

Time Series Forecast of Nigeria's Electricity Using Auto-Regressive Integrated Moving Average (Arima) Model

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ABSTRACT: Electricity generation and consumption in Nigeria play a pivotal role in driving economic growth and improving the quality of life for its citizens. Despite significant energy resources, the country faces challenges such as inconsistent power supply, inadequate infrastructure, and a growing demand for electricity due to population and economic expansion. Addressing these challenges requires sustainable energy strategies to bridge the gap between electricity generation and consumption while supporting the nation's development goals. This study aims to investigate time series data of Nigeria's Electricity consumption variables. The data was collected from Our World in Data on electricity generation (in TWh) and GDP per capita having a coverage of 33 years (1990-2023). Autoregressive Integrated Moving Average (ARIMA) model was used to analyze the data. The result fitted ARIMA (1,1,1), (1,1,2), (1,0,2) and all the results revealed that at 5% level of significance, all the parameters of the model proved to be adequate. The result of the forecast also reveals that there is an increase in electricity consumption with a significant positive correlation between electricity generation and GDP per capita. Therefore, it is recommended that the government and private sector collaborate to develop strategies for sustainable electricity generation and distribution, with a focus on renewable energy sources, to ensure a stable and efficient energy supply that supports economic growth and development in Nigeria.

KEYWORDS: ARIMA, Electricity, GDP, Per Capita, Time Series

I. INTRODUCTION

An electric power supply must be maintained in accordance with the needs of all the clients it serves. Most people are familiar with the basic needs for a power supply, such as adequate voltage, availability of power on demand, dependability, and a suitable price range. On-demand power availability refers to electricity being accessible to the user in whatever quantity he may need at any given moment. Another way of putting it is that electricity may be switched on or off at any time, with or without notification to the electric power supply provider [6]. Random consumer behavior coupled with demographic and weather-controlled demographic and weather factors, along with econometric factors, has posed the greatest challenges, such as the amount of energy to generate and the load (circuits) to switch on or off at a given time on the part of the power utility company. In order to fulfil the expected demand for electricity in the near and far future, a power system must be meticulously constructed. The first step in system planning is to anticipate future power needs realistically. Load forecasting includes the notion of the preceding topic. To put it simply, load forecasting is more than an intelligent projection of past and present demand patterns to predict future demand patterns [10]. Electric utility companies stand to save much money if their load forecasts are accurate. These savings are achieved when load forecasting is utilized to regulate operations and choices, such as unit commitment, fuel allocation, and off-line network analysis. The efficiency and management of

power systems may be quite susceptible to forecasting mistakes. Thus, load estimates must be as accurate as possible [19].

Accurate electric load forecasting is by no means a straightforward endeavour. Uncertainty factors control electric load, and their relevance to the ultimate load cannot be easily derived [13]. Economic considerations, time, day, season, weather, and random influences are some variables or factors. Data from the historical history of load, temperature, humidity, luminosity, and wind speed, among other things, may be used to anticipate electricity use. Accurate load forecasting models that include all of these variables, on the other hand, enhance the complexity of the model. As a result, various approaches to load forecasting have been used, each with its drawbacks. It is possible to develop mathematical models for a wide range of complicated situations using time series analysis [12]. Different models, such as ARIMA Models, are used to detect or forecast the behaviour of phenomena represented by a series of measurements. It is, however, very difficult to create an appropriate model for a time series that depicts non-linear processes or processes with a broad variation. However, the current fad is to use artificial intelligence to tackle most human issues. When it comes to time series modelling, artificial intelligence-based forecasting systems do better [26]. The study aims to investigate time series data of Nigeria's electricity using auto-regressive integrated moving average (ARIMA) model.

II. RELATED WORKS

According to the Nigerian Bureau of Statistics 2013 estimate, the country's teeming population of about 200 million does not have enough electricity to meet its needs. Nigeria has one of the world's lowest net power production per capita rates, according to the U.S. Energy Information Administration (E.I.A.). Load shedding, blackouts, and dependence on private generators are all consequences of inadequate electricity generation. As a result of recent privatization, the nation's eleven recognized power-producing businesses have been unable to keep up with demand. Electricity is a prerequisite for both social progress and economic expansion. The primary goal of the electricity industry is to provide energy. Sustainable development and poverty alleviation activities rely heavily on the availability of energy [32]. Everything from access to water to agricultural production to health to population size to education to gender-related concerns is affected by climate change. The degree of productivity in industry, commerce, agriculture, and even the workplace is directly linked to the energy used. As a measure of a people's or nation's level of life, energy consumption per capita is one of the indicators or benchmarks [32]. As a result, there is little possibility of reaching enviable national development or even raising the level of life of the Nigerian people if the country's energy supply cannot keep up with demand. The National Electricity Regulation Commission's (NERC) administration must gather information indicating the population's energy consumption and compile this data so policymakers, generating firms, and other key stakeholders can readily comprehend it. Such information should be collected and analysed by the Nigerian government's energy regulatory agency to identify and highlight trends in the country's energy output and consumption. Use of up-to-date statistics and forecasting tools and software may be used to make a projection of the predicted use pattern for electrical energy over a specific time in the short or long term. Additionally, with this new knowledge, the nation's power industry can give a solution to and ensure that the country intends to fulfil its energy needs at any moment in the future, as portrayed by the forecast.

One of Africa's major economies, Nigeria has a significant amount of installed generating capacity of around 13.5 gigawatts (GW). Energy production should meet the country's peak demand of 8.25 gigawatts (GW). There was just 3.7 GW of available power in 2019. Sixty percent of the population has access to electricity, but 16 million homes are still without it. Nearly 60% of the power produced is used by the home sector, with the remaining 25% going to business and public sector customers and users. Sub-Saharan Africa's greatest economy is being held back by a lack of electricity. Put it another way: Nigeria has a lot of natural resource potential; it can create 12,522 megawatts from its current facilities. A nation of more over 195 million people can only generate roughly 4,000 MW on most days, which is not enough. With the aid of Power Africa, distribution businesses in Nigeria have increased income by over \$250 million - money

that can be put into the network, improving service and extending access. The Nigerian power industry has been hindered from attaining commercial viability due to several broad difficulties, including the implementation of energy policy, regulatory ambiguity, gas supply, transmission infrastructure limits, and substantial planning shortages. The Nigerian government encourages private sector participation in the country's energy industry. All except transmission are being opened up to the private sector, including policy-making, state-owned company takeovers, and greenfield development, by the government. Nigerian authorities are also improving the investment climate by enhancing management, boosting transparency, and decreasing government and political meddling. PPAs involving 14 different power projects ranging from 50 MW to 100 MW was signed by Nigeria in July 2016. These projects have a combined capacity of more than 1 GW. The administration has recommended a tariff renegotiation for 2019 since none of them has achieved financial closure yet.

Empirical Evidence

ARIMA models have been used to predict Pakistan's population growth [7]. ARI (1,2) was shown to be close to other researchers' and non-government groups' estimates for future planning and projects. An analysis of the ARIMA and neural network methods for forecasting has been carried out by [7]. Using ARIMA, they found that feed forward artificial neural network predictions were inaccurate. Patients with malignant tumour in Anbar province were forecasted using a technique called ARIMA [28]. Analyses suggested that an integrated autoregressive model of order two ARI is the most appropriate model (2,1). Maternal mortality was predicted and modelled using ARIMA models [27]. For predicting quarterly maternal mortality rates at the hospital, the ARIMA (1, 0, 2) model was shown to be appropriate. Forecasting the output of electric power was done using Box-Jenkins models [3]. According to the investigation, the best model was ARIMA (1,0,2), followed by ARIMA (1,0,1) and AR (1) based on prediction method performance. Since recently, population forecasting research have used ARIMA approach. Arrest and sentence data have been used to anticipate prison populations [27] using the ARIMA approach. However, even though the model predicted an uptick in remand prisoners, the drop in sentenced prisoners is expected to outweigh this tendency after a few of months. Race/ethnicity and gender were forecasted using the ARIMA approach [23].

There are statistical models in use by [9] for predicting unintentional fatality in the Indian population. The study's findings demonstrated that ARIMA outperformed damped trend exponential smoothing in model validation (DTES).

III. Materials and Methods

As a result, Nigeria's energy industry has been unable to meet the country's need for electricity. In reality, there is a lack of coordination in data collection that prevents the country's true energy figures from being forecasted. Through the use of statistical forecasting, this study hopes to identify a long-term trend in Nigeria's energy demand so that it may develop an energy demand time series prediction for later years. There would be little chance for Nigerians' living standards to improve or even be envied if the country's energy supply cannot keep up with the country's energy demand. The time series design was adopted in the study. For the projection, the study utilized time series data for Nigeria from 1990-2023 on electricity production, per capita electricity and GDP per capita. The data was collected from the Our World in Data website and World Bank data website.

A. Model Specification

ARIMA [3] is the name given to the forecasting technique supplied by them. Time series data may be examined for their stochastic or probabilistic properties without developing a single equation model or many equation models. Each variable's lagged values and resulting stochastic error term are explained using the ARIMA model. Autoregressive moving average (ARMA) is an improvement on the autoregressive moving average model. We use this formula to calculate the ARIMA (p, q). The ARMA (p, q) model uses time series data that have been different d times to render them stable.

The resulting data are then referred to as ARIMA series (p, d, q). ARIMA models need time series to be stationary or stationary at one or more difference points in order to work. Identification, estimate, diagnostic checking, and forecasting are all part of the ARIMA model procedure. The model specification parameters p, d, and q must be determined in order to perform identification. ACF and PACF are the primary tools for determining the identity of a given object or phenomenon. For identification, the ACF and PACF findings are shown on a correlogram versus the lag duration. Correlograms and formal unit root tests can be used to determine if the data are stationary or not. If they are non-stationary, the data remain different until they become stationary again. After determining the number of differences needed to establish stationarity, the ARIMA model estimate values are calculated. A diagnostic check is performed on the estimated value. The data fitness is obtained by collecting the residual of the estimator and determining whether the ACF or PAC of residuals is statistically significant. If the residuals aren't statistically significant, the model's ARIMA estimate is a good match for the data; if it is, it means the model's residuals are completely random. As a result, a more suitable ARIMA standard is required instead. The forecast is then made using the model that has been fitted.

B. Method of Data Analysis

This study utilized time series data for Nigeria from 1990-2023 on electricity production, per capita electricity and GDP per capita. The data was collected from the Our World in Data website and World Bank data website. For the computing and forecasting of power data, Minitab Data Analysis Application used Time-Series Modeler. It is possible to see how much power is generated, used, lost, and consumed per person by utilizing Minitab Data Analysis. The Auto Regressive Integrated Moving Average (ARIMA) model is the one used by the Time-series modeler. The Mean square difference (MSD) is used to analyze the model's fits and variability. MAPE and MAD are used to determine the amount of forecast error. When a priori is not available, the ARIMA model is utilized since it does not need a priori forecasting models. ARIMA aids in the selection of the 'correct model' for a given time series. The data to be projected is fitted using an autoregressive model. It's also useful for data that's comparable to what was utilized in this study.

IV. RESULTS AND DISCUSSION

The data was analyzed using Minitab 16 version. The results and discussion are as follows

Table 1: Trend Analysis for Electricity generation - TWh

| Data | Electricity generation - TWh |
|--------------------------------|------------------------------|
| Length | 57 |
| Number Missing | 0 |
| Fitted Trend Equation | |
| $Y_t = 14.1989 + 0.384037 * t$ | |

From the trend analysis for electricity -TWh, it shows that the fitted trend equation is $Y_t = 14.1989 + 0.384037 * t$, indicating a linear upward trend in electricity generation over time. The slope coefficient (0.384037) represents an average annual increase of approximately 0.384 TWh.

Table 2: Accuracy Measures for Electricity Generation

| | |
|------|---------|
| MAPE | 21.4122 |
| MAD | 4.8601 |
| MSD | 34.1935 |

The Accuracy Measures show that the Mean Absolute Percentage Error (MAPE) is 21.4122, the Mean Absolute Deviation (MAD) is 4.8601 and the Mean Signed Difference (MSD) is 34.1935.

Table 3: Forecasts for Electricity Generation

| Period | Forecast |
|--------|----------|
| 2025 | 37.4522 |
| 2026 | 38.2516 |
| 2027 | 39.0511 |
| 2028 | 39.8505 |
| 2029 | 40.6500 |
| 2030 | 41.4494 |
| 2031 | 42.2488 |
| 2032 | 43.0483 |
| 2033 | 43.8477 |
| 2034 | 44.6472 |

For the period forecast, these forecasts suggest a continued upward trend in electricity generation

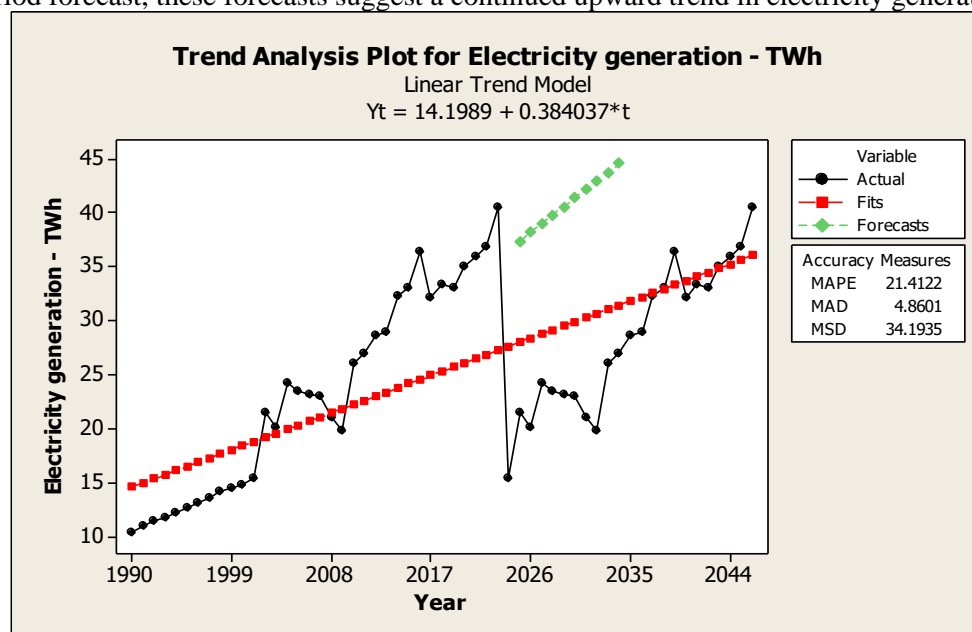


Figure 1: Trend Analysis Plot for Electricity generation – TWh

The figure above revealed that there is an upward trend in electricity generation in Nigeria between the years under study.

Table 4: Trend Analysis for Per capita electricity - kWh

| Data | Per capita electricity - kWh |
|-----------------------------------|------------------------------|
| Length | 57 |
| Number Missing | 0 |
| Fitted Trend Equation | |
| $Y_t = 109.934 + 1.36750 \cdot t$ | |

From the trend analysis for per capita electricity- KWh, it shows the fitted trend equation $Y_t = 109.934 + 1.36750 \cdot t$ indicates a linear upward trend in per capita electricity consumption over time. The slope

coefficient 1.36750 represents the rate of change of the trend per unit time, approximately 1.37 kWh per capita per year.

Table 5: Accuracy Measures

| | |
|------|---------|
| MAPE | 15.562 |
| MAD | 20.332 |
| MSD | 572.483 |

The Accuracy Measures show that the Mean Absolute Percentage Error (MAPE) is 15.562, the Mean Absolute Deviation (MAD) is 20.332 and the Mean Signed Difference (MSD) is 572.483.

Table 6: Forecasts

| Period | Forecast |
|--------|----------|
| 2025 | 191.261 |
| 2026 | 194.136 |
| 2027 | 197.011 |
| 2028 | 199.886 |
| 2029 | 202.761 |
| 2030 | 205.636 |
| 2031 | 208.511 |
| 2032 | 211.386 |
| 2033 | 214.261 |
| 2034 | 217.136 |

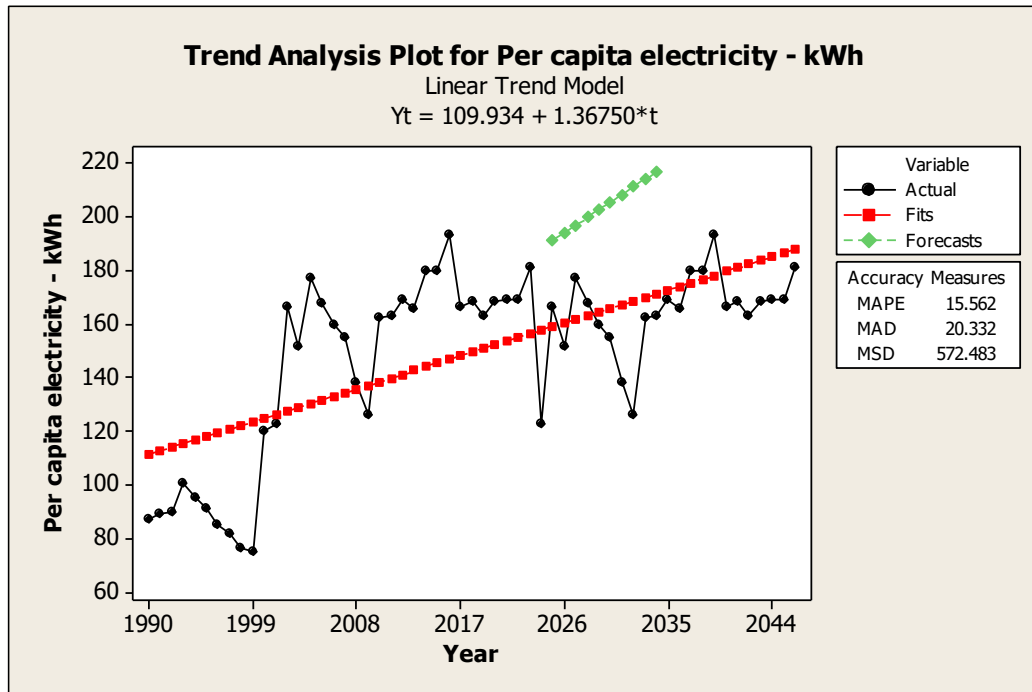


Figure 2: Trend Analysis Plot for Per capita electricity - kWh

The per capita electricity in figure 2 has an upward increase from 1999 until around 2006 when it experiences downward trend and thereafter began its undulating trend.

Table 7: Trend Analysis for GDP per capita

| Data | GDP per capita |
|-----------------------------------|----------------|
| Length | 57 |
| Number Missing | 0 |
| Fitted Trend Equation | |
| $Y_t = 3656.97 + 19.6026 \cdot t$ | |

From the trend analysis for GDP per capita, it shows the fitted trend equation $Y_t = 3656.97 + 19.6026 \cdot t$ indicates a linear upward trend in GDP per capita over time. The slope coefficient 19.6026 represents the rate of change of the trend per unit time, approximately \$19.60 per capita per year.

Table 8: Accuracy Measures

| | |
|------|---------|
| MAPE | 96 |
| MAD | 672 |
| MSD | 1060008 |

The Accuracy Measures show that the Mean Absolute Percentage Error (MAPE) is 96, the Mean Absolute Deviation (MAD) is 672 and the Mean Signed Difference (MSD) is 1060008.

Table 9: Forecasts

| Period | Forecast |
|--------|----------|
| 2025 | 4723.59 |
| 2026 | 4760.07 |
| 2027 | 4796.56 |
| 2028 | 4833.05 |
| 2029 | 4869.54 |
| 2030 | 4906.02 |
| 2031 | 4942.51 |
| 2032 | 4979.00 |
| 2033 | 5015.48 |
| 2034 | 5051.97 |

For the period forecast, these forecasts suggest a continued upward trend in GDP per capita.

Table 10: ARIMA Model: Electricity Generation - TWh

| Estimates at each iteration | | | | |
|-----------------------------|---------|------------|--------|-------|
| Iteration | SSE | Parameters | | |
| 0 | 956.536 | 0.100 | 0.100 | 0.576 |
| 1 | 866.851 | -0.049 | 0.250 | 0.519 |
| 2 | 865.125 | -0.149 | 0.171 | 0.600 |
| 3 | 863.787 | -0.232 | 0.087 | 0.647 |
| 4 | 862.276 | -0.319 | -0.006 | 0.694 |
| 5 | 860.958 | -0.401 | -0.096 | 0.739 |
| 6 | 860.229 | -0.463 | -0.166 | 0.773 |
| 7 | 860.002 | -0.497 | -0.206 | 0.792 |
| 8 | 859.959 | -0.512 | -0.224 | 0.801 |
| 9 | 859.953 | -0.518 | -0.230 | 0.804 |
| 10 | 859.953 | -0.520 | -0.232 | 0.805 |
| 11 | 859.953 | -0.520 | -0.233 | 0.805 |
| 12 | 859.953 | -0.520 | -0.234 | 0.805 |
| 13 | 859.953 | -0.520 | -0.234 | 0.805 |

Relative change in each estimate less than 0.0010

Hypothesis 1

Ho: The Model is Adequate

H1: The Model is not Adequate

Level of significance, $\alpha = 0.05$

Decision Rule: Reject Ho, if P-value $\leq \alpha$, otherwise do not reject

Computation

Table 11: Final Estimates of Parameters for hypothesis 1

| Type | Coef | SE Coef | T | P |
|----------|---------|---------|-------|-------|
| AR 1 | -0.5205 | 0.3612 | -1.44 | 0.156 |
| MA 1 | -0.2336 | 0.4116 | -0.57 | 0.573 |
| Constant | 0.8051 | 0.6641 | 1.21 | 0.231 |

Differencing: 1 regular difference
 Number of observations: Original series 57, after differencing 56
 Residuals: SS = 859.952 (backforecasts excluded)
 MS = 16.226 DF = 53

Table 12: Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

| Lag | 12 | 24 | 36 | 48 |
|------------|-------|-------|-------|-------|
| Chi-Square | 5.6 | 20.3 | 21.4 | 21.8 |
| DF | 9 | 21 | 33 | 45 |
| P-Value | 0.784 | 0.499 | 0.941 | 0.999 |

All of the p-values are greater than 0.05, which means that we fail to reject H_0 . In other words, we conclude that the model is adequate. The ARIMA MODEL (1,1,1) is therefore adequate and can be used for further future forecasting.

Table 13: ARIMA Model: Electricity Generation - TWh
 Estimates at each iteration

| Iteration | SSE | Parameters | | | | |
|-----------|---------|------------|-------|--------|-------|--|
| 0 | 987.044 | 0.100 | 0.100 | 0.100 | 0.576 | |
| 1 | 950.284 | 0.202 | 0.250 | 0.085 | 0.490 | |
| 2 | 929.298 | 0.323 | 0.400 | 0.062 | 0.406 | |
| 3 | 912.047 | 0.444 | 0.550 | 0.030 | 0.326 | |
| 4 | 896.313 | 0.560 | 0.700 | -0.013 | 0.251 | |
| 5 | 882.826 | 0.673 | 0.850 | -0.066 | 0.182 | |
| 6 | 871.934 | 0.792 | 1.000 | -0.122 | 0.112 | |
| 7 | 854.670 | 0.914 | 1.150 | -0.179 | 0.044 | |
| 8 | 834.336 | 0.873 | 1.175 | -0.183 | 0.064 | |
| 9 | 834.024 | 0.869 | 1.163 | -0.161 | 0.043 | |
| 10 | 829.625 | 0.853 | 1.160 | -0.156 | 0.050 | |
| 11 | 826.543 | 0.839 | 1.156 | -0.151 | 0.055 | |
| 12 | 819.476 | 0.821 | 1.130 | -0.105 | 0.062 | |
| 13 | 802.224 | 0.820 | 1.131 | -0.099 | 0.062 | |
| 14 | 788.333 | 0.823 | 1.131 | -0.090 | 0.062 | |
| 15 | 787.457 | 0.823 | 1.131 | -0.090 | 0.062 | |

Relative change in each estimate less than 0.0010

Hypothesis 2

H_0 : The Model is Adequate

H_1 : The Model is not Adequate

Level of significance, $\alpha = 0.05$

Decision Rule: Reject H_0 , if P-value $\leq \alpha$, otherwise do not reject

Computation

Table 14: Final Estimates of Parameters for Hypothesis 2

| Type | Coef | SE Coef | T | P |
|----------|---------|---------|--------|-------|
| AR 1 | 0.8229 | 0.0890 | 9.25 | 0.000 |
| MA 1 | 1.1312 | 0.0016 | 724.91 | 0.000 |
| MA 2 | -0.0897 | 0.0700 | -1.28 | 0.205 |
| Constant | 0.06173 | 0.01004 | 6.15 | 0.000 |

Differencing: 1 regular difference

Number of observations: Original series 57, after differencing 56

Residuals: SS = 779.929 (backforecasts excluded)

MS = 14.999 DF = 52

Table 15: Modified Box-Pierce (Ljung-Box) Chi-Square statistic

| Lag | 12 | 24 | 36 | 48 |
|------------|-------|-------|-------|-------|
| Chi-Square | 6.3 | 23.1 | 25.3 | 25.8 |
| DF | 8 | 20 | 32 | 44 |
| P-Value | 0.617 | 0.282 | 0.793 | 0.987 |

All of the p-values are greater than 0.05, which means that we fail to reject H_0 . In other words, we conclude that the model is adequate. The ARIMA MODEL (1,1,2) is therefore adequate and can be used for further future forecasting.

Table 16: ARIMA Model on Per Capita Electricity - kWh

Estimates at each iteration

| Iteration | SSE | Parameters | | | | |
|-----------|---------|------------|-------|--------|---------|--|
| 0 | 72995.3 | 0.100 | 0.100 | 0.100 | 134.722 | |
| 1 | 65261.6 | 0.250 | 0.203 | 0.083 | 112.293 | |
| 2 | 60458.2 | 0.400 | 0.324 | 0.078 | 89.845 | |
| 3 | 56413.8 | 0.550 | 0.449 | 0.082 | 67.390 | |
| 4 | 52856.6 | 0.700 | 0.577 | 0.096 | 44.929 | |
| 5 | 50081.9 | 0.850 | 0.710 | 0.119 | 22.465 | |
| 6 | 38156.9 | 0.968 | 0.663 | 0.269 | 4.779 | |
| 7 | 33814.6 | 0.965 | 0.513 | 0.402 | 5.307 | |
| 8 | 30585.7 | 0.909 | 0.363 | 0.433 | 13.148 | |
| 9 | 26313.0 | 0.815 | 0.285 | 0.283 | 26.846 | |
| 10 | 22756.4 | 0.740 | 0.200 | 0.133 | 37.765 | |
| 11 | 19722.8 | 0.696 | 0.131 | -0.017 | 44.321 | |
| 12 | 17215.3 | 0.687 | 0.085 | -0.167 | 45.806 | |
| 13 | 15348.4 | 0.727 | 0.067 | -0.317 | 40.334 | |
| 14 | 14707.1 | 0.814 | 0.079 | -0.367 | 27.708 | |
| 15 | 14654.5 | 0.843 | 0.093 | -0.343 | 23.205 | |
| 16 | 14643.8 | 0.854 | 0.108 | -0.340 | 21.489 | |
| 17 | 14640.9 | 0.860 | 0.114 | -0.335 | 20.610 | |
| 18 | 14640.1 | 0.863 | 0.118 | -0.333 | 20.155 | |
| 19 | 14639.9 | 0.864 | 0.120 | -0.331 | 19.908 | |
| 20 | 14639.9 | 0.865 | 0.121 | -0.331 | 19.773 | |

| | | | | | |
|----|---------|-------|-------|--------|--------|
| 21 | 14639.9 | 0.866 | 0.122 | -0.330 | 19.699 |
| 22 | 14639.9 | 0.866 | 0.122 | -0.330 | 19.658 |

Unable to reduce sum of squares any further

Hypothesis 3

Ho: The Model is Adequate

H1: The Model is not Adequate

Level of significance, $\alpha = 0.05$

Decision Rule: Reject Ho, if P-value $\leq \alpha$, otherwise do not reject

Computation

Table 17: Final Estimates of Parameters for hypothesis 3

| Type | Coef | SE Coef | T | P |
|----------|---------|---------|-------|-------|
| AR 1 | 0.8659 | 0.0866 | 10.00 | 0.000 |
| MA 1 | 0.1220 | 0.1406 | 0.87 | 0.389 |
| MA 2 | -0.3299 | 0.1373 | -2.40 | 0.020 |
| Constant | 19.658 | 2.616 | 7.51 | 0.000 |

Mean 146.65 19.52

Number of observations: 57

Residuals: SS = 14081.0 (backforecasts excluded)

MS = 265.7 DF = 53

Table 18: Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

| Lag | 12 | 24 | 36 | 48 |
|------------|-------|-------|-------|-------|
| Chi-Square | 7.4 | 26.5 | 34.4 | 38.8 |
| DF | 8 | 20 | 32 | 44 |
| P-Value | 0.497 | 0.150 | 0.354 | 0.695 |

All of the p-values are greater than 0.05, which means that we fail to reject Ho. In other words, we conclude that the model is adequate. The ARIMA MODEL (1, 0, 2) is therefore adequate and can be used for further future forecasting.

Table 19: ARIMA Model: GDP per Capita

Estimates at each iteration

| Iteration | SSE | Parameters |
|-----------|----------|----------------------|
| 0 | 55185786 | 0.100 0.100 -56.837 |
| 1 | 50325196 | -0.050 0.250 -37.052 |
| 2 | 49788981 | 0.026 0.400 -29.047 |
| 3 | 49616144 | -0.053 0.397 -28.006 |
| 4 | 49615687 | -0.055 0.399 -28.058 |
| 5 | 49615685 | -0.056 0.398 -28.098 |
| 6 | 49615685 | -0.056 0.398 -28.087 |
| 7 | 49615685 | -0.056 0.398 -28.089 |

Relative change in each estimate less than 0.0010

Hypothesis 4

Ho: The Model is Adequate

H1: The Model is not Adequate

Level of significance, $\alpha = 0.05$

Decision Rule: Reject Ho, if $P\text{-value} \leq \alpha$, otherwise do not reject

Computation

Table 20: Final Estimates of Parameters for Hypothesis 4

| Type | Coef | SE Coef | T | P |
|----------|---------|---------|-------|-------|
| AR 1 | -0.0561 | 0.4189 | -0.13 | 0.894 |
| MA 1 | 0.3982 | 0.3876 | 1.03 | 0.309 |
| Constant | -28.09 | 79.68 | -0.35 | 0.726 |

Differencing: 1 regular difference

Number of observations: Original series 57, after differencing 56

Residuals: SS = 49615276 (backforecasts excluded)

MS = 936137 DF = 53

Table 21: Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

| Lag | 12 | 24 | 36 | 48 |
|------------|-------|-------|-------|-------|
| Chi-Square | 1.9 | 31.9 | 33.4 | 36.1 |
| DF | 9 | 21 | 33 | 45 |
| P-Value | 0.993 | 0.060 | 0.446 | 0.825 |

All of the p-values are greater than 0.05, which means that we fail to reject Ho. In other words, we conclude that the model is adequate. The ARIMA MODEL (1, 1, 1) is therefore adequate and can be used for further future forecasting.

The time series analysis of Nigeria's electricity shows that the ARIMA model

Fitted Trend Equations are: $Y_t = 14.1989 + 0.384037*t$, $Y_t = 109.934 + 1.36750*t$, $Y_t = 3656.97 + 19.6026*t$

The trend equations suggest that a linear upward trend in electricity generation, linear upward trend in per capita electricity consumption and also a linear upward trend in GDP per capita over time and is in harmony with the plots.

V. CONCLUSION

This study carried out time series analysis on Nigeria's electricity data. ARIMA models were fitted and trend analysis shows increase by 0.38 TWh, 1.36 KWh and 19.6 annually. ARIMA models were developed, these are ARIMA (1,1,1), ARIMA (1,1,2), and ARIMA (1,0,2). The test showed that all the models are adequate at 5% level of significance. The ARIMA model was used to generate forecast for the year 2025 through 2034 which could be used for future planning purpose. Therefore, ARIMA model is recommended for electricity generation and consumption in Nigeria. Therefore, it is recommended that the government and private sector collaborate to develop strategies for sustainable electricity generation and distribution, with a focus on renewable energy sources, to ensure a stable and efficient energy supply that supports economic growth and development in Nigeria. This framework should include the following key components:

- Establish partnerships with international organizations and financial institutions to secure funding for large-scale renewable energy projects.
- Develop community-based financing schemes to encourage grassroots adoption of renewable energy, particularly in rural areas.
- Invest in research and development for affordable and efficient renewable energy technologies tailored to Nigeria's unique environment (e.g., solar and wind power).
- Build technical capacity through training programs for engineers, technicians, and policymakers to ensure the proper implementation and maintenance of renewable energy systems.
- Leverage smart grid technologies to integrate renewable energy sources with existing infrastructure, ensuring efficient energy distribution and reducing waste.
- Upgrade existing transmission and distribution networks to accommodate renewable energy sources, minimizing transmission losses and ensuring grid stability.
- Establish dedicated renewable energy zones in areas with high solar and wind potential, such as northern Nigeria for solar farms and coastal areas for wind turbines.
- Develop clear and consistent policies to support renewable energy adoption, including setting renewable energy targets and timelines.
- Streamline regulatory procedures to attract private sector investment and reduce bureaucratic bottlenecks.

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