PREDICTING PETROLEUM CONSUMPTION USING TRIGONOMETRIC REGRESSION MODEL

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ABSTRACT

This study is used to model and forecast Nigerian motor gasoline consumption using the Trigonometric Regression model which has the capabilities of handling nonlinear time series. The time plot of Nigerian motor gasoline consumption showed the series is nonlinear. The Trigonometric regression model was estimated using the Ordinary Least Square method. From the result, the coefficients of the model influenced Nigerian motor gasoline consumption and a unit increase may lead to an increase or decrease. The values of coefficient of determination (R^2) revealed that the coefficients of the model explained the variations in Nigerian motor gasoline consumption up to 83%. The value of the adjusted coefficient of determination ($\bar{R}^2$) also revealed that the model is a good fit and has high predictive power. Therefore, the Nigerian motor gasoline consumption forecast from 1980 to 2038 indicated continuous fluctuations from year to year. The shape of the out-sample forecast from 2019 to 2038 exhibited a bell shape. Conclusively, based on the results obtained, the proposed model can be used to obtain future values for Nigerian motor gasoline consumption. This will enhance the Government and shareholders to put in place proper plans and logistics to curtail the challenges that may arise from Nigerian motor gasoline consumption and distribution presently and in the future.

Keywords: Energy and Oil Consumption; Prediction Accuracy; Regression; Forecasting, Time Series

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INTRODUCTION

Availability and access to modern energy is a prerequisite for human development (TWB, 2018). Energy is needed for individual survival, it is important for the provision of social services such as education and health and a critical input into all economic sectors from household production, farming and industry (Gaye, 2013; Castán and Kirshner, 2020). Energy in various forms is used to galvanize the social and economic activities which determine the standard of living of a particular country (IEA, 2006). In Nigeria, motor gasoline, jet fuel, Kerosene and Liquefied gas consumption are primary energy used to enhance and drive Nigerian socio-economic activities (Odularu and Okonkwo, 2009; Chukwu *et al.,* 2015). Their consumptions are erratic and have risen sharply in recent past years (ECN, 2010). The high-level consumption and continuous price rise may cause scarcity but despite this, the demand for energy consumption continues to rise in Nigeria (Oyedepo, 2012; Abam *et al.,* 2014). This is so because all other means of accessing power for industrial and domestic uses in Nigeria is moribund (Aliyu *et al.,* 2013). This put more pressure on the distribution chain of energy products where logistics and corruption is a big challenge (Sayne *et al.,* 2015). The situation mentioned above is prevalent in Nigeria and this is triggered by a lack of an appropriate prediction model to proffer predictions for the future consumption of energy products based on the past observations made on the consumption of energy products (Oyedepo, 2012; Dioha and Emodi, 2019).
Several kinds of research in the recent past have proposed models for modelling and forecasting energy products. This includes the work of Jaja (2010) who analysed recent trends and spatial patterns of gasoline consumption concerning economic growth in Nigeria using multiple regression analysis. From the results of the study, the spatial variation in gasoline consumption is related to the number of gasoline-using vehicles newly registered and per capita income in various states. Chukwu *et al.,* (2015) used descriptive statistics and trend analysis to analyze the

consumption of petroleum products in Nigeria. Their results indicated that consumption of petroleum products grew at an average annual rate of about 18.63% during the period 1970-1979, by about 6.32% during the period 1980-1989. A decline in consumption averaging about 0.97% per annum was recorded during the period 1990-1999, the period of 2000-2014 was characterized by rebounded petroleum product consumption with an average growth rate of about 7.7% per annum. Folorunso *et al.,* (2018) used their research to focus on predicting the consumption of Petroleum in Thousands of Barrels per year in Nigeria. They used Autoregressive integrated moving average (ARIMA), Linear Regression (LR) and Random Forest Regression (RFR) models to fit consumption of Petroleum from 1980 to 2017. The result they obtained revealed that LR and RFR outperformed the ARIMA model with lower values of prediction accuracy in terms of MAE, MAPE and RMSE.

Based on the discussion above, most of the researches on energy consumption has not been used to obtain out-sample predicted values. Even the few researchers that have worked on this subject matter usually use regression analysis. This model may not be suitable since the energy consumption dataset is nonlinear. Therefore, this study will be used to model and predict Nigerian motor gasoline consumption (NMGC) in Thousands of Barrels per year using a Trigonometric regression model. This model is considered since it is capable of handling a time series dataset that is nonlinear. In essence, the performance of traditional regression and trigonometric regression models will be compared based on the forecast evaluation metrics considered in this study.

MATERIALS AND METHOD

Trigonometric regression model

Let a simple deterministic model be defined

$$y = \rho \cos(\omega t - \theta) \qquad (1)$$

where ρ is the amplitude, ω is the frequency and θ is the phase.

By using the compound angle formula

$$\cos(A - B) = cosAcosB + sinAsinB$$

and when further simplified, equation 1 can be given as

$$y = \rho \cos\theta cos(\omega t) + \rho \sin sin(\omega t)$$

$$y = \alpha \cos(\omega t) + \beta \sin(\omega t) \qquad (2)$$

where $\alpha = \rho cos\theta$, $\beta = \rho sin\theta$ and $\alpha^2 + \beta^2 = \rho^2$.

Concerning equation 2, the trigonometric regression model can be of the form

$$y_t = \alpha_0 + \delta \sum_{j=1}^{m} \left(\alpha_j \cos(\omega t_j) + \beta_j \sin(\omega t_j)\right) + \varepsilon_t, \quad j = 1, \dots, m \qquad (3)$$

where $\cos(\omega_j t)$ and $\sin(\omega_j t)$ are the trigonometric function predictors, $\omega = \frac{2\pi k}{n}$, y_t is the dependent variable, α_j and β_j are the trigonometric coefficients, δ is the number of frequency components to be included and $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$ is the uncorrelated error term.

Ordinary least square estimation method

The trigonometric function coefficient will be obtained using the least square estimation method. This will be obtained by minimising the residual error of the model. Based on equation 4, the residual sum of square can be expressed as

$$\Sigma(\varepsilon_t)^2 = \Sigma(y_t - \alpha_0 - \alpha_j \cos(\omega t_j) - \beta_j \sin(\omega t_j))^2 \qquad (4)$$

Differentiating Equation 4 with respect to α_0, α_j and β_j gives

$$\left.\begin{aligned} \Sigma y_t &= n\alpha_0 + \alpha_j \Sigma\cos(\omega t_j) + \beta_j \Sigma \sin(\omega t_j) \\ \Sigma(cos(\omega t_j) y_t) &= \beta_0 \Sigma(cos(\omega t_j)) + \alpha_j \Sigma(cos^2 \omega t_j) + \beta_j\, \Sigma(\cos(\omega t_j)\sin(\omega t_j)) \\ \Sigma((\sin\omega t_t) y_t) &= \beta_0 \Sigma(\sin\omega t_j) + \alpha_j \Sigma(\cos(\omega t_j)\sin(\omega t_j)) + \beta_j\, \Sigma(sin^2(\omega t_j)) \end{aligned}\right\} \qquad (5)$$

Transforming (5) into matrix form gives

$$\begin{pmatrix} \sum(y_t) \\ \sum(\cos(\omega t_j) y_t) \\ \sum(\sin(\omega t_j) y_t) \end{pmatrix} = \begin{pmatrix} n & \sum(\cos(\omega t_j)) & \sum(\sin(\omega t_j)) \\ \sum(\cos(\omega t_j)) & \sum(\cos^2(\omega t_j)) & \sum(\cos(\omega t_j)\sin(\omega t_j)) \\ \sum(\sin(\omega t_j)) & \sum(\cos(\omega t_j)\sin(\omega t_j)) & \sum(\sin^2(\omega t_j)) \end{pmatrix} \begin{pmatrix} \alpha_0 \\ \alpha_j \\ \beta_j \end{pmatrix} \qquad (6)$$

Equation 5 can be further written as

$$\begin{pmatrix} \alpha_0 \\ \alpha_j \\ \beta_j \end{pmatrix} = \begin{pmatrix} n & \sum(\cos(\omega t_j)) & \sum(\sin(\omega t_j)) \\ \sum(\cos(\omega t_j)) & \sum(\cos^2(\omega t_j)) & \sum(\cos(\omega t_j)\sin(\omega t_j)) \\ \sum(\sin(\omega t_j)) & \sum(\cos(\omega t_j)\sin(\omega t_j)) & \sum(\sin^2(\omega t_j)) \end{pmatrix}^{-1} \begin{pmatrix} \sum(y_t) \\ \sum(\cos(\omega t_j) y_t) \\ \sum(\sin(\omega t_j) y_t) \end{pmatrix} \qquad (7)$$

where α_0, α_j and β_j are the estimated trigonometric coefficients.

Coefficient of determination and adjusted coefficient of determination

The Coefficient of determination given in equation 8 will be used to measure the level of variation in the dependent variable explained by the independent variables where SSE is the sum of square of error and SST is the sum of sum of total. While the adjusted coefficient of determination given in equation (9) will be used to determine maybe the model has a good fit and has high predictive power where n is the of observation and k is the number of coefficients.

$$R^2 = 1 - \frac{SSE}{SST} \quad (8)$$

$$\bar{R}^2 = \frac{1}{n-k}[nR^2 - k] \quad (9)$$

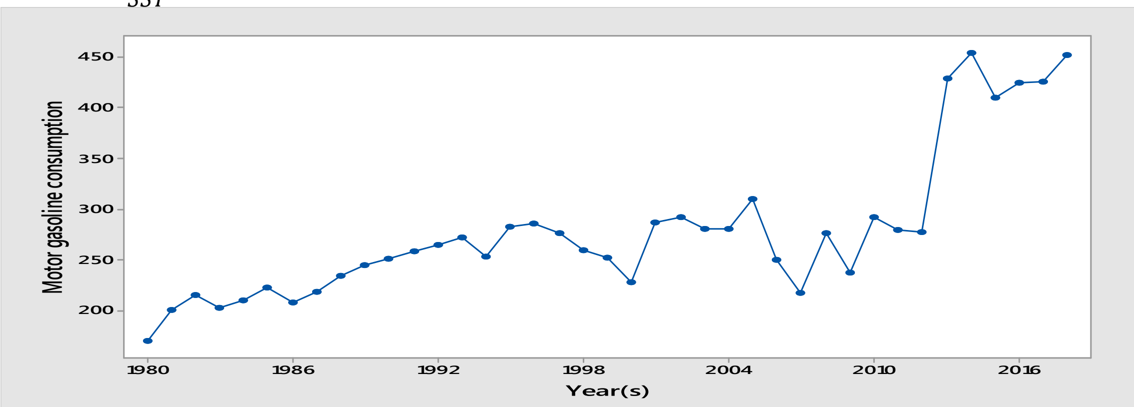

Figure 1. Nigerian motor gasoline consumption from 1980 to 2018

Forecasting with Trigonometric Regression model

The predicted values for Nigerian motor gasoline consumption will be obtained from the fitted trigonometric model. The predicting model will be expressed as

$$\hat{y}_{t+h} = \hat{\alpha}_0 + \hat{\alpha}_j\, \delta\cos(\omega t_{j+h}) + \hat{\beta}_j\, \delta\sin(\omega t_{j+h}) \quad h = m+1, m+2+\ldots \quad (10)$$

where $\hat{y}_{t+h}$ is the one step ahead predicted values, $\hat{\alpha}_0, \hat{\alpha}_j$ and $\hat{\beta}_j$ are the estimated trigonometric coefficient, h is the one step ahead prediction point and $\cos(\omega t_{j+h})$ and $\sin(\omega t_{j+h})$ are the trigonometric predictors.

Error term performance based on Durbin-Watson statistic

If ε_t is the residual associated with the observation at time t, then the test statistic is

$$d = \frac{\sum_{t=2}^{T}(\varepsilon_t - \varepsilon_{t-1})^2}{\sum_{t=1}^{T}\varepsilon_t^2} \quad (11)$$

where *T* is the number of observations. Note that if the sample is lengthy, then this can be linearly mapped to the Pearson correlation of the time-series data with its lags.

RESULTS AND DISCUSSION

This research work is used to model and forecast Nigerian motor gasoline consumption in Thousands of Barrels. The motor gasoline consumption data is yearly and span from 1980 to 2018. The dataset is obtained from http://nigeria.opendataforafrica.org/ovfhfrg/total-petroleum-consumption-1980-2018. The time plot of the Nigerian motor gasoline consumption is exhibited in Figure 1. This indicated that the series is nonlinear and this signified the use of trigonometric regression which can handle the nonlinearity present in Nigerian motor gasoline consumption (NMgc). The nonlinear nature can be attributed to logistic challenges, corruption and natural occurrences.

The trigonometric regression model used to analyze Nigerian motor gasoline consumption is given as

$$y_t = \alpha_0 + \alpha_1 \cos(\omega t_j) + \beta_1 \sin(\omega t_j) + \varepsilon_t, \quad j = 1, \ldots, m \quad (12)$$

where $\omega = \frac{2\pi}{12}$ *is the period and* $t = 1, 2, \ldots, 39$.

The fitted trigonometric time series regression model using ordinary least square is

$$NMgc_t = 277.7 + 37.6\, cos\frac{2\pi}{12}t_j - 0.3\, sin\frac{2\pi}{12}t_j \quad (13)$$

with $R^2 = 0.8314$, *Adjusted* $R^2 = 0.8220$ and Durbin Watson $= 0.2756$

The Durbin Watson statistics value for the fitted model showed that the error terms are not serially correlated. The trigonometric time series regression model showed that the coefficients $cos\frac{2\pi}{12}t_j$ and

$sin\frac{2\pi}{12}t_j$ influenced Nigerian motor gasoline consumption. These indicated that for every unit increase in time, the Nigerian motor gasoline consumption may increase and decrease. The values of coefficient of determination (R^2) revealed that $cos\frac{2\pi}{12}t_j$ and $sin\frac{2\pi}{12}t_j$ explained the variations in Nigerian motor gasoline consumption up to 83%. The value of the adjusted coefficient of determination $(\bar{R}^2)$ also revealed that the model has a good fit and has high predictive power.

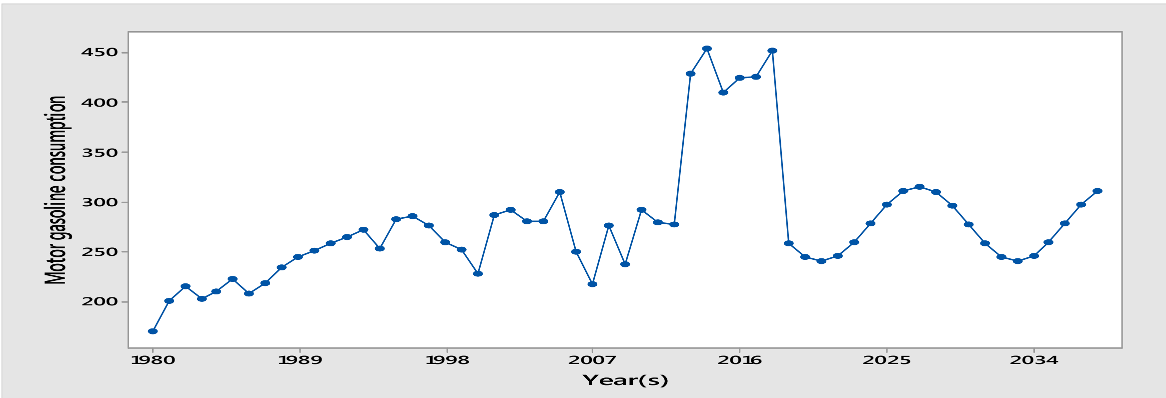

Figure 2. Nigerian motor gasoline consumption forecast from 1980 to 2038

Table 1. Nigerian motor gasoline consumption forecast from 1980 to 2038

Year(s)	Nigerian motor gasoline consumption (Thousands of Barrels)
2019	258.5
2020	244.9
2021	240.1
2022	245.4
2023	259.3
2024	278.2
2025	296.9
2026	310.5
2027	315.3
2028	310.0
2029	296.1
2030	277.2
2031	258.5
2032	244.9
2033	240.1
2034	245.4
2035	259.3
2036	278.2
2037	296.9
2038	310.5

The Nigerian motor gasoline consumption forecast from 1980 to 2038 is displayed in Figure 2 and Table 1 respectively. This motor gasoline consumption forecast indicated continuous fluctuations from year to year. The shape of the out-sample forecast from 2019 to 2038 exhibited a bell shape and this can be attributed to factors like motor gasoline scarcity,

Logistic, corruption, use of other sources of energy and nature.

CONCLUSION

This study was used to model Nigerian motor gasoline consumption from 1980 to 2018 using the Trigonometric Regression model which has the capabilities of handling nonlinearity exhibited by Nigerian motor gasoline consumption. The time plot of Nigerian motor gasoline consumption showed the series is nonlinear. The fitted Trigonometric regression model was estimated using the Ordinary Least Square method. From the result, the coefficients of the model influenced Nigerian motor gasoline consumption and a unit increase may lead to an increase or decrease in Nigerian motor gasoline consumption. The values of coefficient of determination (R^2) revealed that $cos\frac{2\pi}{12}t_j$ and $sin\frac{2\pi}{12}t_j$ explained the variations in Nigerian motor gasoline consumption up to 83%. The value of the adjusted coefficient of determination $(\bar{R}^2)$ also revealed that the model is a good fit and has high predictive power. Therefore, the Nigerian motor gasoline consumption forecast from 1980 to 2038 indicated continuous fluctuations from year to year. The shape of the out-sample forecast from 2019 to 2038 exhibited a bell shape and this can be attributed to factors like motor gasoline scarcity, logistics, corruption, use of other sources of energy and nature. Conclusively, based on the results obtained, the proposed model can be used to obtain future values for Nigerian motor gasoline consumption. This will enhance the Government and shareholders to put in place proper plans and logistics to curtail the challenges that may arise from Nigerian motor gasoline consumption and distribution presently and in the future.

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