Modelling Liquified Petroleum Gas Prices in Nigeria Using Machine Learning Models

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ABSTRACT

The usage of Liquefied Petroleum Gas in households has been to increase in recent years. The energy used by households has proved difficult to forecast due to the nature of the independent variables. In recent years, deep learning models has been broadly utilized in the machine learning area to model time series data. Most noticeable is in the field of forecasting. In this work, Neural Network Autoregressive model (NNETAR), Naive forecasting and the Autoregressive Integrated Moving Average (ARIMA) models were used to model the price of Liquefied Petroleum Gas prices(LPG) of 37 states (including the FCT) in Nigeria, with input variables in the form of the price of refilling LPG for 12.5 kg from January 2016 to April 2019 covering a 1480 data points. The Mean Absolute Percentage Errors was used to measure the performance of the model. The result shows that Naive produced lower MAPE for more states compare to NNETAR and ARIMA models.

1. Introduction

A measurement for the country a few years prior showed that a simple 5% of the utilization possibilities of liquefied petroleum gas (LPG) were achieved. It is thusly obvious that we have quite far to soak the Nigeria LPG Market if it somehow happened to be completely evolved since, supposing that a homegrown buyer makes certain of getting kerosene to liquefied petroleum gas (LPG) when and where he wants it at the right value, he would most enthusiastically change over from kindling, coal or kerosene to liquefied petroleum gas (LPG).

Following the exceptional interest for condensed liquefied petroleum gas (LPG) in Nigeria and chaperon shortage of the item which has brought about sharp and subjective cost expands, the conveyance of gas items has been liberated. Subsequently, this has opened up a lot of chances in the business and one of such open doors is the development of liquefied petroleum gas (LPG) cylinders in Nigeria.

Yaya *et.al.* (2015) studied the relationship between natural gas prices and consumer prices, how and it may provide us with better indicators for analyzing economic activity. The analysis of natural gas spot prices using fractional integration techniques in the setting of non-linear deterministic trends is the subject of this research. The daily and monthly series, as well as their logarithmic conversions, show non-stationarity with mean reverting coefficients. Only the monthly series shows evidence of non-linearity, which could be due to the increased degree of volatility associated with this frequency.

Olubusoye O.E and Yaya O.S (2016), in order to analyze the volatility persistence in crude oil and petroleum products prices, researchers used both fractional persistence and volatility modeling frameworks. They were given the option of using symmetric, asymmetric, or jumps volatility models. When compared to the volatility series of other petroleum products, the results showed that crude oil and gasoline prices were less stable.

In predicting the volatility of crude oil, heating oil, and diesel prices, the newly proposed jump volatility model variants beat other current volatility models. The exception was the Asymmetric Power ARCH (APARCH) model, which was found to be the most accurate in predicting gasoline, kerosene, and propane prices; nevertheless, GAS versions were still placed second and third in predicting gasoline and kerosene price volatility. Using an incorrectly stated model to predict the outcome of volatility in petroleum pricing can misinform oil markets, thereby generating intense conditional oil market volatility that is capable of distorting the price of oil and macroeconomic stability of the entire globe.

Tei *et.al.* (2016), Energy prices, income, urbanization, and economic structure are significant demand drivers of the different energy types in Ghana, with varying estimated elasticity, according to disaggregated analysis in estimating energy demand in Ghana, which used key disaggregated energy components such as gasoline, diesel, liquefied petroleum gas (LPG), kerosene, biomass, residual fuel oil (RFO), and electricity. It also demonstrated a significant level of inter-fuel substitution in Ghana's energy demand, especially from gasoline, diesel, and kerosene to LPG.

Gould and Urpelain (2018), understanding the incorporation of a clean cooking fuel into rural families' energy mixes using the 2014–2015 Access survey with over 8500 households from six energy-poor Indian states.

The findings of a large survey of LPG use in rural India, conducted using a descriptive analysis approach, found that LPG fuel cost is a major barrier to widespread adoption, and that both users and non-users of LPG have extremely favourable views of it as a convenient and clean cooking fuel. The research also revealed that increasing LPG use in rural India has significant potential, but that affordability precludes a complete switch from conventional biomass to clean cooking fuels.

Afimia, (2019) on estimating natural gas demand elasticity in Nigeria, the study used the bound testing approach to co-integration within the framework of ARDL to estimate annual time series data over a 33-year period (1984–2016) with the goal of investigating the responsiveness of natural gas demand to changes in natural gas price, income, and prices of other energy products.

The findings indicate that domestic gas price, AGO price, international LNG price, and electricity consumption per capita are major predictors of Nigeria's natural gas demand, and that natural gas demand elasticity in Nigeria is relatively price inelastic.

As a result, a decrease in natural gas prices will result in an increase in natural gas demand by less than the percentage fall in price and vice versa, *ceteris paribus,* which concludes that natural gas price is a major determinant of the quantity demanded of natural gas in Nigeria.

The deep learning models have been applied in addressing various managerial problems like sales forecasting, price elasticity modeling, brand analysis, new product acceptance research, and market segmentation and more (Hakimpoor et al., 2011). Tayo et al. (2021), emphasised the importance of using ANN models in predictions.

The purpose of this study is to apply machine learning models to predict the price of 12.5kg of LPG refilling in Nigerian states. This paper is section as below: Section 2 explains the materials and methods, sections 3 and 4, the results and the conclusion respectively.

2. Materials and Methods

2.1 Study Area and Data

Nigeria, a country in West Africa is the largest country in Africa. It has distinguished demographic characteristics in Sub-Saharan Africa and shares a border in the North with Niger, at North East Chad, at East Cameroon and also Benin in the west region. Nigeria at 9.0820º N, 8.6753 º E is a tropical region at the extreme inner corner side of Guinea which is on the west coast of Africa, which has an area of 923,768 square km and a coastline of 85km. the country is 1,045 km long and 1,126 km wide. Nigeria comprises 36 states and the country capital Abuja which has the Federal Capital Territory. Nigeria is divided into six geopolitical zones. Nigeria has various ethnic groups and different cultures across the states and geopolitical zones.

Figure 1. Map of Nigeria showing the states

Monthly panel data of 12.5kg of LPG prices for 36 states and Abuja in Nigeria are considered. These series span from January 2016 to April 2019 covering a 1558 data points. The data were sourced from the Nigeria Data Portal. The states were divided into: North Central which include Benue, Niger, Kogi, Kwara, Plateau, Nassarawa, and FCT. North West which include Jigawa, Kano, Katsina, Kaduna, Kebbi, Zamfara, and Sokoto states. North East which include Gombe, Bauchi, Yobe, Benue, Adamawa, Taraba states. South-South which include Akwa-Ibom, Cross Rivers, Bayelsa, Rivers, Delta and Edo. South East which include Abia, Imo, Ebonyi, and Anambra states and South West which include Ekiti, Ondo, Osun, Oyo, Ogun and, Lagos.

2.2 Neural Network Autoregressive model (NNETAR)

The "nnetar" function in the package "caret" (R environment), is used to identify NNAR models.We can write NNAR models as NNAR (p,k) for non-seasonal data, where p represents the number of non-seasonal lags used as inputs and k denotes the number of nodes/neurons in the hidden layer. The NNAR (p,k) process is similar to the AR process but with nonlinear functions. The AICc metric is used to determine the ideal number of non-seasonal delays, and the optimal number of neurons is determined by calculating (p+P+1)/2, where p is the nonseasonal AR order and P is the seasonal AR order (if any). Finally, the MAE, MAPE, MASE, and RMSE metrics are used to assess the goodness of fit.

2.3 Naive Forecasting Model

One of the most basic predicting approaches is naive. The one-step-ahead forecast is equal to the most recent actual value, according to each:

$$\hat{y}_t = y_{t-1} \tag{1}$$

The "Random Walk" statistical model that underpins Naive is written as:

$$y_t = y_{t-1} + \varepsilon_t \tag{2}$$

y_t is the price of the refilling LPG of the current year while y_{t-1} represent the prices of the 12.5kg refilling LPG for the previous year and e_i represents random error which is assumed to be stochastic.

2.4 ARIMA model

ARIMA models are recognized using the "auto.arima" function, which was developed by Hyndman and Khandakar (2008) and is included in the package "forecast" (in R environment). The number of p parameters of the autoregressive process (AR), the order I of differencing (I), and the number of q parameters of the moving average process are all used in this function to find the best ARIMA models (MA). It incorporates unit root tests as well as the reduction of the bias corrected Akaike's information criterion (AICc) and maximum likelihood estimation methods (MLE). The unit root tests can be used to determine the order of differencing, while the AICc and MLE methods can be used to determine the AR and MA processes' optimal parameters.

2.5 Model Performance Measures

Assessing ANN performance of these models, conventional measurements like mean absolute percentage error (MAPE) was used to examine the performance of these model. In this study, to assess the performances of all models, the goodness of fit measure namely mean absolute percentage error was utilized.

Mean Absolute Percentage Error is a measure of how accurate a forecast is. It measures accuracy as a percentage.

$$\text{Mean Absolute Percentage Error} = \left| \frac{1}{y_T} \sum_{i=1}^{n} (y_T - y_P) \right| \tag{3}$$

Where y_T = actual price and y_P is the predicted price.

3. Results and Discussion

This presents the analysis of the modelling of the price of 12.5kg refilling LPG in Nigeria. The data obtained from the Nigeria Data Portal span from January 2016 to April 2019. The zones in Nigeria considered are North East North Central, North West, South South, South East and South West.

3.1 Descriptive Statistics

The summary of the data are displayed below in terms of the Minimum (Min), maximum (Max), mean, standard deviation (S.D) and median (Med) values of the 12.5kg refilling prices of LPG in Nigerian states. Tables 1 to 6 shows the descriptive statistics of price of 12.5kg of refilling LPG for North East, North Central, North West, South South, South East and South West respectively.

Table 1. Descriptive Statistics of the 12.5kg refilling prices of LPG for North East

NORTH EAST				
STATE	MIN	MAX	MEAN± SD	MED
GOMBE	*1700*	*2650*	*2145.293 ± 2854078*	*2136.76*
BAUCHI	*1850*	*2550*	*2253.650 ± 238.1346*	*2308.175*
YOBE	*1843.8*	*2700*	*2243.021 ± 246.2442*	*2300.997*
ADAMAWA	*1720*	*2700*	*2126.879 ± 267.6890*	*2108.333*
TARABA	*1850*	*2580*	*2163.504 ± 201.5800*	*2151.5*
BORNO	*1800*	*2825*	*2287.875 ± 252.6571*	*2362.5*

Table 2. Descriptive Statistics of the 12.5kg refilling prices of LPG for North Central

NORTH CENTRAL				
STATE	*MIN*	*MAX*	*MEAN± SD*	*MED*
BENUE	*1800*	*2740*	*2183.289 ± 238.1493*	*2200*
NIGER	*1800*	*2800*	*2102.836 ± 228.0681*	*2007.143*
KOGI	*1803.13*	*2650*	*2071.667 ± 226.8594*	*2000*
KWARA	*1816.67*	*2800*	*2090.430 ± 246.1266*	*2000*
PLATEAU	*1800*	*2820*	*2110.039 ± 229.2054*	*2084.444*
NASSARAWA	*1814.88*	*2860*	*2105.772 ± 241.8497*	*2077.451*
FCT	*1730*	*2800*	*2003.056 ± 271.2168*	*1900*

Table 3. Descriptive Statistics of the 12.5kg refilling prices of LPG for North West

NORTH WEST				
STATE	MIN	MAX	MEAN± SD	MED
JIGAWA	*1775*	*2500*	*2060.193±206.8024*	*1977.017*
KANO	*1750*	*2750*	*2097.443±229.4912*	*2070.833*
KATSINA	*1757.143*	*2572.222*	*2089.130±219.8488*	*2023.185*
KADUNA	*1687.5*	*2566.667*	*2006.436±248.6832*	*1933.333*
KEBBI	*1850*	*3000*	*2130.074±237.3954*	*2050.165*
ZAMFARA	*1700*	*3000*	*2113.924±268.4952*	*2038.75*
SOKOTO	*1800*	*2575*	*2058.047±195.5089*	*2000.447*

Table 4. Descriptive Statistics of the 12.5kg refilling prices of LPG for South-South

SOUTH-SOUTH				
STATE	MIN	MAX	MEAN± SD	MED
AKWA-IBOM	*1705.65*	*3000*	*2167.797 ± 253.1529*	*2181.335*
CROSS RIVERS	*1800*	*3000*	*2156.812 ± 260.7478*	*2122.917*
BAYELSA	*1800*	*3000*	*2131.340 ± 250.5978*	*2061.111*
RIVERS	*1800*	*3000*	*2157.388 ± 260.9368*	*2121.023*
DELTA	*1771.429*	*2984.615*	*2121.364 ± 277.2808*	*2094.712*
EDO	*1700*	*3030.769*	*2092.955 ± 285.1201*	*2072.5*

Table 5. Descriptive Statistics of the 12.5kg refilling prices of LPG for North Central

SOUTH EAST				
STATE	MIN	MAX	MEAN± SD	MED
ABIA	1657.14	3000	*2089.043 ± 276.9539*	*2112.5*
IMO	*1750*	*2700*	*2084.864 ± 246.2536*	*1998.875*
EBONYI	*1690*	*2880.34*	*2033.262 ± 292.4602*	*1913.333*
ANAMBRA	*1666.67*	*2800*	*2218.837 ± 250.7015*	*2245.113*
ENUGU	*1672.222*	*2944.444*	*2047.211 ± 302.4435*	*2000*

Table 6. Descriptive Statistics of the 12.5kg refilling prices of LPG for South West

SOUTH WEST				
STATE	MIN	MAX	MEAN± SD	MED
EKITI	*1745.455*	*2580*	*2008.860 ± 221.1862*	*1956.667*
ONDO	*1731.25*	*2600*	*2091.869 ± 192.0355*	*2093.18*
OSUN	*1703.571*	*2616.66*	*2091.675 ± 220.5871*	*2045.536*
OYO	*1753.684*	*2700*	*2067.757 ± 254.3063*	*2000*
OGUN	*1700*	*2555.556*	*2063.711 ± 231.9369*	*2058.723*
LAGOS	*1813.89*	*2650*	*2066.9430 ± 224.896*	*1977.273*

Table 1 shows that the descriptive statistics for the North East. It shows that Gombe has mean and standard deviation of 2145.293 and 2854078, Bauchi has 2253.650 and 238.1346, Yobe has 2243.021 and 246.2442, Adamawa has 2126.879 and 267.6890, Taraba has 2163.504 and 201.5800 and Borno has 2287.875 and 252.6571 respectively. We could see that on the average, Adamawa has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the North East with price of 2126.879 naira. Table 2 shows that the descriptive statistics for the North Central. It shows that Benue has mean and standard deviation of 2183.289 and 238.1493, Niger has 2102.836 and 228.0681, Kogi has 2071.667 and 226.8594, Kwara has 2090.430 and 246.1266, Plateau has 2110.039 and 229.2054, Nasarawa has 2105.772 and 241.8497 and FCT has 2003.056 and 271.2168 respectively. We could see that on the average, FCT has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the North Central with price of 2003.056 naira. Table 3 shows that the descriptive statistics for the North West. It shows that Jigawa has mean and standard deviation of 2060.193 and 206.8024, Kano has 2097.443 and229.4912, Kastina has 2089.130 and 219.8488, Kaduna has 2006.436 and 248.6832, Kebbi has 2130.074 and 237.3954, Zamfara has 2113.924 and 268.4952 and Sokoto has 2058.047 and 195.5089 respectively. We could see that on the average, Kaduna has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the North West with price of 2006.436 naira. Table 4 shows that the descriptive statistics for the South South. It shows that Akwa-Ibom has mean and standard deviation of 2167.797 and 253.1529, Cross Rivers has 2156.812 and 260.7478, Bayelsa has 2131.340 and 250.5978, Rivers has 2157.388 and 260.9368, Delta has 2121.364 and 277.2808 and Edo has 2092.955 and 285.1201 respectively. We could see that on the average, Edo has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the South South with price of 2092.955 naira. Table 5 shows that the descriptive statistics for the South East. It shows that Abia has mean and standard deviation of 2089.043 and 276.9539, Imo has 2084.864 and 246.2536, Ebonyi has 2033.262 and 292.4602, Anambra has 2218.837 and 250.7015 and Enugu has 2047.211 and 302.4435 respectively. We could see that on the average, Ebonyi has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the South East with price of 2033.262 naira. Table 6 shows that the descriptive statistics for the South West. It shows that Ekiti has mean and standard deviation of 2008.860 and 221.1862, Ondo has 2091.869 and 192.0355, Osun has 2091.675 and 220.5871, Oyo has 2067.757 and 254.3063, Ogun has 2063.711 and 231.9369 and Lagos has 2066.9430 and 224.896 respectively. We could see that on the average, Ekiti has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the South west with price of 2008.860 naira.

3.2 Forecast measures for the models

Table 7 below shows the mean absolute percentage error results for the models used for the price of 12.5kg of refilling LPG in 37 states of Nigeria. The coloured values marked in the tables are the least MAPE values produced for each state. From the result, NNETAR and ARIMA best predict the price of 12.5kg refilling LGP for 12 and 11 states respectively while Naive predicts for 14 states.

Table 7. Forecast measures for the models using MAPE

State	ARIMA	Naive	NNETAR
Abia	0.3984873	0.3984873	0.01242292
Abuja	0.03152774	0.19276	0.06222852
Adamawa	0.3244903	0.5741522	0.07843926
Akwa Ibom	0.3229858	0.2305255	0.2296724
Anambra	0.2659146	0.4064739	0.6248645
Bauchi	1.354522	1.854664	1.522133
Bayelsa	0.3770372	0.5410757	0.4711242
Benue	0.4946475	0.3919953	0.6060867
Borno	0.2224315	0.04651095	0.05739366
Cross River	0.4342346	0.8379205	0.4317453
Delta	0.07834129	0.3710712	0.1998949
Ebonyi	0.2359589	0.001648152	0.1553445
Edo	0.3989752	0.1298232	0.3851524
Ekiti	0.2927878	0.07778386	0.3971776
Enugu	0.3138865	0.04509449	0.1952926
Gombe	0.3227813	0.5397284	0.04946849
Imo	0.1506556	0.2236358	0.4041998
Jigawa	0.2972069	0.4076087	0.3352684
Kaduna	0.5438156	0.5438156	0.3424322
Kano	0.01648947	0.4983143	0.2404467
Katsina	0.1323356	0.1504144	0.00542202
Kebbi	0.1680548	0.1173754	0.1493791
Kogi	0.1878467	0.134234	0.4363876
Kwara	0.5020068	0.2578385	0.7497674
Lagos	0.1273739	0.02536944	0.4018972
Nasarawa	0.2845860	0.2845861	0.04729451
Niger	0.05939995	0.4034468	0.4690108
Ogun	0.1354385	0.2713824	0.001506067
Ondo	0.4401882	0.3995298	0.1362453
Osun	0.1412026	0.2214668	0.08729425
Oyo	0.2024877	0.1955366	0.7445525
Plateau	0.03584741	0.2297746	0.005409473

Rivers	0.09964443	0.07063571	0.1906414
Sokoto	0.3687059	0.2089954	0.4322136
Taraba	0.1562326	0.07520401	0.2184252
Yobe	0.3877903	0.3638269	0.5743241
Zamfara	0.7021517	0.8626734	0.8146726

4. Conclusion

In this work, we have been able to model the price of 12.5kg of refilling LPG for 37 states in Nigeria for the data span from January 2016 to April 2019. The Artificial Neural Network model has been used because of its ability to capture both the linearity and the non-linearity part of the data. From the results, we could deduce that Adamawa has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the North East with price of 2126.879 naira, FCT has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the North Central with price of 2003.056 naira, Kaduna has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the North West with price of 2006.436 naira, Edo has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the South South with price of 2092.955 naira, Ebonyi has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the South East with price of 2033.262 naira and Ekiti has the lowest price of 12.5kg refilling LPG from January 2016 to April 2019 in the South west with price of 2008.860 naira.

Reference to the result of the mean absolute percentage error, the Naive models produced lower MAPE values for most states compare to Neural network Autoregressive (NNETAR) model and Autoregressive Integrated Moving Average(ARIMA) model. This implies that Naive model can give a worthy prediction of the price of 12.5Kg refilling LPG for most states in Nigeria.

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