reported because none of the linear equations tested yielded good results suggesting that the relationship between the variables was a non-linear one. The overall performance of the models was generally good in terms of signs and statistical significance of estimated coefficients. The adjusted R^2 were also reasonably high.

Residential:

In the first equation in table 1, all the coefficients were properly signed. However, C_{t-1} and DMV_t were not significant. We can therefore eliminate the dummy variable leaving us with equation 2 of the form:

$$l_nC_t = \underset{(-4.69)}{-4.42} + \underset{(3.93)}{0.812}\, l_n Y_t \underset{(-0.94)}{-0.187}\, l_n c_{t-1} + \underset{(4.77)}{0.967}\, l_n NC_t$$

*$_t$ – ratios in parenthesis

$$\bar{R}^2 = 98.4;\ F = 412.27;\ d - \text{stat.} = 2.25$$

The smallness in the size of the coefficient of C_{t-1}, that is the lag coefficient, implies that there are short lags in adjustment. The non-significance of C_{t-1} is explained by the fact that residential users of electricity do not normally make long-run plans for electricity consumption. The coefficients of Y_t and NC_t were significant, suggesting that economic growth and the number of residential consumers were important variables in the consumption equation of this sector.

Industrial/Commercial:

Of all the equations reported in table 2, equation 7 was preferred because all the coefficients were properly signed and (except for the dummy variable) were significant. Equation 7 is of the form:

$$l_n C_t = \underset{(2.11)}{1.09} + \underset{(2.13)}{0.390}\, l_n C_{t-1} + \underset{(2.10)}{0.196}\, l_n ID_t + \underset{(2.60)}{0.466}\, \ln NC_t \underset{(-1.17)}{-0.033}\, DMV_t$$

$_t$ – ratios in parenthesis

$$\bar{R}^2 = 97.9;\ F = 229.55;\ d - \text{stat.} = 2.04$$

This result suggests that the major factors that influenced electricity consumption in the sector were lagged consumption, industrial production, and the number of consuming units in the sector. Here the coefficient of C_{t-1} is slightly large and significant, thus implying long lags in adjustment. This is expected because firms are expected to incorporate their desired energy input into their short- and long-term production plans. The coefficient of industrial production was significant. This conforms with expectations because electricity is used in the sector for operating machines and equipments, chemical processes, and for premises illumination and cooling. The last two are only indirectly related to production and constitute a minute proportion of electricity consumed. The number of consuming units was also a significant variable implying that as the number and sizes of firms or industries increase, electricity consumption would increase.

III

SUMMARY AND CONCLUSION:

From the result presented in part II, it is clear that growth in GDP (economic growth) and the number of consuming units were important factors in the determination of electricity consumption in the residential sector while in the industrial/commercial sector the important variables were industrial production, the number of consuming units and lagged consumption. Since Nigeria is currently passing through a phase of rapid industrialization reflected in the substantial growth in her GDP (the current depression, notwithstanding) and of rapid urbanization, it is expected that electricity consumption would maintain a strong upward trend. The implication of this would be increasing pressure on the facilities of NEPA which they may not be able to cope with given their present level of performance. The importance of the present pre-occupation of the Government with the search for the best strategy to guarantee adequate and efficient supply of electricity, cannot be over-emphasized. In this regard the privatization of NEPA appears to be an attractive option. Even though this may lead to an initial increase in the price of electricity, the long-run effect would be an improvement in services, cost reduction and consequently a reduction in the price that consumers would have to pay.

Sam Chuka Ljeh,
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[4]See Central Bank of Nigeria Annual Report, 1964, p. 25.

Table 1

ESTIMATED CONSUMPTION EQUATIONS FOR THE RESIDENTIAL SECTOR

(All variables are in log form)

	Constant	Y_t	C_{t-1}	NC_t	DMV_t	$\bar{R}^2$	F	d-Stat
*1	−4.78 (−3.81)	0.877 (3.41)	−0.212 (−1.01)	0.972 (4.67)	0.0367 (0.45)	98.3	294.76	2.28
*2	−4.42 (−4.69)	0.812 (3.93)	−0.187 (−0.94)	0.967 (4.77)		98.4	412.27	2.25
3.	−3.57 (−1.95)	0.877 (2.29)	0.622 (3.74)		0.025 (0.20)	96.3	173.24	2.10
4.	−3.34 (−2.45)	0.833 (2.71)	0.637 (4.42)			96.5	274.28	2.12
5.	−4.04 (−3.97)	0.746 (3.37)		0.794 (7.21)	0.0146 (0.18)	98.3	392.67	2.40
6.	−3.92 (−5.04)	0.725 (3.93)		0.082 (8.10)		98.4	623.07	2.39

t – ratios are in parenthesis

Table 2

ESTIMATED CONSUMPTION EQUATIONS FOR THE INDUSTRIAL/COMMERCIAL SECTOR

(All variables are in log form)

	Constant	Y_t	C_{t-1}	I_t	ID_t	NC_t	DMV_t	$\bar{R}^2$	F	d-Stat
1.	−6.34 (−1.38)	1.38 (2.19)	0.508 (3.12)	0.085 (0.58)	−0.289 (−1.44)		0.135 (0.94)	97.7	169.32	1.64
2.	−2.91 (−1.05)	0.862 (2.81)	0.594 (4.42)	0.116 (0.81)	−0.199 (−1.13)			97.7	213.22	1.91
3.	−0.95 (−0.48)	0.538 (2.41)	0.375 (2.30)	0.049 (0.45)		0.352 (2.12)		98.1	254.88	1.85
4.	−7.16 (−1.68)	1.45 (2.42)	0.541 (3.60)		−0.243 (−1.35)		0.153 (1.12)	97.8	220.84	1.72
5.	−2.35 (−2.01)	0.743 (2.59)	0.351 (2.02)			0.353 (2.14)	0.0593 (0.60)	98.1	254.92	1.84
6.	−1.79 (−2.65)	0.604 (3.64)	0.419 (3.27)			0.343 (2.13)		98.2	354.07	1.91
*7.	1.09 (2.11)		0.390 (2.13)		0.196 (2.10)	0.466 (2.60)	−0.033 (−1.17)	97.9	229.55	2.04

t – ratios are in parenthesis

Table 3

NIGERIA: SELECTED INDICATORS

Year	GDP at 1977/78 Factor Cost (₦' Million)	Index of Industrial Production 1977/78=100	Investment in Machineries/ Equipment (₦' Million)	Electricity Consumption (Residential) 10^3 KWH	Electricity Consumption Industrial/Comm. 10^3 KWH	No. of Consumers (Residential)	No. of Consumers (Industrial/ Commercial
1961	11578.02	8.15[1]	99.08[1]	179284	258931	96089	31351
1962	12070.63	9.18	111.28[1]	204855	318861	116535	38021
1963	13131.52	10.34	124.98[1]	234523	406691	129732	41042
1964	13698.06	12.01	198.98[1]	256066	496008	144728	47373
1965	14621.53	17.67	207.85	288313	559014	154488	50865
1966	14150.11	20.91	250.39	311071	644249	162921	54258
1967	11953.11	16.97	270.21	239481	478638	141352	48042
1968	11821.10	12.34	287.55	259234	534198	154414	52721
1969	15019.29	24.69	401.42	332936	581112	173772	56654
1970	19451.57	40.42	740.70	445197	702818	193423	54802
1971	21628.94	54.27	642.40	573507	894231	234810	65629
1972	22926.64	64.98	1177.49	633593	1118207	265204	73109
1973	24850.32	75.13	991.74	752063	1287378	309041	81296
1974	27843.33	87.20	1408.62	894779	1448398	351713	85647
1975	27172.02	75.54	1413.13	1021897	1693098	410569	92453
1976	30018.41	94.07	1575.17	1357246	1909060	492746	105224
1977	31283.40	100.00	2280.31	1496201	2131273	589852	118391
1978	30234.82	95.69	2154.24	2108000	1965034	693939	135543
1979	32033.66	104.28	2255.14	1956000	2050000	811219	153765
1980	32173.73	104.43	2040.81	1518874	1978714	902987	167836
1981	30470.51	90.25	2176.88	2724093	2902984	1031997	189367

[1]Estimates

Sources: 1. National Electric Power Authority. 2. Federal Office of Statistics. 3. Central Bank of Nigeria.

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