MODELING NIGERIAN ELECTRICITY GENERATION AND CONSUMPTION PATTERN

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Abstract
This study examined annual amount of electricity generated and consumed in Nigeria for the period spanning 1970 to 2012. The Box-Jenkins modeling approach was employed after the series were transformed to ensure stationarity using the first differencing method. The empirical results showed that ARIMA (1, 1, 0) and ARIMA (0, 1, 1) models fitted the electricity generation and consumption datasets adequately. The whiteness of the residuals from the models was verified using Ljung-Box methodology. Theprojections for both electricity generation and consumption for five years ahead were made with 80% and 95% confidence limits.

Keywords: Electricity generation, electricity consumption, Box-Jenkins modeling, Augmented Dickey-Fuller, Ljung-Box method, confidence limits

Introduction
Energy accessibility is one of the cardinal criteria to distinguish poor nations from the rich ones. This explains why the developed nations of the world generate more energy with steady power supply than developing and underdeveloped ones. Undoubtedly, adequate power supply is the bedrock for the socio-economic and technological development of any nation. Availability of power supply induces industrialization, good communication system, better healthcare delivery, improvedscience and technological advancement and general high standard of living of the citizens.

Nigeria, the most populous nation in Africa has 36 states and Federal Capital Territory (FCT). The nation is endowed with enormous energy resources (renewable and non-renewable) that could be used to generate power for her populace (Obadote, 2009). These resources include hydro, solar, wind, biomass, natural gas, coal, geothermal and so on. Unfortunately, to generate sufficient electricity to meet national demand has become herculean task for successive government in Nigeria till date.

Given the importance of the electricity to Nigeria economy, this paper utilizes statistical tools to model over 40 years of energy generation and consumption in Nigeria in order to project future values for both generation and consumption given the availability of endowed resources in Nigeria.

A Synopsis of Nigerian Energy Sector
Electricity was first produced in Nigeria in 1896. This was done using generators with 60kW capacity installed in Ijora, Lagos by the Colonial Government. The establishment of Nigeria Electricity Supply Company (NESCO) at Kurra falls (Plateau state), African Timber and Plywood (AT&P) Company at Sapele (Delta state) and Shell Development Company at Bonny (Rivers state) in 1925, 1930 and 1942 respectively, increased Nigerian electricity generation capacity within these periods. In 1946, Public Works Department (PWD) was established and charged

with the responsibility of supervising electricity generation and supply. About four years later, the Colonial Government on the recommendation of the Legislative Council (LC) set up Electricity Corporation of Nigeria (ECN) to coordinate and regulate all the activities of power generating plants in Nigeria which includes the operations of PWD.

To facilitate and enhance speedy completion of hydroelectric project in Kainji (Niger State), Niger Dams Authority (NDA) was established in 1962. The NDA was also given the mandate to develop hydropower potentials of the country and maintain dams and other projects on the River Niger. Meanwhile, the amalgamation of ECN and NDA became inevitable in 1972 which gave birth to the National Electric Power Authority (NEPA). The NEPA which was later rechristened Power Holding Company of Nigeria (PHCN) was given the monopoly to coordinate the generation, transmission, distribution, pricing and supply of electricity in Nigeria.

From the foregoing, it can be observed that between 1946 and 2005, the Nigeria power sector has transfigured from agency to agency which were totally controlled by the Federal Government. However, since March 2005, private organizations have been encouraged to actively participate in the Nigerian energy sector as evident in the Power Sector Reform Bill (PSRB) that was signed into law by the Administration of President OlusegunObasanjo (Obadote, 2009; Sambo et al., 2010).

Basically, Nigeria has three functional hydropower stations (Kainji, Jebba and Shiroro) with several other hydropower resources yet to be harnessed. The Kainji hydropower station on River Niger was commissioned in 1968 with an installed capacity of 320MW. The station was upgraded ten years later to the capacity of 760MW. The Jebba hydropower station is also on River Niger and is about 100km downstream of Kainji. It started operation in 1984 and has an installed capacity of 540MW. The Shiroro hydropower station was built on River Kaduna and commissioned in 1990 with a capacity to generate 600MW. Recently, the Nigerian Government approved counterpart funding for construction of three new hydropower stations, Zungeru, Mambilla and Gurara with 700MW, 350MW and 300MW capacities respectively.

Apart from hydropower stations, Nigeria has thermal generating stations in Sapele (commissioned in 1985 with 1,020MW installed capacity), Afam (1985 with 702 installed capacity), Egbin (1988 with 1,320 installed capacity), Delta (1993 with 840 installed capacity) among others. Despite all these, the nation's electricity demand is above the generation from the combined installed capacity of power stations in the country which results to epileptic supply of electricity. It is therefore imperative to study the generation and consumption of electricity in Nigeria so as to have a broader overview of the instability of power supply and its consumption over time. This would assist the government and other stakeholders to proffer strategies to ameliorate the situstion.

There are number of studies that had considered electricity generation, consumption and other indicators within the Nigeria context. See Ibitoye and Adenikinju (2007), Olusegun (2008), Akinlo (2009), Sambo et al. (2010), Esso (2010),Ubi et al. (2012),Akpan and Akpan (2012), Akinwale et al. (2013), Ogundipe and Apata (2013) among others. Specifically, Akpan and Akpan (2012) studied electricity consumption, carbon emissions and economic growth in Nigeria. They used annual data from 1970 to 2008 and employed a multivariate vector error correction approach to examine the causation between the pairs of electricity consumption, carbon emissions and economic growth. They reported that economic growth is associated with increased carbon emissions which is induced by increase in the electricity consumption being generated mostly via burning of petroleum fuels by individual generating plant as a result of erratic power supply.

Other researchers have worked on electricity consumption and/or generation in developed and developing countries. See Chang et al. (2001), Yoo and Kim (2006), Mehrara (2007), Halicioghu (2009), Jamil and Ahmad (2010), Adebola (2011), Pao et al. (2011) among others. This present work modeled the Nigerian 43-year annual electricity generation and consumption and predicted future values for both generation and consumption.

Material and Methods

The datasets used for this study were extracted from Research Department of the Central Bank of Nigeria (CBN). Although, the statistics of energy generation, distribution and consumption were provided by the defunct National Electricity Power Authority (NEPA) which has the monopoly of the Nigerian energy information,the CBN, among other agencies, publishes such information as obtained from the PHCN on regular basis. There were two sets of data obtained for this study:the data on annual electricity generation and electricity consumption in Nigeria measured in megawatts per hour (MW/h) over forty-three years beginning from 1970 to 2012.

Time plots and autocorrelation function plots (ACF) were obtained for the datasets to examine the pattern of the series as shown by Figures 1 and 2 respectively. Augmented Dickey-Fuller (ADF) test was employed to confirm the non-stationarity displayed in the plots. Sequel to the not rejecting the null hypothesis of non-stationarity, first-difference approach was used to attain stationary in the data.

For the analysis, the Box-Jenkins' methodology was carried out on the data using ACF and PACF plots at different lags to identify appropriate models for the data on generation and consumption of electricity in Nigeria. Thereafter, the identified models were subjected to diagnostics and an information criterion was used to select an appropriate model for forecasting based on their corresponding estimates of the parameters. The analysis of data was done in the environment of R statistical package obtainable on www.cran.org. The results obtained from this analysis were presented and discussed in the next section.

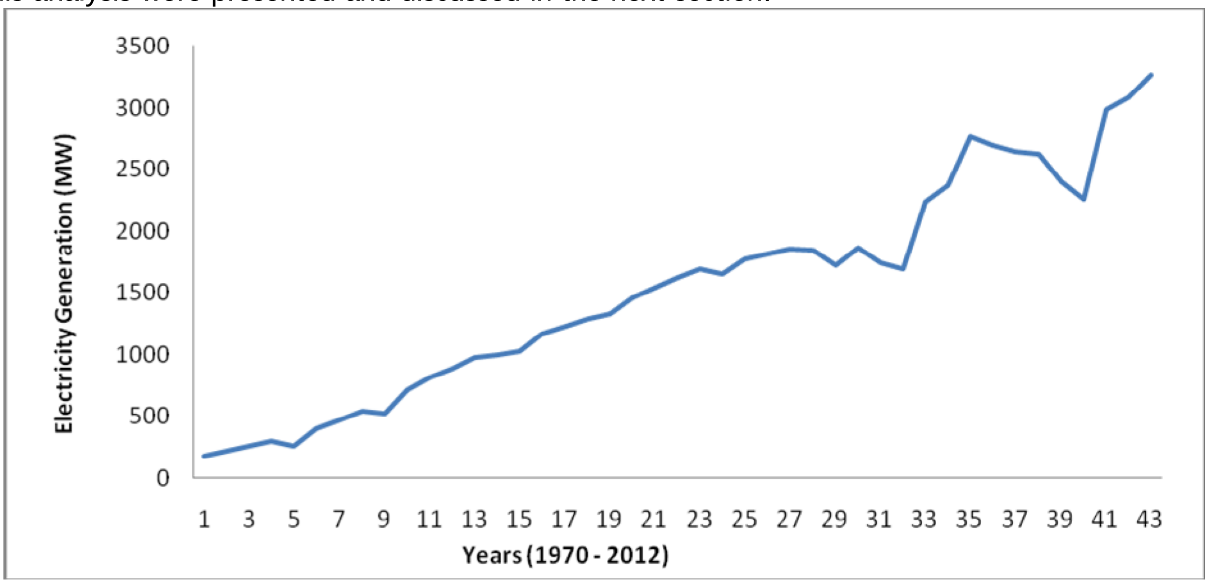

Figure 1: Time Plot for the Electricity Generation

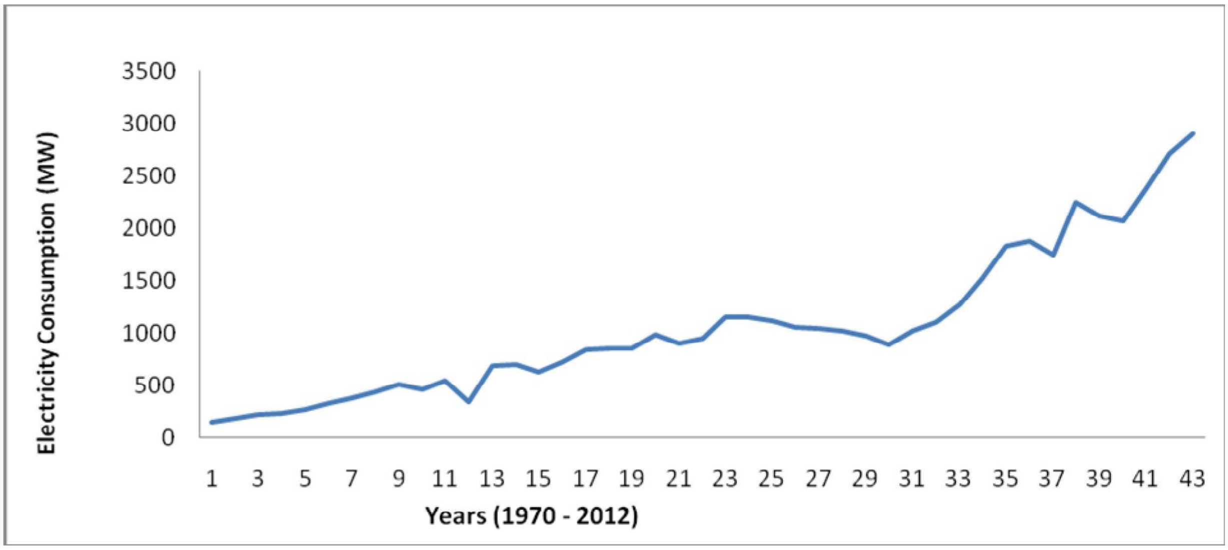

Figure 2: Time Plot for the Electricity Consumption

Thetime plots in Figures 1 and 2 show that the two series,the annual electricity generated and consumed in Nigeria between 1970 and 2012 are not stationary. Theydisplayed upward trends which were removed accordinglyafter the Augmented Dickey-Fuller test was performed to confirm the non-stationarity displayed by the time plots.

A formal procedure of testing for non-stationary or unit root was utilized and the findings are presented below.

Suppose the time series data on electricity generation and consumption are respectively denoted by X_t and Y_t. The electricity generated at time t is expected to be predicted by the electricity generated at immediate past time period (t-1). That is,

$$X_t = \rho X_{t-1} + \varepsilon_t \qquad (1)$$

Where

X_t *is electricity generated at time* t,

X_{t-1} *is the immediate pass value of* X_t, ρ *is the association between* X_t *and* X_{t-1}

, *and* ε_t *is the random error term at time* t.

Therefore, subtracting the lagged value of X_t from both sides of equation (1) yields

$$X_t - X_{t-1} = \rho X_{t-1} - X_{t-1} + \varepsilon_t \qquad (2)$$

$$X_t - X_{t-1} = (\rho - 1)X_{t-1} + \varepsilon_t$$

If we let $\alpha = \rho - 1$and $\Delta X_t = X_t - X_{t-1}$, then equation (2) becomes

$$\Delta X_t = \alpha X_{t-1} + \varepsilon_t \qquad (3)$$

If $\alpha = 0$, then $\rho = 1$ implying there is a unit root. This means the time series under consideration is non-stationary. But if $\alpha < 0$, then $\rho < 1$ indicates there is no unit root, which means the time series being considered is stationary.

The Augmented Dickey-Fuller test was used to test for the stationarity condition of the series. The test is equivalent to testing if α is significantly different from zero.The conventional t-test approach was adopted to test the significance of α value. The decision rule is to reject the null hypothesis if p-value is less than 5% level of significance.

Results and Discussion

Here, the results obtained from the analyses carried out are presented and discussed.
The test for stationarity of the two datasets showed that the data for electricity generation and consumption in Nigeria are not stationary (p-value = 0.1392 and 0.99 respectively).

Table 1: Results of Augmented Dickey-Fuller Tests

	Dickey-Fuller Statistic	Lag Order	P-value
Electricity Generation	-4.1255	3	0.1392
Electricity Consumption	0.1505	3	0.99

These results are in agreement with the deductions from the time plots in Figures 1 and 2. Hence, first-order differencing method was employed to attain stationarity in the two series.

The time plots for the differenced data are given in Figures 3 and 4. The series, Nigeria electricity generation and consumption, were found to be stationary after the first-difference transformation. Therefore, the series are technically referred to as time series of first order integration.

Figure 3: Time Plot for the Differenced Electricity Generation Data

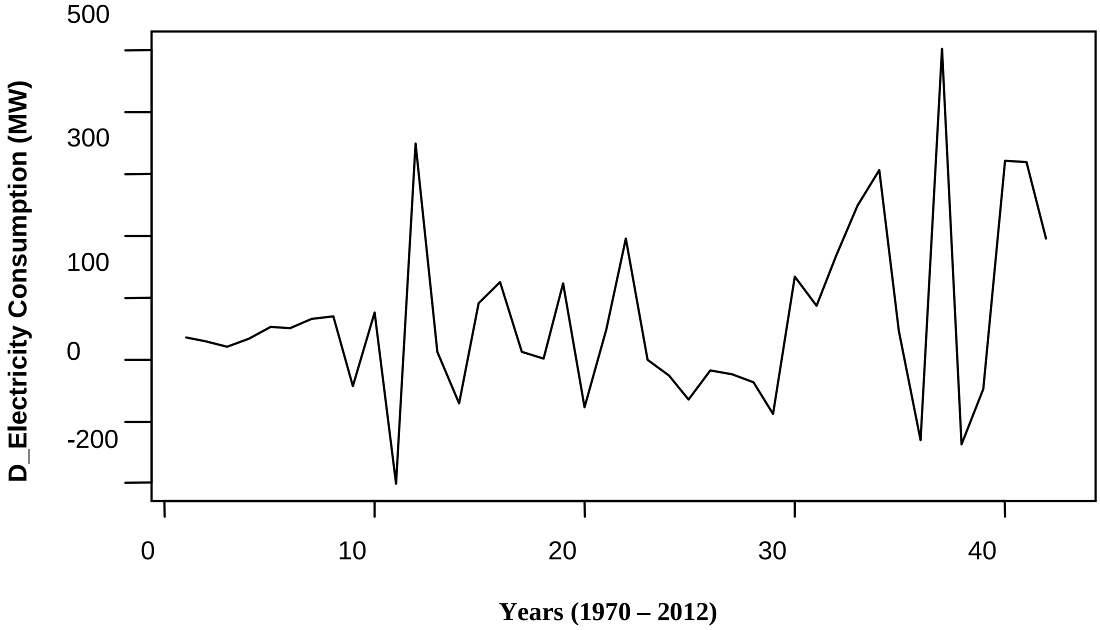

Figure 4: Time Plot for the Differenced Electricity Generation Data

Based on the deductions from the correlograms and partial correlograms of the transformed data of the two series given as Figures 5 to 8 in the appendix, there is no evidence of visible signature that suggest the usage of AR, MA or ARMA model. Then the Box-Jenkins modeling approach also known as ARIMA model (Box and Jenkins, 1976) was adopted for this study. This approach is a four-step procedure involving identification, estimation, diagnosis and forecasting.

Model Identification

In accordance with inferences from the said correlogramsand the partial correlogramsof the transformed data in the appendix, the series exhibit random walk with drift. Let $\boldsymbol{X_t^*}$ and $\boldsymbol{Y_t^*}$ be the transformed data for electricity generation and electricity consumption respectively, the random work models with drift are

$$X_t^* = \alpha + X_{t-1}^* + \varepsilon_t^* \qquad (4)$$

$$Y_t^* = \alpha + Y_{t-1}^* + \varepsilon_t^* \qquad (5)$$

Model Estimation

The parameters of the models stated as equations 4 and 5 were estimated and the results were presented in Table 2.

Table 2: Estimates of ARIMA Model Parameters

Series	Parameter Estimate	Standard Error	t-value	P-values
$\boldsymbol{X_t^*}$	73.6048	25.5058	2.8858	0.003904
$\boldsymbol{Y_t^*}$	65.5520	22.349	2.9331	0.003356

Thus, the fitted models for Nigerian electricity generation and consumption were respectively

$$\widehat{X_t^*} = 73.6048 + X_{t-1}^* \qquad (6)$$

and

$$\widehat{Y_t^*} = 65.5520 + Y_{t-1}^* \quad (7)$$

Model Diagnosis

Here, goodness-of-fit of the models to the datasets was verified, the conformity of white noise residuals of the fitted models was checked by plotting the ACFs and PACFs of the residuals emanated from the two models to observe whether they possess any pattern. It was discovered that the points on ACFs and PACFs plotted fall within the confidence limits at all lag points. Hence, the fitted models were adequate. The Ljung-Box test of no serial correlation was performed on the residuals of the fitted modelsvia the test statistic as

$$LB = n(n+2)\sum_{k=1}^{m}\left(\frac{\hat{\rho}_k^2}{n-k}\right) \sim \chi_m^2 \quad (8)$$

Table 2 presents the summarized results of the Ljung-Box statistical procedures performed on the two datasets.

Table 3: Results of the Ljung-Box test of no Serial Correlation of Residuals

Series	Statistic	df	P-value
X_t^*	17.2256	17	0.4392
Y_t^*	11.4787	17	0.8306

From Table 3, the LB statistics were 17.2256 and 11.4787 with the corresponding P-values of 0.4392 and 0.8306. These imply that the null hypothesis cannot be rejected, we therefore conclude that the residuals from the fitted models are not serially correlated thus they are white noise.

Forecasting

Having diagnosed the models and discovered that they were adequate and fit the data well, both electricity generation and consumption for the next five years (2013 – 2017) were predicted with 80% and 95% confidence limits. The projections in mega watts (MW) were given in Tables 4 and 5.

Table 4: Predicted Nigerian Electricity Generation (MW) for 2013 to 2017

Year	Predicted Electricity Generation	80% Confidence Limits		95% Confidence Limits	
		Lower	*Upper*	*Lower*	*Upper*
2013	3341.605	3129.769	3553.441	3017.63	3665.58
2014	3415.21	3115.628	3714.791	2957.039	3873.38
2015	3488.814	3121.904	3855.725	2927.673	4049.956
2016	3562.419	3138.747	3986.091	2914.469	4210.369
2017	3636.024	3162.344	4109.703	2911.593	4360.454

Table 5: Predicted Nigerian Electricity Consumption (MW) for 2013 to 2017

Year	Predicted Electricity Consumption	80% Confidence Limits		95% Confidence Limits	
		Lower	*Upper*	*Lower*	*Upper*
2013	2964.052	2778.433	3149.672	2680.171	3247.933
2014	3029.605	2767.099	3292.111	2628.136	3431.073
2015	3095.157	2773.654	3416.66	2603.461	3586.854
2016	3160.71	2789.47	3531.949	2592.947	3728.472

2017	3226.262	2811.203	3641.321	2591.485	3861.039

Conclusion

This paper examines the electricity generated and consumed in Nigeria between 1970 and 2012. The Box-Jenkins statistical modeling procedure was employed for this study. The Augmented Dickey-Fuller test carried out to examine the stationarity of the series showed that both series were not stationary. Hence, First-order differencing transformation was utilized to ensure stationarity. Our empirical results showed that the models fitted the data adequately and the Ljung-Box test performed confirmed the whiteness of the residuals from the models. We, therefore, made five years projections for both generation and consumption of electricity with both 80% and 95% confidence limits.

The predictions from the fitted models revealed that electricity generations shall be slightly improving in Nigeria starting from 2013, while the electricity consumption shall equally be increasing accordingly probably due to expansion in terms of population and amenities in Nigeria.

The amount of megawatts of electricity generation in Nigeria produced by the fitted model for 2013, 2014 and 2015 were quite close to the actual electricity generated by PHCN for 2013 and by the electricity generation companies (after unbinding) for 2014 and 2015.

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Appendix I

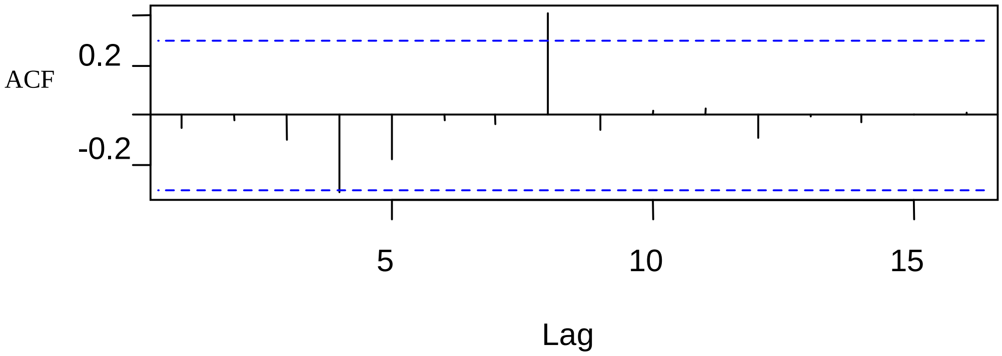

Figure 5: Plot of Autocorrelation for Differenced Electricity Generation

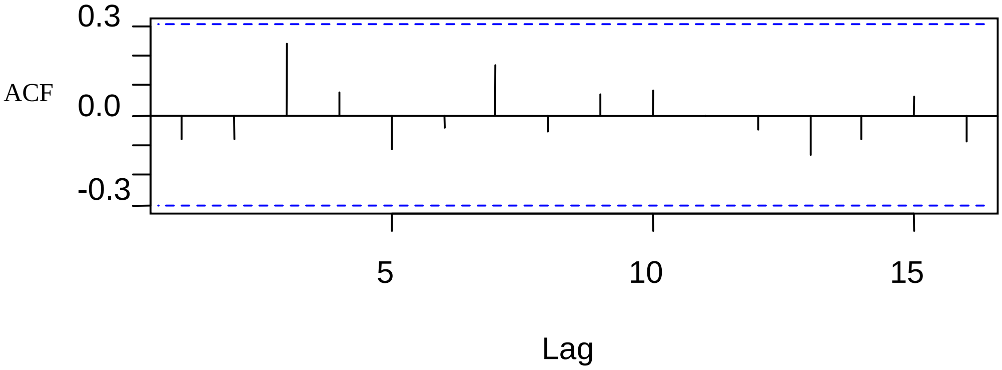

Figure 6: Plot of Autocorrelation for Differenced Electricity Consumption

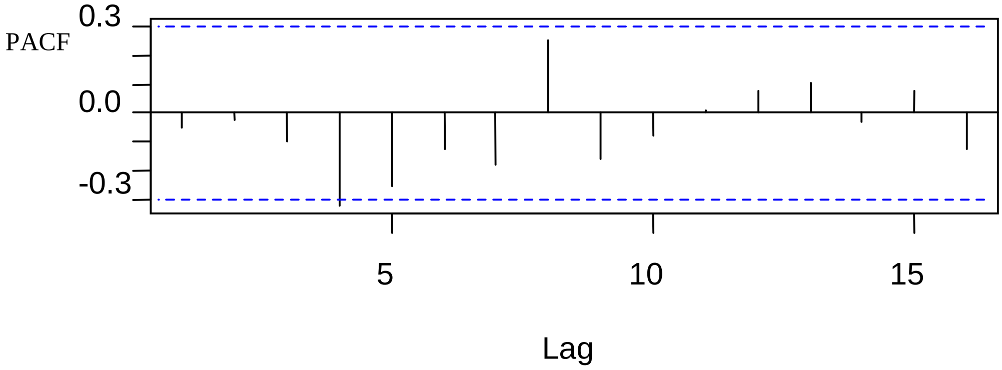

Figure 7: Plot of Partial Autocorrelation for Differenced Electricity Generation

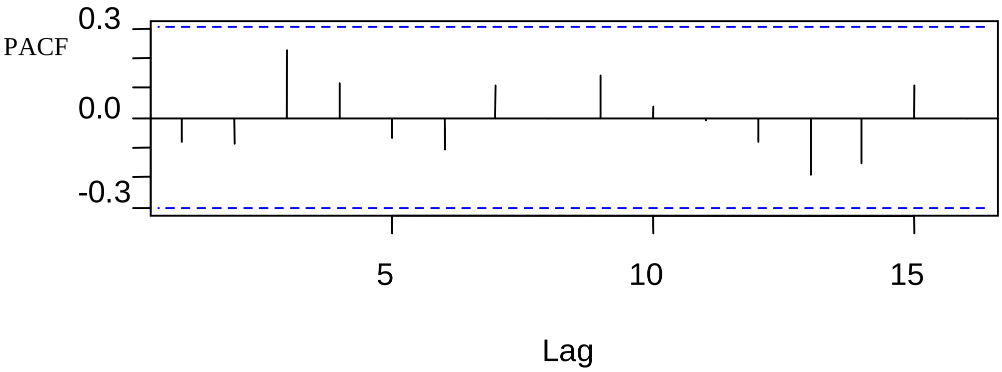

Figure 8: Plot of Partial Autocorrelation for Differenced Electricity Consumption

Appendix II

Nigerian Electricity Generation and Consumption in MW from 1970 to 2012

Year	Electricity Generation	Electricity Consumption	Year	Electricity Generation	Electricity Consumption
1970	176.6	145.3	1992	1693.4	1141.4
1971	215.4	181.1	1993	1655.8	1141.4
1972	255.4	211.1	1994	1772.9	1115
1973	299.7	232.7	1995	1810.1	1050.9
1974	261.1	266.2	1996	1854.2	1033.3
1975	395.4	318.7	1997	1839.8	1009.6
1976	468.7	369.8	1998	1724.9	972.8
1977	538	435.7	1999	1859.5	883.7
1978	522.7	504.4	2000	1738.3	1017.3
1979	710.7	460.1	2001	1689.9	1104.7
1980	815.1	536.9	2002	2237.3	1271.6
1981	887.7	335.9	2003	2367.5	1519.5
1982	973.9	685.6	2004	2763.6	1825.8
1983	994.6	696.7	2005	2687.3	1873.1
1984	1025.5	625.5	2006	2638.1	1742.9
1985	1166.8	717.4	2007	2623.1	2245.5
1986	1228.9	841.8	2008	2403.2	2108
1987	1286	852.9	2009	2257	2060.71
1988	1330.4	853.5	2010	2981.9	2383.08
1989	1462.7	976.8	2011	3086.1	2703
1990	1536.7	898.5	2012	3268	2898.5
1991	1617.2	946.6			