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Predictive Modelling and Analysis of Petroleum Prices (PMS, AGO, DPK) Using the Non-Linear Logistic Approach

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Abstract: The study investigated the use of mathematical equations to predict and analyze the unit pump price of petroleum products in Nigeria. A logistic model was developed and solved into its analytic solution. Fuel pump prices from all over Nigeria for premium motor spirit (PMS), automotive gas oil (AGO), and dual-purpose kerosene (DPK) were obtained from the statistical facts sheet of the Nigerian Upstream Petroleum Regulatory Commission and plotted into a scatter diagram. The analytic solution of the model developed was superimposed on the scatter diagram to see its fitness. The model fitted into the scatter diagram excellently, with R^2 values reaching 0.996 for PMS, 0.9915 for AGO, and 0.9984 for DPK, confirming its robustness in predicting future prices and the meandering of the profile among the points of the scatter diagram. The model showed that the pump price phenomenon was model-able and predictive and revealed a projected saturation point for AGO prices at NGN 2062.25 by 2058, which indicated a gradual stabilization of the market. The Nigerian unit pump prices of petrol, diesel, and kerosene from 1992 to 2016 obey the model equation up to a degree of accuracy. The logistic model employed effectively captured the non-linear behavior of petroleum prices and offered a more accurate representation compared to traditional linear models. However, the rate of price increases was projected to decline over time, suggesting a potential mitigation of the burden of rising fuel costs in the long run. The study's findings have implications for policymakers, consumers, and industry stakeholders and provide valuable insights for informed decision-making.

Keywords: petroleum pricing, energy economics, logistic growth modeling, premium motor spirit, automotive gas oil, dual-purpose kerosene, price prediction

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1. Introduction

Petroleum is an essential commodity in the global economy [1]. Some of these commodities include Premium Motor Spirit (PMS), also known as gasoline; Automotive Gas Oil (AGO), also known as diesel; and dual-purpose kerosene (DPK). These products, when combined, make up over 60% of all petroleum products [2, 3].

The availability and affordability of crude oil and petroleum products are crucial for maintaining a country's standard of living and driving economic growth. This is true in developing countries, where these resources are often essential for transportation, industry, and power generation. However, the price of oil is volatile and can fluctuate significantly, which can have a major impact on a country's economy [4]. Many governments around the world have implemented price controls on petroleum products in an attempt to shield consumers from the effects of rising global oil prices. These policies can help to keep prices stable and affordable, but they can also have unintended consequences. For example, they can lead to shortages of petroleum products, as suppliers may be unwilling to sell at artificially low prices. They can also create a fiscal burden for governments, as they may need to subsidise the cost of petroleum products [5–7]. In the period from 2007 to 2008, when global oil prices rose sharply, many countries chose not to pass on the full increase to domestic consumers. This resulted in significant losses for oil distributors, who were often compensated by governments. While these policies may have provided some short-term relief to consumers, they also created a number of long-term problems. In particular, they discouraged investment in the oil industry and led to a build-up of government debt. In the long run, the best way to ensure affordable access to petroleum products is to promote competition in the oil industry and to invest in alternative energy sources. This will help to reduce dependence on volatile global oil markets and create a more sustainable energy future [8].

Like many other countries, the growth in the economy has led to an increase in the consumption of petroleum products in Nigeria [9, 10]. As the population grows, the number of people owning automobiles increases, the demand for petroleum products multiples, and so do the pump price exponents [11]. This is, however, not just the case for Nigeria. In spite of the abundant oil reserves in Nigeria and its neighboring countries, they still experience low capability of energy generation, with their inhabitants suffering the highest form of energy poverty in the world. In trying to bridge the gap, residents of urban areas litter every neighborhood with generators powered by fossil fuels, thereby endangering the environment [10, 12]. This contributes to exacerbating the growing scarcity and hike in price. According to empirical research, urban poor people suffer more from price increases for products like kerosene than wealthier people do in Nigeria, but the prices of these petroleum products have been increasing over the years, and they seem to have no end. The unit pump price of petroleum products, especially petrol, kerosene, and diesel, are key factors that affect the economy and welfare of Nigerians [13].

However, the unit pump price is influenced by many factors, such as crude oil price, exchange rate, inflation rate, taxes, subsidies, distribution costs, and market forces [14]. Like with other oil-exporting nations, Nigeria's domestic petroleum product pricing has been fixed administratively since 1973. They were initially established and periodically adjusted to pay a significant portion of the expenses of manufacturing. Since the marginal supply (measured in liters) originates from imports, the pricing of petroleum products in Nigeria ought to be based on the prices of crude oil internationally [15]. In other words, the economic price should be the import parity price when the marginal unit of consumption is imported. But for a variety of reasons, mostly socio-political ones, this hasn't always been the case. The government's stance on petroleum prices has been impacted by three factors: the first is the wish to safeguard the interests of the underprivileged, who may suffer from rising costs; the second is the necessity of cutting industrial costs because energy products are considered essential components of manufacturing processes; and the third is the possibility that rising energy prices could have an inflationary effect. The Nigerian government has enacted a number of trade policies throughout the years to promote international trade and reduce volatility in export revenue. These policies date back to the 1940s and include austerity measures in the 1980s [16, 17].

Pricing reform for petroleum products has emerged as a key element of macroeconomic policy in many developing nations. Price controls, trade restrictions, and special treatment for state-owned oil corporations are examples of governmental interventions that are being eliminated, along with the dismantling of monopolies [18]. Thus, understanding the nature of their demand, including key drivers, is necessary to plan consumption that is consistent with long-term growth objectives. Since the first oil price shocks of the early 1970s, there has been increasing attention on oil demand studies to generate accurate demand parameters for planning, projections, and policy formulation [19].

Modeling and analyzing the unit pump price of PMS, DPK, and AGO can help to understand the dynamics of the petroleum products market and the extent to which the prices of these petroleum products are subsidized. This is the aim of this study. It will assist in predicting the future price of these petroleum products, thereby equipping the stakeholders, policymakers, and consumers with the necessary information that will enable them to curb the harsh effects it will bring about. Following these goals, the objectives of this study are as follows: (1) To investigate the use of mathematical equations to predict and analyze the unit pump price of petroleum products in Nigeria for PMS, AGO, and DPK, (2) to develop a logistic model that can effectively capture the non-linear behavior of petroleum prices over time, (3) to analyze the price dynamics of the petroleum products market, including understanding the extent to which prices are subsidized and the factors influencing price changes.

2. Literature Review

Research on the relationship between petroleum consumption and various economic variables, such as price and income, has been a focal point in energy economics [20, 21]. Various modeling and estimation techniques have been utilized to capture this relationship, providing insights into petroleum demand and supply. Among these, static models have traditionally been employed to assess the immediate impact of price changes on consumption, offering a snapshot of consumer behavior in response to fluctuating prices [22–25]. These models, however, often fail to account for the dynamic nature of economic variables and their lagged effects, which limits their applicability in predicting long-term trends [11].

To address these limitations, partial adjustment models (PAMs) and autoregressive distributed lag (ARDL) models have been introduced, allowing for a better understanding of how consumption adjusts over time. PAMs have been instrumental in highlighting the gradual adjustment of petroleum consumption to changes in economic variables, suggesting that consumers do not immediately alter their behavior in response to price changes but rather adjust gradually over time [26]. This insight is important in understanding the inertia in consumer behavior, which static models fail to capture. However, the assumption of a constant adjustment speed in PAMs has been criticized for oversimplifying the complexities of market behavior, which can vary significantly across different economic contexts [27].

In contrast, ARDL models offer a more flexible framework by allowing for different lag lengths across variables, thereby providing a more detailed representation of the temporal dynamics of petroleum consumption. These models have been particularly useful in capturing the short-term and long-term effects of price changes and income fluctuations on petroleum demand [28]. Baumeister and Kilian [29] employed ARDL models to disentangle the effects of price shocks on oil consumption in the United States. They found that the long-term effects of price increases were more muted than previously thought. However, the reliance of ARDL models on large datasets and the assumption of linear relationships between variables can limit their applicability in contexts with less comprehensive data or non-linear dynamics [30].

Cointegration and error correction models (ECMs) have also been widely used to explore the long-term equilibrium relationships between petroleum consumption, prices, and income. These models are particularly valuable in their ability to distinguish between short-term deviations and long-term equilibrium trends, providing insights into the persistent effects of economic shocks on petroleum demand [28]. However, ECMs have been criticized for their sensitivity to the choice of variables and the length of the data sample, which can significantly affect the robustness of the results. Also, it assumes that all variables in the system converge to a long-term equilibrium. This may not hold in the face of structural breaks or regime changes, which are common in the energy markets [31].

Structural time series models (STSMs) offer a different approach by explicitly modeling the unobserved components of a time series, such as trends, cycles, and seasonality. These models have been effective in capturing the underlying structure of petroleum consumption data, particularly in markets with significant seasonal fluctuations [32]. STSMs have been used to model the structural breaks and non-stationarities in petroleum consumption, providing a more flexible approach to understanding the underlying patterns in the data [19]. However, the complexity of STSMs and their reliance on sophisticated estimation techniques can make them less accessible to practitioners and policymakers, limiting their widespread adoption [33].

Despite the advancements in these modeling techniques, there are several gaps in the literature. Firstly, the majority of studies have focused on developed economies, with relatively few examining the dynamics in developing countries, where data availability is often limited and market structures are different [34, 35]. This geographical bias limits the generalizability of the findings to global contexts, particularly in regions like sub-Saharan Africa, where the relationship between petroleum prices and consumption is likely to be mediated by factors such as fuel subsidies, regulatory interventions, and informal market dynamics. Additionally, most studies assume a linear relationship between variables, which may not adequately capture the complexities of market behavior, particularly in the face of economic shocks or policy changes [11, 36].

Therefore, this current study addresses these gaps by employing a logistic model to predict future prices of PMS, DPK, and AGO in Nigeria. This approach offers a novel perspective by focusing on a predictive modeling framework that incorporates both linear and non-linear dynamics, making it more adaptable to the complexities of the Nigerian petroleum market. Logistic models are particularly well-suited for this context as they can accommodate the non-linear effects of price changes and income fluctuations on petroleum consumption, which are prevalent in markets with significant government intervention and informal sector activity [37]. Moreover, the use of a logistic model allows for the incorporation of various economic and non-economic factors that influence petroleum prices in Nigeria, such as exchange rates, government policies, and geopolitical events, thereby providing a more comprehensive analysis of the determinants of petroleum prices. This will be very useful to policymakers, consumers, and stakeholders in the petroleum sector. It will assist in understanding the dynamics of price formation, identify the sources of price fluctuations, evaluate the impacts of policy interventions, and forecast future price trends.

3. Methodology

3.1. Data collection and model development

The Nigerian unit pump was extracted from statistical facts sheet of the Nigerian Upstream Petroleum Regulatory Commission and the Nigerian National Petroleum Corporation. The data were systematically extracted for the different petroleum products of concern from which the cumulative data was calculated.

All natural growth phenomena operate with the same model (growth model). As a result, the growth census model by Hubert King was used. Hubert King, a German American geologist, used the growth census model to predict the availability of American petroleum. Following his model, the rate of change of petrol is proportional to the petroleum itself [38].

$$\frac{dv}{dt} \alpha\ v$$

Or

$$\frac{dv}{dt} = k_1 \times v \tag{1}$$

where k_1, v *and* t are constants that represent the rate of increase of the petroleum, the quantity of petroleum (or the unit pump price of petroleum products) at a given time, and response time, respectively.

The rate of change of petroleum is directly proportional to the square of the inhibitor.

$$\frac{dv}{dt} \alpha\ (av)^2$$

Or

$$\frac{dv}{dt} = a^2 v^2 \tag{2}$$

where $k_2 = a^2$ and takes place in opposition to the direction of the rate of change.

Putting Equations (1) and (2) together, we have

$$\frac{dv}{dt} = k_1 \times v - k_2 \times v^2 \tag{3}$$

The minus sign (−) is a change in direction.

k_2 is a constant that represents the rate of decrease in the price due to inhibiting factors (market forces) and a is a constant related to the inhibiting factors affecting the price increase.

3.1.1. Model assumptions

Since Nigerian petroleum product retail and unit pump prices have been rising over the years, some factors have either directly or indirectly contributed to this growth. For this study, these variables were divided into two categories in order to select a mathematical model that would fit the provided data. Based on preliminary research in Section 1, the assumptions were made.

1) A closer look at the historical pump prices (then cumulative pump prices) of PMS, AGO, and KERO shows that the same price of each product at a particular time limits the rate at which that same price increases at that same time. It can be said that "the rate of increase in the pump prices (the cumulative. pump prices) of these petroleum products at any time is a function of (or directly proportional to) the pump prices (then cumulative pump prices) of these same products at that time." The actual factor that is considered in this assumption is the unit pump prices at a particular time.
2) A lot of forces, like those of the federal government and the oil industry, are working to drive up prices, while some forces, including those of the citizens, are working to drive down prices. These variables are referred to as "market forces" because it is believed that they will have some effect on how quickly the unit pump prices of these items increase. They serve as a restraint or inhibition.

3.1.2. Model equations

Given that prices cannot rise indefinitely, the time rate of change or increase in the cumulative unit pump price of Nigerian petroleum products, $\frac{dy}{dt}$, is proportional to the cumulative unit pump price that is currently in effect at the filling station, p, as well as to a decreasing braking cumulative function, F (market forces). This cumulative braking (inhibition) term is proportional to the square of the cumulative unit pump price, $F \alpha y^2$, and works in opposition to the cumulative unit pump price increases.

Equation (3) can be rewritten as:

$$\frac{dy}{dt} = k_1 \times y - k_2 \times y^2 \tag{4}$$

And letting $k_2 = bk_1$, yields,

$$\frac{dy}{dt} = k_1 y(1 - yb) \tag{5}$$

Which results in a logistic solution, on integration, as

$$y(t) = \frac{y_0 e^{k_1 t}}{1 - by_0\left(1 - e^{k_1 t}\right)} \tag{6}$$

With an annual unit pump price rate of

$$\frac{dy}{dt} = p(t) = \frac{k_1 y_0 (1 - by_0) e^{k_1 t}}{1 - by_0 (1 - e^{k_1 t})^2} \tag{7}$$

Peak time and unit peak price are obtained at $\frac{d^2y}{dt^2} = 0$, as

$$t_{pk} = \frac{1}{k_1} ln \frac{1 - by_0}{by_0} \tag{8}$$

and

$$p_{pk} = \frac{k_1}{kb} = \frac{1(k_1^2)}{4(k_2)} \tag{9}$$

The cumulative unit pump price at peak time is obtained by substituting Equation (9) in (6) for t_{pk} to yield

$$y_{pk} = \frac{1}{2}\left(\frac{k_1}{k_2}\right) \tag{10}$$

y: represents the cumulative unit pump price of petroleum products at a given time.

F: represents the cumulative braking (inhibition) function, which is proportional to the square of the cumulative unit pump price, indicating the market forces that work against price increases.

b: A constant that relates to the inhibiting factors in the context of the logistic model, specifically in the equation where $k_2 = bk_1$.

3.2. The plots

The data obtained from scholarly works were queued in with time in a MATLAB TOOLBOX to form a scatter diagram, and the models (cumulative models) were superimposed on the scatter diagram in a MATLAB TOOLBOX version 7.5. This sigmoidal profile and its model were differentiated so that the numerical value of the first derivative was plotted with the analytical solution of the first derivative to produce a dumbbell whose peak was read. The coefficient of the model was declared by the MATLAB TOOLBOX as well as the statistical goodness of fit.

3.3. Validation of the model

The validation was adjudged by the high R-squared of the model over 90% and the shape of the profile, i.e., profile was attempted to pick all the points on the scattered diagram or to pass through the points with its line of best fit.

4. Results and Discussion

4.1. Premium motor spirit (PMS)

The logistic model effectively captures the non-linear behavior of PMS prices over time. The analysis of PMS prices reveals significant insights into the long-term behavior of PMS prices in Nigeria. The model indicates an ultimate price level of NGN 1554.13, which is projected to be reached at approximately 66.1 years, or by the year 2058, assuming all other factors remain constant. This price level represents the maximum cumulative value that PMS can attain, reflecting a natural asymptotic behavior over time where the price becomes relatively stable and ceases to increase further. This is shown in Figure 1 below and it suggests that, in the absence of significant market disruptions or

Figure 1
Cumulative PMS price (NGN) versus time (R^2 = 0.996)

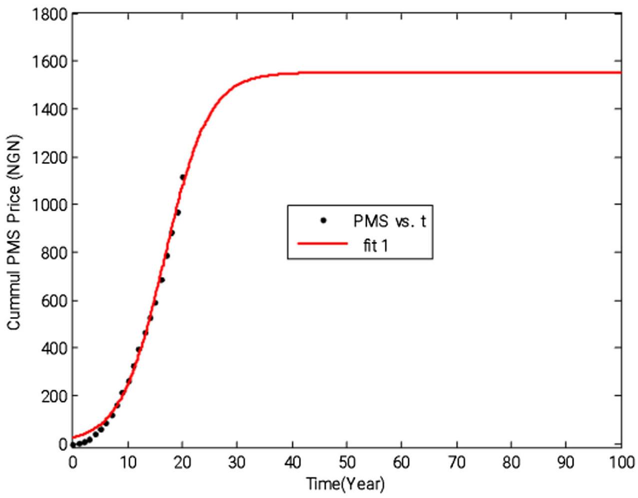
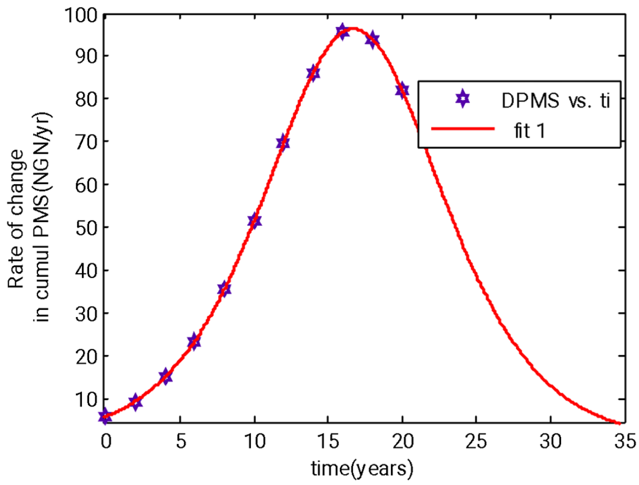


Figure 2
Rate of change in cumulative PMS versus time



policy changes, the price of PMS will plateau, reaching a saturation point that represents market equilibrium.

The price behavior PMS as in Figure 1 agrees with the logistic model's underlying assumptions, where initial growth is fueled by high demand and limited supply, leading to significant price increases. As the market matures and the effects of demand-supply imbalances are mitigated, the growth rate diminishes, eventually tapering off to an asymptotic value. This tapering effect is important for policymakers and market analysts, as it indicates that beyond a certain point, further investments or technological advancements are unlikely to yield proportional increases in price or revenue, signaling a need for strategic shifts in the market approach.

However, the rate of change in Figure 2 showed a peak price identified as NGN 96. This is shown to have occurred around 16.7 years from the base year or approximately in 2009. This peak reflects the highest rate of price increase before the price begins to stabilize, indicating a shift in market dynamics during this period. The rapid rise to NGN 96 could be attributed to a combination of factors such as increased demand, supply constraints, or external shocks, which caused a significant but temporary spike in prices. The subsequent flattening of the curve suggests a return to a more balanced supply-demand equilibrium, where prices are less sensitive to fluctuations.

Table 1 shows the robustness of the logistic model used in this analysis. The high R-squared values ($R^2 = 0.996$, adjusted $R^2 = 0.9953$) indicate that the logistic model provides a strong fit

Table 1
Coefficient and statistical goodness of fit for premium motor spirit (PMS)

Coefficients with 95% confidence bound	Goodness of fit
$b = 1.738$	$\mathrm{SSE} = 1.002 * 10^4$
$f = 2701$	R-square = 0.996
$k_1 = 0.2481$	Adjusted R-square = 0.9953
$y_0 = 0.008944$	RMSE = 24.28

Ultimate Value: $f(66.1) = 1554.13$ (This means that the ultimate value of PMS = 1554.13 at $t = 66.1$, which is equivalent to 2058.)

Table 2
Differentiated Table of Figure 1

xi	*df(xi)/dx*
0	5.89926
2	9.49821
4	15.1052
6	23.556
8	35.6323
10	51.4811
12	69.6287
14	86.1756
16	95.6138
18	94.0056
20	82.0619

to the data. The model's ability to capture the non-linear dynamics of PMS prices is a significant strength. The standard error of the estimate (SSE = 1.002 × 10^4) and the root mean square error ($RMSE = 24.28$) are within acceptable ranges. The high coefficient values and narrow confidence intervals indicate strong statistical significance, affirming the model's robustness and the reliability of its forecasts.

Table 2 shows the differentiated analysis of PMS. This offers additional layers of understanding by quantifying the rate of change in PMS prices over time. The differentiated values indicate a sharp initial increase in prices (Figure 2), which gradually slows as the market approaches equilibrium. This pattern is consistent with logistic growth models, where the rate of increase slows as the carrying capacity of the market is approached.

4.2. Automotive gas oil (diesel)

Similar to PMS, the logistic model effectively captures the non-linear behavior of AGO prices over time. The cumulative price was plotted in Figure 3, and it shows a similar pattern of rapid initial growth, followed by a gradual deceleration and asymptotic convergence.

The ultimate price level is projected to reach NGN 2062.25 in approximately 65.7 years (around 2058). After that, there will be a saturation point where further price increases become negligible.

Figure 3
Cumulative AGO price (NGN) versus time (R^2 = 0.9915)

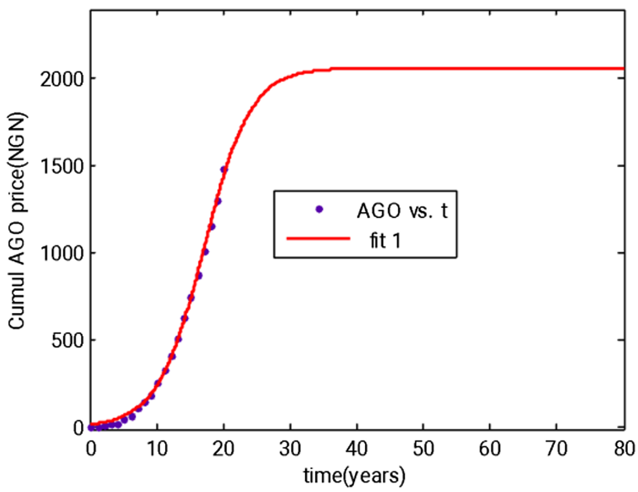
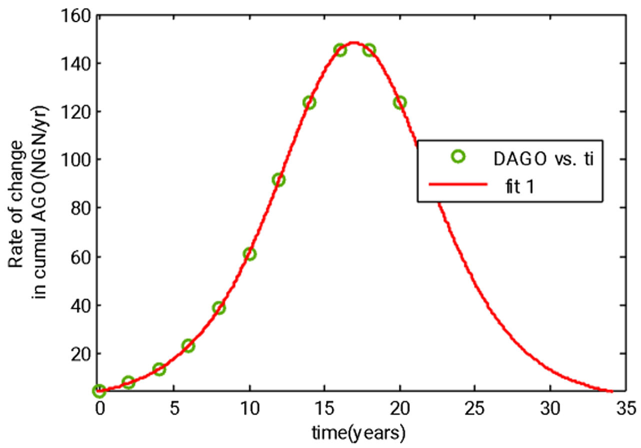


Figure 4
Rate of change in cumulative AGO versus time in years



This saturation suggests that the AGO market, like the PMS market, will stabilize over time.

Following the cumulative price, the rate of change reveals a peak at approximately 17 years from the baseline (around 2010), with a peak price of NGN 148. This peak signifies the point of maximum growth rate, after which the rate of increase in AGO prices diminishes. This deceleration indicates that the market is reaching its capacity limit, beyond which additional price growth is unsustainable under current market conditions. Such a trend, as in Figure 4, highlights the importance of understanding price elasticity and market saturation when planning future supply and demand scenarios.

Table 3 shows the high R-squared values ($R^2 = 0.9984$, Adjusted $R^2 = 0.998$), which indicate that the logistic model provides a strong fit to the data. The minimal difference between the R-squared and adjusted R-squared values suggests that the model is parsimonious, avoiding overfitting and maintaining generalizability across different time frames and market conditions.

The findings of this study have important implications for policymakers, consumers, and industry stakeholders. The predicted price ceiling and the decreasing rate of price increases suggest that the burden of rising fuel costs may be mitigated in the long run. Understanding these dynamics allows for better resource allocation and more effective policy measures to stabilize the market and ensure a sustainable energy future. However, Table 4 shows the differentiated table of the rate of change for AGO.

4.3. DPK

The analysis of kerosene (KERO) prices reveals a peak price of approximately NGN 980 occurring 18 years after the base year of 1992, specifically around 2010. The model demonstrates a high level of fit, as evidenced by the R-squared value of 0.9915 and an adjusted R-squared of 0.9894. These values suggest a strong correlation between the model predictions and actual historical data as shown in Figure 5.

However, despite the high goodness-of-fit metrics, the predictive capacity of the model is influenced by various external factors that are not solely price-driven. Factors such as illegal bunkering, smuggling, pipeline breakages, and changes in government policy significantly impact kerosene prices in Nigeria. These factors introduce variability that cannot be fully captured by the model.

The dumbbell plot in Figure 6 reflects the typical behavior of kerosene prices in a market influenced by both supply and demand dynamics as well as the externalities mentioned above. The observed pattern indicates a period of rapid price escalation followed by stabilization, suggesting that the kerosene market reached a temporary equilibrium in the mid-2000s.

The high R-squared values ($R^2 = 0.9915$, adjusted $R^2 = 0.9894$) in Table 5 indicate that the logistic model provides a strong fit to the data. The model's ability to capture the non-linear dynamics of kerosene prices is a significant strength.

Table 3
Coefficient and statistical goodness of fit for automotive gas oil (AGO)

Coefficients with 95% confidence bound	Goodness of fit
$b = 0.1132$	SSE = 7221
$f = 337.5$	R-square = 0.9984
$k_1 = 0.2876$	Adj.R-square = 0.998
$y_0 = 0.06605$	RMSE = 21.24

Ultimate Value: $f(65.7) = 2062.25$

Table 4
Differentiated Table of Figure 3

xi	*df(xi)/dx*
0	4.39932
2	7.72899
4	13.4592
6	23.0802
8	38.5516
10	61.6393
12	91.9407
14	123.749
16	145.225
18	145.237
20	123.778

Figure 5
Cumul Kero price versus time (R^2 = 0.9915)

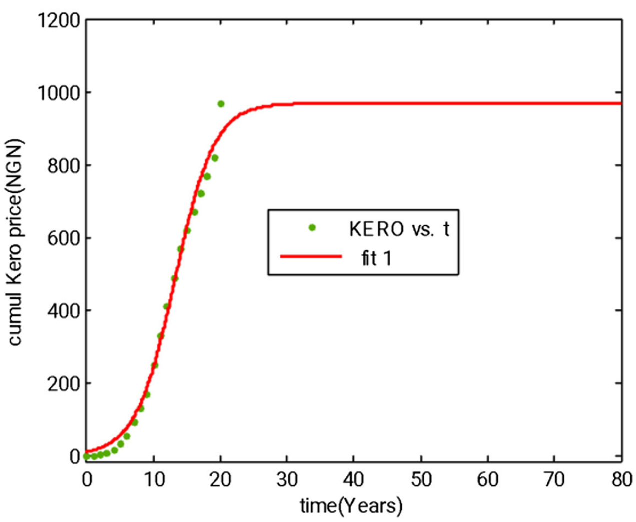


Figure 6
Rate of change in cumulative KERO versus time

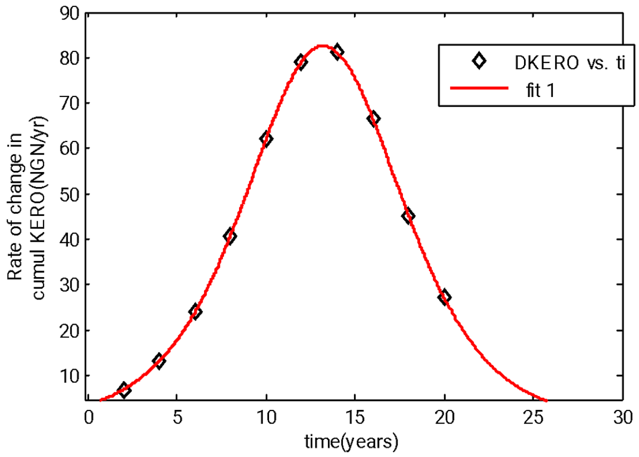


Table 5
Coefficients and statistical goodness of fit for kerosene

Coefficients with 95% confidence bound	Goodness of fit
$b = 0.1339$	SSE = 1.786e + 004
$f = 246.4$	R-square = 0.9915
$k_1 = 0.341$	Adjusted R-square = 0.9894
$y_0 = 0.08138$	RMSE = 33.41

Ultimate Value: $f(59) = 968.605$

The differential analysis presented in Table 6 further supports this interpretation, showing that the rate of price increase peaked around year 14 before declining sharply. This pattern suggests that the kerosene market, similar to PMS and AGO, follows a sigmoidal growth curve where early rapid growth eventually gives way to a plateau as market forces and externalities exert their influence.

The findings of this study not only illuminate the current dynamics of petroleum pricing in Nigeria but also provide a robust framework for anticipating future price movements. A logistic growth model is used in the study to show how market demand, exchange rates, and government rules all affect the price of oil and how these factors interact with each other in complex ways. High R-squared values show how well the model can predict, which means that price trends in the future can be guessed with a high level of accuracy. This is especially important for people involved in the petroleum sector because it gives them the knowledge to make smart choices about pricing strategies, business opportunities, and how to handle risk. It is also useful to know the likely price caps and saturation points because they show how well Nigeria's oil business will do in the long run. As the model indicates a gradual stabilization of prices, it reveals the importance of strategic policy interventions aimed at mitigating the adverse effects of price volatility.

Table 6
Differential Table of Figure 5

xi	*df(xi)/dx*
0	3.55957
2	6.89217
4	13.0797
6	23.8984
8	40.7643
10	61.9239
12	79.0834
14	81.131
16	66.5018
18	45.2697
20	27.1058

5. Conclusion

1) The study successfully employed a logistic model to predict future prices of PMS, DPK, and AGO in Nigeria.
2) The logistic model provided a robust framework for analyzing the non-linear effects of economic variables on petroleum prices, accommodating the complexities of the Nigerian market characterized by significant government intervention and economic volatility.
3) Predictions indicate a gradual increase in prices for PMS, DPK, and AGO, with potential price ceilings expected to be reached by 2058.
4) The rate of price increase for each product is projected to decline over time, suggesting a potential mitigation of the burden of rising fuel costs in the long run.
5) The model effectively captures the non-linear behavior of petroleum prices, offering a more accurate representation compared to traditional linear models.
6) Policymakers should consider implementing a transparent pricing model based on the findings of this study to determine when subsidies are necessary, fostering economic growth and stability.
7) Future research should focus on integrating external factors such as political instability, regulatory changes, and global economic shocks into predictive models to enhance their robustness and applicability.
8) A comprehensive modeling approach that incorporates both quantitative and qualitative factors should be developed to provide a holistic understanding of the petroleum market dynamics in Nigeria, thereby improving policy formulation and economic planning.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

Author Contribution Statement

Chinemerem Jerry Chukwu: Conceptualization, Writing – original draft, Supervision. **Lawal Kunle Adam:** Conceptualization, Writing – original draft. **Obasi Daniel Ebubechi:** Methodology, Investigation, Writing – review & editing. **Ugochukwu Chibuzo Akomah:** Methodology, Investigation, Writing – review & editing. **Ajadalu Samson Oseiwe:** Software, Visualization. **Ogamba Chidube:** Software, Visualization. **Olaremi Samuel Oluwasijibomi:** Validation, Project administration. **Sunday Abayomi Joseph:** Validation, Supervision, Project administration. **Mohammed Sherif Ali:** Formal analysis, Data curation. **Chukwuma Richard Chukwudi:** Formal analysis, Data curation. **Eze Simeon Okechukwu:** Investigation, Resources. **Saifullahi Abdullahi Abubakar:** Investigation, Resources.

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