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FORECASTING ELECTRICITY CONSUMPTION IN NIGERIA'S COMMERCIAL SECTOR: A LINEAR REGRESSION APPROACH

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Abstract

The increasing level of electricity consumption in the commercial sector of Nigeria's economy calls for accurate and plain understanding of the key variables dictating the electricity consumption profile. Such information is critical to day-to-day electricity market operations, policy formulation as well as the nation's energy sector capacity planning initiatives. In this paper, some of the notable variables selected from literature were studied in order to ascertain their present influence on the annual electricity consumption in the commercial sector of Nigeria's economy. The study initially selected seven independent variables from literature being the most frequently used in previous studies. They are temperature, relative humidity, electricity price, rainfall, gross domestic product; total electricity generated and total primary energy resources available. In the course of model selection, only four out of the seven variables were shown to be significant enough to be included in the final subset of variables needed to produce the most appropriate model. Those four final variables are rainfall, total electricity delivered, total primary energy and population. The model selection exercise was done using R software based on Akaike Information Criterion (AIC). The data are all annual data frame from 1990–2014. Electricity consumptions models are then developed and analysed using multiple linear regression analysis. The model shows high predictive capacity with a root mean squared error (RMSE) of 0.049 and a probability value of 2.2 x 10-16. The average annual growth rate of electricity demand is estimated to be 5.44%.

Keywords: Electricity consumption, commercial sector, modelling, linear regression, variables.

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1. Introduction

Electricity consumption in Nigeria is divided among three principal sectors namely, the industrial, residential and commercial sectors, respectively. The commercial sector of any nation's economy is one of the key sectors responsible for such nation's overall wellbeing (Oluseyi, Babatunde, & Babatunde, 2016; Ying, Hanyu, Wenchao, & Lixin, 2017; Hussain, Rahman, & Memon, 2016). In Nigeria, electricity is the biggest infrastructure problem to the commercial sector owing to the erratic and unreliable nature of supply from the national grid. However, the commercial sector is rapidly growing due to expanding economic opportunities in both urban as well as rural areas; and that requires a commensurate supply of electricity to support and sustain the sector in order to achieve the much needed socio-economic development. Hence, understanding the key variables driving demand for electricity in the sector is crucial from the viewpoint of sustainability, demand management, forecasting and analysis of energy policy. Specifically, ascertaining the extent to which the demand for electricity in the commercial sector is particularly influenced by each identified key variable is a significant operation concern for electricity generation architecture operators, electricity market operators as well as energy policy makers.

Furthermore, combating the high level of unemployment among the teeming youths and able bodied individuals in the country by promoting small scale commercial enterprises in addition to the government's determination to revive agro allied commercial businesses will certainly increase the demand for electricity in the sector. This is against the backdrop of the fact that small and medium scale enterprises are globally recognized as catalysts for sustained, rapid and massive economic growth of any nation. Consequently, determining the future electricity demand trajectory in the sector is strategic for capacity planning bearing in mind environmental concerns.

Generally, electricity generation and supply to all sectors in the country have been erratic and unreliable. As a result, several key players in the commercial sector have been forced to reduce their dependence on public power supply by employing privately generated electricity for sustaining their operations. Presently, it is difficult to access data on self-electricity generation in the country, and as such this study focuses on the trend of total annual electricity demand as a whole and not electricity consumption by various sub-sectors in the sector. In view of the recent reforms embarked upon by Nigerian government in the power sector christened "Electric Power Sector Reform" aimed at guaranteeing access to adequate and reliable electricity supply by the citizens, it becomes imperative to obtain accurate estimates of variables that dominantly dictating electricity consumption for the purposes of demand and supply projections.

2. Problem Statement

Adequate availability, affordability and usability of energy are critical needs of every human society as energy is a catalyst for socio-economic transformations as well as sustenance of nations. As a result, a thriving commercial sector of any nation's economy is contingent on the quantity, quality, safety and regularity of energy supply the country enjoys. For a developing country like Nigeria which is experiencing rapid growth in population and commerce but witnessing endless erratic and inadequate supply of electricity, maintaining the current growing indices of expansion in the commercial sector will be undermined if deliberate and concerted efforts are not made to resolve energy supply deficits. While

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considerable number of studies could be found in literature focusing on electricity consumption in the industrial as well as residential sectors in Nigeria, the commercial sector, remain relatively unattended to. A contributing factor to this scenario is the apparent limited availability of data, given the widespread absence of electricity meters and lack of records of fuel consumption by those using self-generating devices. Equally responsible is the sector's diversity, as the sector includes all the business outfits in the country with exception of those involved in manufacturing and/or agriculture and transport. The goal of this study is to fill this gap by identifying the core variables instigating electricity consumption in this sector and use their present values to forecast future electricity consumption values for the sector. To the best of our knowledge, this will be the first study modelling and forecasting electricity consumption in Nigeria's commercial sector using other modelling technique than econometric technique.

3. Research Questions

This study is carried out to answer some important questions relating to knowledge and understanding of electricity consumption in the commercial sector of Nigeria's economy with a view to making helpful deductions. These questions direct the research efforts reported in this paper and they are:

- What are the key variables that significantly motivate electricity consumption in the commercial sector of the country's economy under consideration?
- Does the developed energy consumption model adequately predict the observed electricity consumption values of the sector?
- What are the implications of the forecast values for policy and practice?

4. Purpose of the Study

The aim of this study is to bring to the fore the salient factors responsible for commercial sector electricity demand as well as their potent empirical influences on present and future energy use in the commercial sector. To achieve this:

- First, we identify key determinants of electricity consumption in the commercial sector both in developed and developing economies from literature.
- Second, we model and select the best set of variables responsible for the growth in electricity demand in the sector.
- Third, we use the developed model to predict electricity consumption in the commercial sector so as to evaluate the predictive capacity of the developed model.
- Fourth, on the basis of the model's accuracy, it is used to forecast the future electricity consumption profile of the sector.
- Fifth, the forecasted values are analysed, interpreted and conclusions derived with a view to making necessary recommendations for stakeholders in the sector.

5. Research Methods

To model and estimate the electricity demand forecast, this study adopts a multiple linear regression approach; which is a transparent, simple and effective method useful in dealing with analyses that require tracking the contributions of respective variables used in the study. This modelling approach is particularly

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desirable in the absence of adequate knowledge on the cardinal data generating process and in a situation where a comprehensive understanding of the underlying relationships between the subset of variables used in the analysis is critical. In addition, since the number of observations of the dataset used covers a fairly short time frame (not more than 25 years), it was considered that a multiple linear regression is most suitable rather than machine learning techniques which require larger datasets and most effective in dealing with nonlinear equations. Similarly, simple linear forecasting procedures is used based on the nature of the time plot of the data which is clearly dominated by trend and have no seasonality features because they are entirely annual datasets.

A multiple linear regression function for electricity demand analysis aiming to delineate the nature of relationship between a dependent variable (referred to in this case as energy consumption) and two or more independent variables (usually called explanatory variables or predictors) can be expressed using the following equation:

$$y(x) = \beta_0 + \beta_1 \mathrm{X}_1 + \beta_2 \mathrm{X}_2 + ... + \beta_n \mathrm{X}_n + \varepsilon \quad \text{(i)}$$

where y(x) represents the dependent variable, β0……βn are the regression coefficients of respective explanatory variables and their values are estimated by fitting a model depending on the record of observations. The model fitting is achieved by curve fitting based on the least square technique which seeks to minimize the difference between the observed and estimated values of the variables (Braun, Altan, & Beck, 2014). X refers to the various predictors, and ε is the residual (or fitted error term) which accounts for any error in the model's representation of the actual relationship between the independent variables and the dependent variables. The validity of the results obtained from the model is based on predefined attributes of the residuals usually evaluated by conducting residual analysis. For instance, the output of the model is adjudged to be acceptable if the residuals are normally and independently distributed; and having a zero mean as well as constant variance (Douglas, Montgomery, & Kulahci, 2015). Residual analysis is also useful in the determination and elimination of data outliers which could imperil the entire analysis if left untreated.

5.1. Data

This study used observed electricity consumption data for the period of 1990–2014 obtained from the International Energy Agency (IEA) and National Bureau of statistics (NBS) to estimate an electricity demand forecast. Data obtained from the Agency include the country's population, total primary energy and total electricity consumed in the nation's commercial sector. The data on the annual rainfall, relative humidity and electricity price were sourced from the Annual Abstracts of Statistics published in Nigeria by the National Bureau of Statistics (NBS).

5.2. Model development

After extracting relevant variables from literature, a time plot of each variable is done to evaluate its trend pattern. Then the correlation plot is carried out to determine the correlation coefficient of the variables so as to establish the degree of their relationship, one with another. Correlation plot is useful in determining the presence and level of multicollinearity in a given set of variables. At this point, variables showing high

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correlation coefficient could be dropped from the analysis. In this study, the seven chosen variables were used to fit the initial model so as to understand their respective statistical significance. Furthermore, the choice of the optimum subset of variables that will produce the best model is carried out using the R software.

5.3. Model testing

The best model selected is analysed using the statistical parameters of the variables such as the coefficient of determination, the adjusted R squared, the F-test, t-test and the p-values. The suitability of the model is assessed based on its predictive ability which in this case is determined by the value of the root mean square error (RMSE). The smaller the value of the root mean square error, the better the model's predictive capacity.

5.4. Forecasting

Forecasting the future values of the Commercial sector electricity consumption is done using the forecast values of the independent variables. In order to do this, the point forecasts of the individual independent variables are made. These new set of values are inserted into the existing regression equation and a forecast value of the Commercial sector electricity consumption is obtained (Makridakis, Wheelwright, & Hyndman, 2008), (Douglas, Montgomery, & Kulahci, 2015). The equation for the forecasts from the simple linear model becomes

$$\hat{y}(x) = \hat{B}_0 + \hat{B}_1 x \quad \text{(ii)}$$

And for *n* number of *x*, the equation becomes,

$$\hat{y}(x) = \hat{B}_0 + \hat{B}_1 x_1, ..., \hat{B}_n x_n \quad \text{(iii)}$$

where *x* is the value of the predictor for which we require a forecast. That is, if we input a value of x in the equation we obtain a corresponding forecast. The future values of Commercial sector electricity demand are shown in table 02 below.

6. Findings

6.1. Model Evaluation

The plot of the actual values from the datasets and the predicted values of the regression analysis is shown in figure 01. A brief look at the plots shows that they are close and that indicates that the model has high predictive capacity, thus validating the value of the coefficient of determination, R2, which is a measure of the amount of variation of the dependent variable explained by the regression equation. The root mean square error of the plot estimated to be 0.049 which indicates that the errors between the actual and predicted values are minimal.

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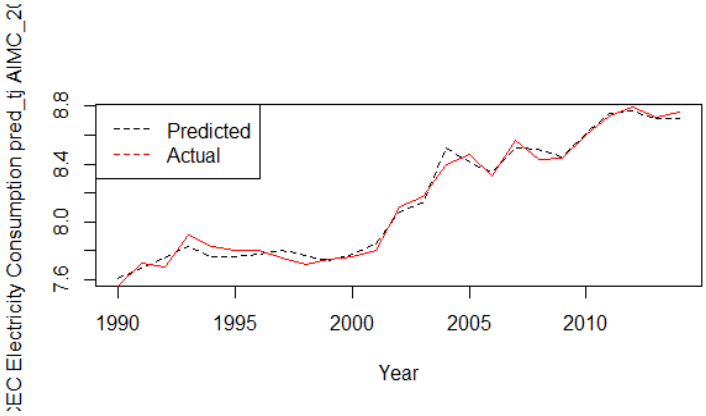

Figure 01. A plot of the observed and predicted commercial electricity consumption.

Table 01 presents year by year difference between the observed electricity consumption and the electricity consumption values predicted by the developed model.

Table 01. Comparison between observed and predicted Commercial sector electricity Consumption Values

Year	Observed Consumption (GWh)	Predicted Consumption (GWh)	Difference (GWh)
1990	1906	2003	-97
1991	2226	2165	61
1992	2182	2307	-125
1993	2714	2515	200
1994	2514	2330	184
1995	2449	2347	102
1996	2453	2388	65
1997	2317	2436	-119
1998	2222	2360	-138
1999	2298	2285	13
2000	2346	2369	-23
2001	2439	2544	-105
2002	3298	3189	109
2003	3538	3395	143
2004	4410	4955	-545
2005	4754	4523	231
2006	4077	4188	-111
2007	5252	4984	268
2008	4574	4942	-368
2009	4639	4662	-23
2010	5449	5476	-27
2011	6180	6299	-119
2012	6627	6405	222
2013	6130	6070	60
2014	6379	6122	257

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Table 02. Forecast values of future commercial sector electricity demand

Year	Observed Consumption (GWh)	Predicted consumption (GWh)	Difference (GWh)
2015	6841	2026	12256
2016	7214	2027	12924
2017	7606	2028	13627
2018	8020	2029	14369
2019	8457	2030	15151
2020	8917	2031	15976
2021	9403	2032	16846
2022	9915	2033	17763
2023	10454	2034	18730
2024	11024	2035	19750
2025	11624		

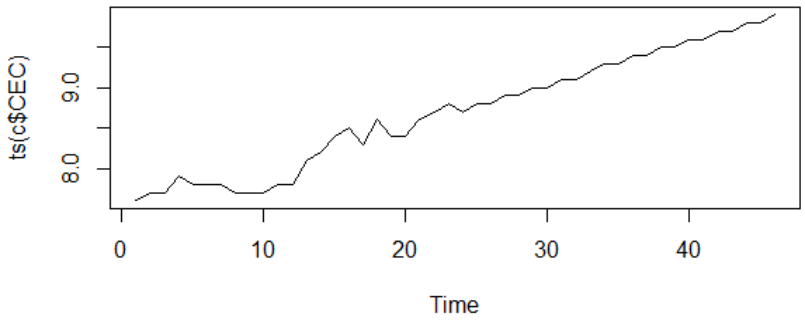

Figure 02. Plot of Forecasted Commercial Sector Electricity Demand

The plot of the forecasted values of commercial electricity consumption for the next twenty-one years shown in figure 02 indicates a steadily increasing demand trend. And that is a call to embark on necessary measures to contain the demand trend.

7. Conclusion

This paper first determined the fundamental drivers of electricity consumption in the commercial sector and then forecasted electricity demand for commercial use in Nigeria for the period from 2015 to 2035. The variables analysed are commercial electricity consumption, rainfall, total electricity given, total primary energy and population. Observed data frame from 1990 – 2014 was used. The regression equation formulated for these data was used to estimate the consumption as well as the regression coefficients of the predictors. A plot of the actual or observed and predicted consumption values are acceptably close and the root mean squared error (RMSE) value is 0.049. Each predictor is then forecasted and their forecasts were later used to forecast the commercial sector's future consumption value. The average annual growth rate is estimated to be 5.44%

The forecasted values indicated a considerable increase in commercial electricity consumption in the years ahead. This finding prompts the following conclusions:

- From the analysis of the model, it is imperative to consider rainfall, total electricity given, total primary energy and population as significant explanatory variables in forecasting models for Nigerian commercial sector electricity consumption.
- Electricity price, temperature and relative humidity do not significantly induce electricity consumption in the commercial sector, in this given instance.
- Consequently, there is need to intensify electricity generation in the country, taking advantage of all available primary energy resources in order to accommodate the influence of rainfall on the demand for commercial electricity. This is very important given the link between rainfall, agriculture and commerce in the country.
- In addition, a considerable increase in commercial electricity use driven by increase in population should be expected in the country.

It is believed that the model, electricity consumption forecasts and recommendations set forth in this paper would be important aids to operators of power utilities, energy policy makers as well as energy market operators in building outlines of future electricity demand in the nation's commercial sector.

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