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Linear and Non-Linear Relationship between Energy Consumption and Economic Growth in Nigeria: An Application of the Arima Models

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Abstract

Energy consumption refers to the amount of energy consumed by individuals, businesses, and industries in order to meet their needs and to carry out their activities. The primary sources of energy consumption are fossil fuels such as coal, oil, and natural gas, as well as renewable sources such as solar, wind, and hydropower. This study examines the correlation between energy consumption and economic growth in Nigeria, utilizing both linear and nonlinear models, including ARIMA. The stability and acceptability of the data for time series analysis are confirmed through a thorough examination of descriptive statistics and unit root tests. The linear regression analysis reveals the substantial impact of energy consumption and inflation on GDP. However, the presence of residual autocorrelation indicates the need for further improvements in the model. The ideal ARIMA model for predicting GDP differentials is identified as ARIMA (3,1,1) through forecasting. The model assumptions are confirmed by validation using the Ljung-Box Q test.

The results highlight a strong link between energy use and economic development, supporting the need for sustainable energy strategies. Suggested approaches including expanding the range of energy sources, advocating for efficiency initiatives, improving infrastructure, encouraging policy collaboration, and implementing rigorous monitoring and evaluation systems. These findings offer essential viewpoints for comprehending economic dynamics and plotting future courses towards sustainable growth in Nigeria.

***Keywords*:** Energy, consumption, economic growth, linear and non-Linear, ARIMA, Nigeria.

Introduction

Energy consumption refers to the amount of energy used by a particular system or society over a given period of time. It is typically measured in units of joules (J), kilowatt-hours (kWh), or British thermal units (BTUs) Mushtaq, (2023). Energy is a fundamental component of economic growth, and its consumption has increased significantly over the past few decades. However, the impact of energy consumption on economic growth remains a subject of debate among researchers and policymakers. Aksoy et al. (2024) and Bildirici et al. (2023) argue that energy consumption is a driver of economic growth, while others contend that it hinders economic progress by contributing to environmental degradation and creating resource scarcity. Therefore, there is a need to investigate the relationship between energy consumption and economic growth, particularly in light of the growing concern over the depletion of natural resources and climate change. This research aims to examine the impact of energy consumption on economic growth, and the findings will inform policy decisions related to energy consumption and environmental sustainability.

Energy consumption is a vital aspect of economic growth, as it fuels industries, transportation, and households. However, the impact of energy consumption on economic growth is a topic of considerable interest and controversy among scholars and policymakers. On the one hand, Dergiades et al. (2013) argue that increased energy consumption is essential for economic development, as it drives productivity and innovation, creates employment opportunities, and improves the standard of living. On the other hand, Hu et al. (2023) critics contend that energy consumption has adverse effects on the environment, contributes to resource depletion, and can lead to energy insecurity.

Furthermore, the relationship between energy consumption and economic growth is complex and multifaceted. While energy consumption can lead to economic growth in the short term, there are concerns about its long-term sustainability, given the finite nature of natural resources and the environmental consequences of excessive energy consumption. Moreover, the relationship between energy consumption and economic growth may vary across countries and regions, depending on their natural resource endowments, technological capabilities, and institutional frameworks.

Therefore, there is a need to investigate the impact of energy consumption on economic growth, taking into account the different dimensions of the relationship, such as the short-term versus long-term effects, the environmental consequences, and the heterogeneity across countries and regions. The findings of this research can inform policy decisions related to energy consumption and environmental sustainability, such as the promotion of renewable energy, the adoption of energy-efficient technologies, and the implementation of energy conservation measures.

Energy consumption is driven by a variety of factors, including population growth, economic activity, and technological development. Fossil fuels such as coal, oil, and natural gas have traditionally been the primary sources of energy for human societies, but renewable sources such as solar, wind, and hydro power are becoming increasingly important as concerns about climate change and energy security grow.

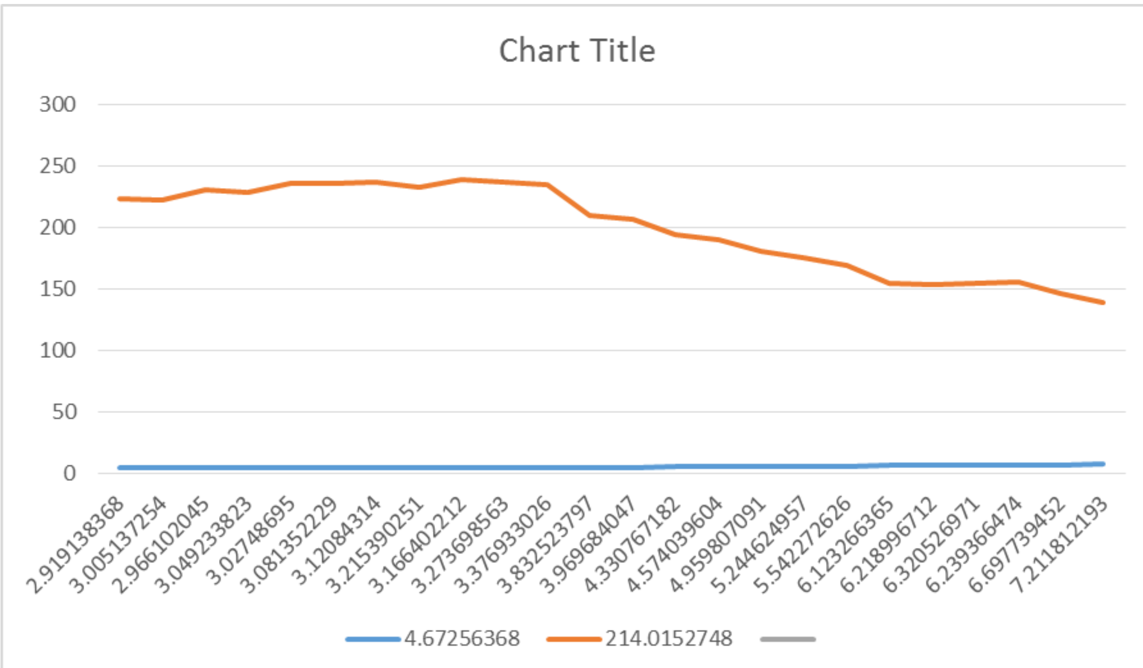


Fig.

figure1.1 Energy consumption in Nigeria

Source: compile by the author (2024)

H_{01} There is no relationship between energy consumption and economic growth

Literature Review

Empirical Review

Amin & Song (2022) investigate the journey towards achieving carbon neutrality in South and East Asian nations. They analyse the effects of renewable and non-renewable energy use, trade, economic growth, and urbanisation on sustainability objectives. Their comparative study explores the intricacies of attaining sustainable energy transitions in the face of changing economic environments. Furthermore, the research conducted by Androniceanu & Georgescu (2023), Ayhan et al. (2023), Bank-Ola et al. (2024), Borah (2024), Dahmani, Mabrouki, & Ben Youssef (2023), Gershon et al. (2024), Hu et al. (2023), and other scholars adds to the expanding body of knowledge regarding the complex connections between energy consumption, economic growth, environmental sustainability, and policy implications in different regions and sectors. Alqaralleh and Hatemi-J (2024) provide a deeper insight by examining the effects of renewable and non-renewable energy consumption on economic growth through the use of an asymmetric panel quantile technique. However, Borah (2024) examines the complex linkages between corruption, environmental quality, energy consumption, and economic growth in ASEAN countries. This study utilises econometric approaches to reveal the deep dynamics of these interconnections. The results underscore the significance of all-encompassing policy frameworks in tackling issues pertaining to corruption, environmental deterioration, energy consumption trends, and promoting inclusive economic expansion in the ASEAN area.

Nexus between Energy Consumption Economic Growth

The relationship between energy consumption and economic growth is intricate and has been extensively studied and discussed by economists and policymakers. Typically, there is a direct relationship between energy consumption and economic growth, as energy is an essential factor for both producing and consuming goods and services in the economy. Ritu, and Kaur, (2024). As economies grow and develop, they tend to use more energy to power industries, transportation, and households. This increased energy consumption can lead to higher productivity, greater economic output, and improved standards of living for citizens. On the other hand, energy usage can also lead to negative environmental and health impacts, such as air pollution, climate change, and depletion of resources. In 2015, Azam et al. did a study to investigate the causal relationship between energy consumption and economic growth in the ASEAN-5 countries. Their goal was to investigate this specific connection throughout the region. The analysis revealed a significant causal association between energy use and economic development in the ASEAN-5 nations.

Table 2 National Policy Program and Target

Renewable Energy	2015	2020	2030
Solar Energy	600mw	6136mw	48132mw
Wind Energy	23mw	40mw	50mw
Hydro Energy	4100mw	9760mw	14750mw
Biofuel Energy	5mw	30mw	100mw
Total	4728mw	15966mw	63032mw
Jobs Created	23640	79830	315160

Source: Transmission Company of Nigeria, 2023.

Method

The chosen research methodology for this study is quantitative, employing statistical analysis to investigate the link between energy consumption and economic growth in Nigeria. This methodology enables the examination of hypotheses and the quantification of variables through the utilization of numerical data in order to obtain empirical conclusions. the Autoregressive Integrated Moving Average (ARIMA) popularly known as BOX-Jenjkins (1976) methodology was applied in this study.

Model Specification

In order to derive the ARIMA model, it is necessary to determine the level of stationarity of the variables in the model. Unit root tests, such as the Augmented Dickey-Fuller (ADF) or Phillips-Perron (PP) tests, can be employed to ascertain this. In this study, the Augmented Dickey-Fuller (ADF) test is employed to examine the existence of unit roots in the variables.

The ADF test findings suggest that all variables in the model are non-stationary at their original levels, but become stationary after being differenced once.

$$\Delta GDP_t = \beta 0 + \beta_1 \Delta TEC_2 + \beta_2 \Delta INF_t + \beta_3 \Delta TMS_t + \varepsilon_t \text{.................................}(1)$$

where ΔGDP_t, ΔTEC_2, ΔINF_t, $and\ \Delta TMS_t$ are the first differences of the respective variables, and β0, β1, β2, and β3, are the parameters to be estimated.

However, to capture any potential long-run relationship between the variables, we also include lagged values of the variables in the model. The ARIMA model can be specified as follows:

$$\Delta GDP_t = \beta 0 + \beta_1 \Delta TEC_2 + \beta_2 \Delta INF_t + \beta_3 \Delta TMS_t + \alpha 1L(\Delta GDPt, 1) + \alpha 2L(\Delta GDPt, 2) + \ldots + \alpha pL(\Delta GDPt, p) + \gamma 1L(\Delta TECt, 1) + \gamma 2L(\Delta TECt, 2) + \ldots + \gamma pL(\Delta TECt, p) + \delta 1L(\Delta INFt, 1) + \delta 2L(\Delta INFt, 2) + \ldots + \delta pL(\Delta INFt, p) + \theta 1L(\Delta TMSt, 1) + \theta 2L(\Delta TMSt, 2) + \ldots + \varepsilon t$$

. The lag operator, denoted as L, is used in determining the appropriate lag length, p. This is done by applying criteria such as the Akaike Information Criterion (AIC) or the Schwarz Bayesian Criterion (SBC).

The Autoregressive Distributed Lag (ARIMA) model will be utilized to analyses the influence of energy consumption on economic growth in Nigeria. The precise model for this investigation can be depicted as follows:

$$GDP_t = \beta_0 + \beta_1 TEC_t + \beta_2 INF_t + \beta_3 TMS_t + \varepsilon_t.$$

where:

GDP_t is the GDPt of Nigeria in year t.

TEC_t is the energy demand of Nigeria in year t.

INF_t is inflation Rate in Nigeria in year t.

TMS_t is total emission in Nigeria in year t.

β_0, β_1, β_2, and β_3, are parameters to be estimated.

ε_t. is error term at time t.

The ARIMA model is suitable for this study because to its ability to estimate both short-term and long-term connections between variables, enabling a full investigation of the intricate and ever-changing connection between energy consumption and economic growth in Nigeria. Moreover, the model takes into consideration the possibility of endogeneity and stationarity problems that could occur in time series data, making it an appropriate tool for examining the correlation between energy use and economic growth.

Analysis and presentation of Result

Table 4.1: Descriptive Statistics

	GDP	TEC	INF	TMS
Mean	3.083027	143.8394	18.50352	276.4175
Median	3.921555	148.1829	12.94178	287.7046
Maximum	15.32916	257.5113	72.83550	446.9068
Minimum	-13.12788	0.000000	0.000000	0.000000
Std. Dev.	5.423401	75.19517	15.58356	111.9670
Skewness	-0.734096	-0.168372	1.906392	-0.399910
Kurtosis	4.075064	1.762731	5.915281	2.157083
Jarque-Bera	6.898649	3.425481	47.99207	2.812963
Probability	0.031767	0.180371	0.000000	0.245004
Sum	154.1514	7191.972	925.1758	13820.87
Sum Sq. Dev.	1441.251	277061.4	11899.52	614293.5
Observations	50	50	50	50

Source: E-views 12

The descriptive statistics offer vital insights into the features of the variables Gross Domestic Product (GDP), Total Energy Consumption (TEC), Inflation (INF), and Total Emission (TMS). The GDP, with a mean value of 3.083027, represents the average economic performance throughout the specified period. The median GDP number of 3.921555 indicates that the middle GDP value is greater than the mean, suggesting a potential right skewness in the distribution. The substantial disparity between the highest GDP value of 15.32916 and the lowest number of -13.12788 underscores the volatility in economic production. The standard deviation of 5.423401 represents the extent to which GDP values deviate from the mean. The skewness of -0.734096 indicates a small leftward asymmetry in the distribution, while the kurtosis of 4.075064 suggests that the distribution has heavier tails and is more peaked compared to a normal distribution.

When considering TEC, INF, and TMS, i observe similar patterns in terms of their average values, spread, and distribution shape. The mean and median numbers offer insight into the average amount of energy use, inflation rate, and money supply. The standard deviations of 75.19517 for TEC, 15.58356 for INF, and 111.9670 for TMS represent the extent to which values deviate from their respective averages. The skewness values of -0.168372 for TEC, 1.906392 for INF, and -0.399910 for TMS indicate different levels of asymmetry in their distributions. Positive values indicate right skewness. Similarly, the kurtosis values offer information about the degree of peakedness and the tails of the distributions. For example, a kurtosis value of 5.915281 for INF suggests that the tails of the distribution are heavier compared to a normal distribution.

The Jarque-Bera statistics assess the normality hypothesis for each variable, using varying probability of normality. The importance of these statistics indicates that the distributions of GDP, TEC, INF, and TMS may differ from a normal distribution, leading scholars to examine the consequences of non-normality on modelling and statistical studies.

Table4. Unit Root Test

Null Hypothesis: D(GDP) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=10)

	t-Statistic	Prob.*

Augmented Dickey-Fuller test statistic	-12.10579	0.0000
Test critical values: 1% level	-3.574446	
5% level	-2.923780	
10% level	-2.599925	

Null Hypothesis: D(TEC) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.895330	0.0000
Test critical values: 1% level	-3.574446	
5% level	-2.923780	
10% level	-2.599925	

Null Hypothesis: D(INF) has a unit root

Exogenous: Constant

Lag Length: 1 (Automatic - based on SIC, maxlag=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.104534	0.0000
Test critical values: 1% level	-3.577723	
5% level	-2.925169	
10% level	-2.600658	

Null Hypothesis: D(TMS) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.146443	0.0001
Test critical values:	1% level	-3.574446	
	5% level	-2.923780	
	10% level	-2.599925	

Source: E-views 12

At a significance level of 5%, the unit root test demonstrates that all variables, including GDP, Total Energy Consumption (TEC), Inflation (INF), and TMS, reject the null hypothesis of having a unit root. These variables are stable, indicating that they do not show any trend over time that would affect their statistical features. The t-statistic values for each variable, namely -12.10579 for GDP, -6.895330 for TEC, -7.104534 for INF, and -5.146443 for TMS, are all statistically significant with probabilities (Prob.*) of 0.0000 or around 0.0000. These results suggest that the variables exhibit a consistent average and variability, which makes them appropriate for time series analysis without the requirement of first-differencing to attain stationarity. In addition, the critical values of the test at the 1%, 5%, and 10% significance levels provide evidence to reject the hypothesis that there is a unit root for all variables. This supports the conclusion that the data is stable.

Table 4. Linear Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.677610	1.949245	-0.347627	0.7297
TEC	0.008685	0.015901	0.546207	0.5876
INF	-0.097565	0.046488	-2.098712	0.0414
TMS	0.015617	0.010835	1.441336	0.1563

R-squared	0.224321	Mean dependent var	3.083027
Adjusted R-squared	0.173734	S.D. dependent var	5.423401
S.E. of regression	4.929828	Akaike info criterion	6.105104
Sum squared resid	1117.948	Schwarz criterion	6.258066
Log likelihood	-148.6276	Hannan-Quinn criter.	6.163353
F-statistic	4.434301	Durbin-Watson stat	1.546019
Prob(F-statistic)	0.008071		

Source: E-views 12

The regression model, with GDP as the dependent variable, reveals significant findings. The values assigned to the independent variables are as follows: The Total Energy Consumption (TEC) has a coefficient of 0.008685, the Inflation (INF) has a coefficient of -0.097565, and the TMS has a coefficient of 0.015617. Out of these variables, the coefficient for INF is statistically significant at the 5% level, indicating that fluctuations in inflation have a noteworthy influence on GDP. The R-squared value of 0.224321 suggests that around 22.43% of the variation in GDP can be accounted for by the independent variables in the model. The F-statistic of 4.434301 is statistically significant at the 1% level, suggesting that the entire regression model effectively explains the variation in GDP.

The Durbin-Watson statistic value of 1.546019 indicates the presence of positive autocorrelation in the residuals. This means that neighboring residuals are positively correlated, which can impact the accuracy of the coefficient estimates. The Akaike Information Criterion (AIC) and Schwarz Criterion are metrics employed for model selection, where lower values indicate superior model fit. The model's AIC (Akaike Information Criterion) of 6.105104 and Schwarz Criterion of 6.258066 offer valuable information for comparing this model with others.

In summary, although the model shows some ability to explain the relationship between inflation and GDP, and this relationship is statistically significant, the presence of autocorrelation indicates that additional diagnostics or improvements to the model may be needed to increase the reliability and accuracy of the regression analysis.

Model Selection (ARIMA)

Differenced GDP	ARIMA(1,1,1)	ARIMA(2,1,1)	ARIMA(3,1,1)	ARIMA(1,1,2)
Significant Coefficients	2	2	2	3
Sigma(volatility)	28.06599	27.77333	27.37013	28.03713
Adjusted R2	0.30	0.26	0.28	0.30
AIC	6.34	6.34	6.32	6.34
SBIC	6.50	6.49	6.47	6.50

Source: E-view 12

In order to ascertain the superior model among the Differenced GDP models with varying ARIMA specifications (ARIMA (1,1,1), ARIMA (2,1,1), ARIMA (3,1,1), and ARIMA (1,1,2)), we can assess multiple crucial criteria:

The presence of significant coefficients in a model is indicative of the effectiveness of the variables in explaining the variability in the dependent variable. Models with larger coefficients are typically selected because they offer greater explanatory power.

Sigma, often known as volatility, is a metric that quantifies the level of variability or volatility in the residuals of a model. Smaller volatility numbers indicate a stronger alignment between the model and the data.

The adjusted R-squared, also known as Adjusted R2, quantifies the extent to which the independent variables account for the variation in the dependent variable. Greater adjusted R-squared values imply a more accurate alignment of the model with the data.

The Akaike Information Criterion (AIC) is a metric used to select models, where lower AIC values indicate a more optimal trade-off between model fit and complexity.

The Schwarz Bayesian Information Criterion (SBIC) is a metric that, similar to the AIC, indicates the quality of a model fit. Lower SBIC values indicate a better fit, taking into account the complexity of the model.

Given the available data for the various ARIMA models:

ARIMA (1,1,1) and ARIMA (2,1,1) exhibit 2 statistically significant coefficients, whereas ARIMA (3,1,1) displays 2 significant coefficients and ARIMA (1,1,2) demonstrates 3 significant coefficients. Greater coefficients can imply a model that better captures the underlying dynamics in the data.

The volatility values are generally similar among the models, with ARIMA (3,1,1) exhibiting the lowest volatility.

The corrected R-squared values for ARIMA (1,1,1), ARIMA (3,1,1), and ARIMA (1,1,2) are all approximately 0.30, whereas ARIMA (2,1,1) has a slightly lower value of 0.26.

The AIC values exhibit consistency among the models, with ARIMA (3,1,1) having a little lower value of 6.32.

The SBIC values are comparable, and the ARIMA (3,1,1) model has the lowest value of 6.47.

Based on the given criteria, it can be concluded that ARIMA (3,1,1) is the superior model choice among the listed ARIMA models. The model demonstrates a favorable combination of important coefficients, reduced volatility, comparatively higher adjusted R-squared, and lower AIC and SBIC values in comparison to the other models. This indicates a superior fit and a more concise representation of the data.

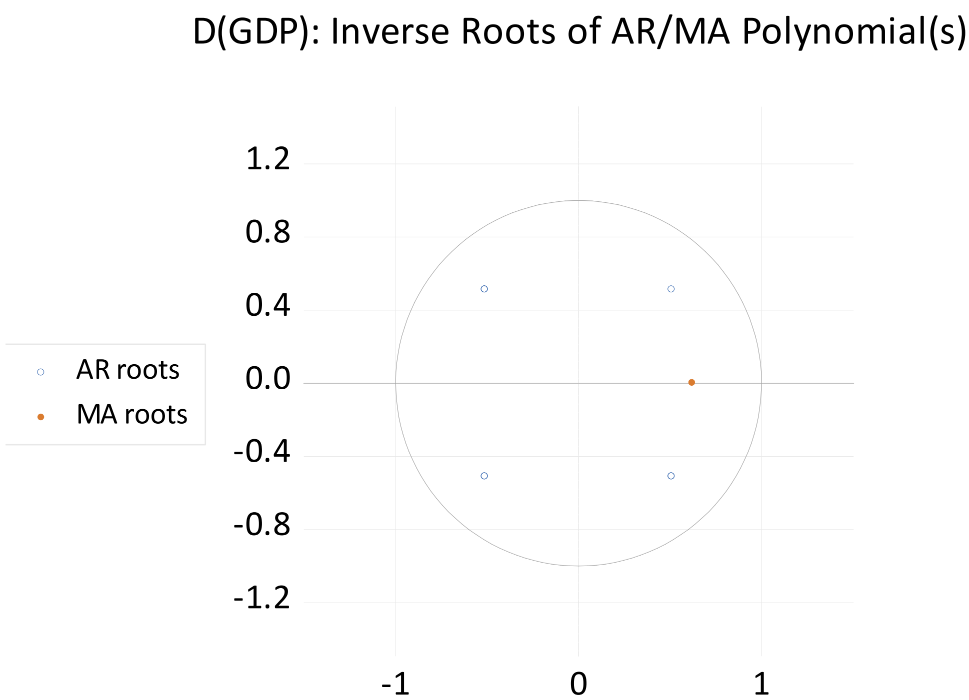
Table 4.5 Ljung-Box Q Test

Q-statistic probabilities adjusted for 2 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	0.019	0.019	0.0192	
. | . |	. | . |	2	0.037	0.037	0.0924	
. |*. |	. |*. |	3	0.137	0.136	1.1110	0.292
.*| . |	.*| . |	4	-0.153	-0.162	2.4157	0.299
. | . |	. | . |	5	-0.039	-0.043	2.5020	0.475
. |*. |	. |*. |	6	0.075	0.074	2.8260	0.587
**| . |	**| . |	7	-0.241	-0.210	6.2936	0.279
. |*. |	. |*. |	8	0.088	0.093	6.7686	0.343
**| . |	**| . |	9	-0.223	-0.270	9.8776	0.196
. | . |	. | . |	10	-0.062	0.048	10.125	0.256
. | . |	. | . |	11	0.067	-0.006	10.423	0.317
. |*. |	. |*. |	12	0.124	0.213	11.469	0.322
. | . |	. | . |	13	0.003	-0.059	11.470	0.405
. | . |	.*| . |	14	0.028	-0.082	11.524	0.485
.*| . |	.*| . |	15	-0.139	-0.110	12.945	0.452
. |*. |	. | . |	16	0.083	0.055	13.465	0.490
. | . |	. |*. |	17	0.066	0.151	13.803	0.541
. | . |	. | . |	18	0.022	-0.055	13.843	0.610
.*| . |	.*| . |	19	-0.073	-0.093	14.281	0.647
. | . |	.*| . |	20	-0.062	-0.137	14.608	0.689

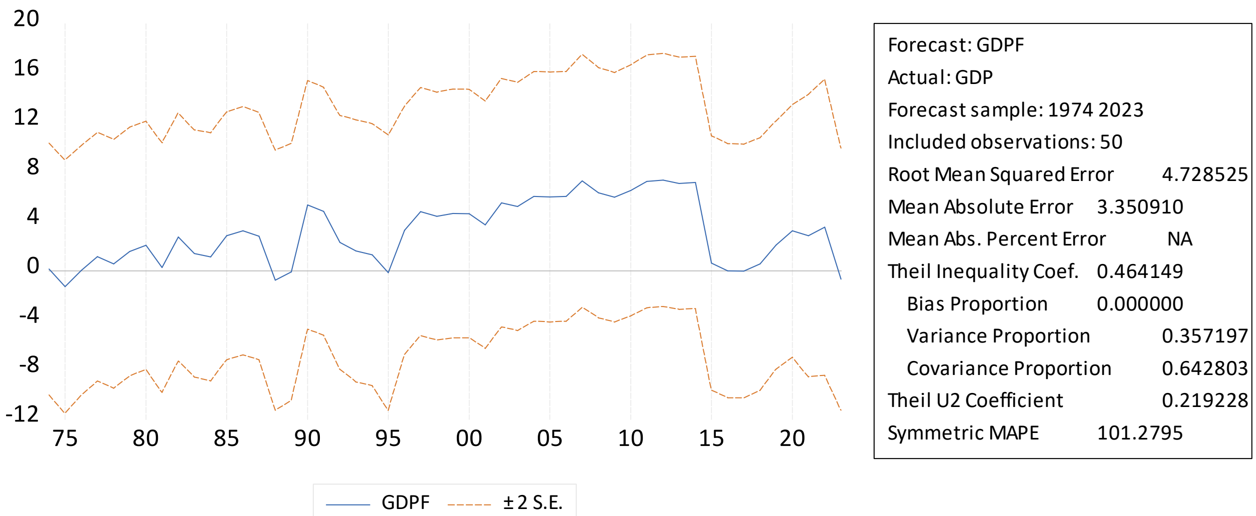
From the above model, all the residuals are white noise. The autocorrelation (AC) and partial Correlation fall in the bands. Non is crossing the lines. Also all the probability values are greater than 0.05.

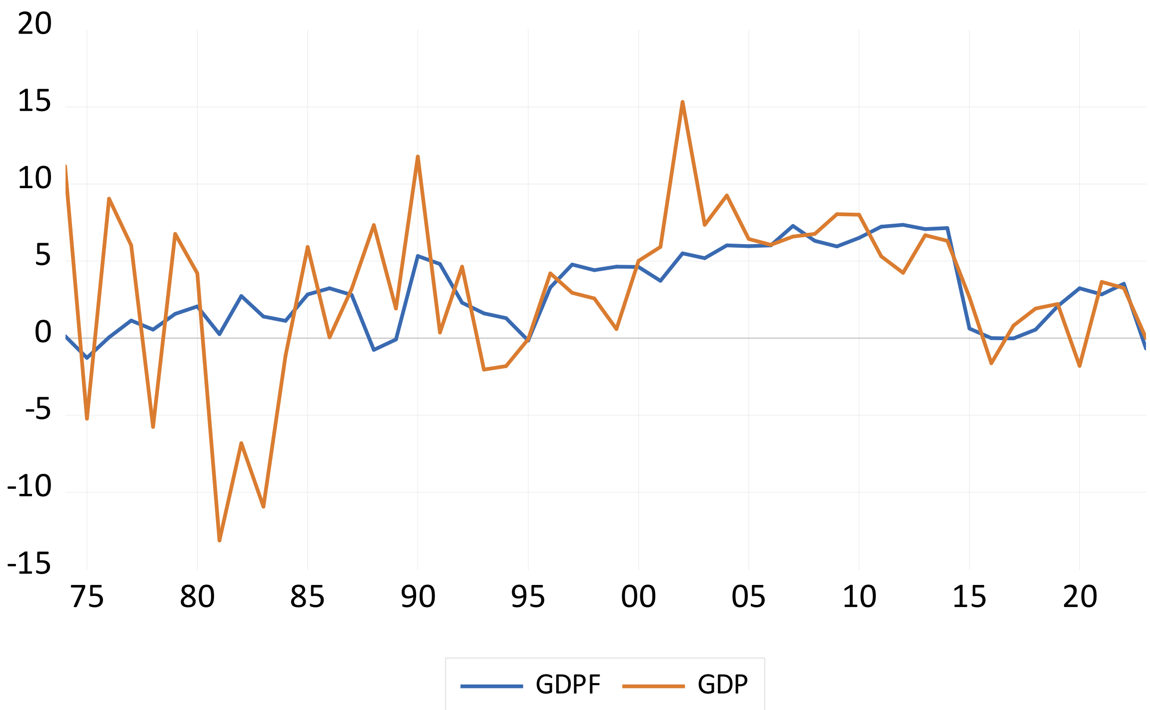
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	-0.038	-0.038	0.0744	0.785
. |*. |	. |*. |	2	0.080	0.079	0.4184	0.811
. |** |	. |** |	3	0.317	0.325	5.8651	0.118
. |*. |	. |*. |	4	0.083	0.121	6.2502	0.181
. | . |	. | . |	5	0.032	-0.008	6.3073	0.277
. |** |	. |*. |	6	0.303	0.211	11.651	0.070
. |*. |	. |*. |	7	0.101	0.097	12.258	0.092
. | . |	. | . |	8	-0.007	-0.052	12.261	0.140
. |*. |	. | . |	9	0.178	0.011	14.239	0.114
. |*. |	. | . |	10	0.103	0.037	14.924	0.135
. | . |	.*| . |	11	-0.062	-0.086	15.179	0.174
. |*. |	. | . |	12	0.146	0.009	16.624	0.164
. | . |	.*| . |	13	-0.022	-0.111	16.657	0.215
. | . |	. | . |	14	-0.013	-0.012	16.669	0.274
. |*. |	. | . |	15	0.076	0.012	17.093	0.313
.*| . |	.*| . |	16	-0.077	-0.118	17.536	0.352
. | . |	. | . |	17	-0.014	-0.001	17.552	0.418
. | . |	.*| . |	18	-0.030	-0.068	17.624	0.481
. | . |	. | . |	19	-0.030	0.005	17.697	0.543
.*| . |	. | . |	20	-0.091	-0.057	18.417	0.560



The also confirms the null hypothesis are white noise, because the process is covariance and stationary if the AR-root Falls in the unit circle. And also the process is invertible, all MA roots must fall in the circle unit. The above conforms to the apriori expectations.

Forecasting the model





Conclusion

The study examines the relationship between energy use and economic growth in Nigeria, with the objective of predicting energy consumption patterns and providing policy suggestions for promoting sustainable energy utilization and economic progress. The research examines the dynamic relationship between energy consumption and economic growth in Nigeria, using both linear and nonlinear models (ARIMA). This study offers unique insights into the Nigerian situation. Table 4.1 presents descriptive data for four variables: Gross Domestic Product (GDP), Total Energy Consumption (TEC), Inflation (INF), and Total Emission (TMS). These statistics provide information about the average, spread, asymmetry, peakedness, and conformity to the normal distribution assumptions of the data. The table demonstrates that although GDP exhibits certain fluctuations, all variables refute the null hypothesis of possessing a unit root, indicating long-term stability.

Table 4.2 displays the outcomes of the stationarity tests for the variables, confirming their stability and appropriateness for time series analysis without the need for differencing. All variables have t-statistic values that are statistically significant, with probabilities approaching zero, indicating that the data is stable.

The analysis in Table 4.3 focuses on a linear regression model where the dependent variable is GDP. The model emphasizes the importance of inflation on GDP, but it also detects positive autocorrelation in the residuals, indicating the necessity for more improvements to the model. The Total Energy Consumption (TEC) has a coefficient of 0.008685, the Inflation (INF) has a coefficient of -0.097565, and the TMS has a coefficient of 0.015617. Among these variables, the coefficient for INF is significant at the 5% level, indicating that changes in inflation have a significant impact on Gross Domestic Product (GDP). The R-squared value of 0.224321 suggests that approximately 22.43% of the variation in GDP can be explained by the regressors in the model. The F-statistic of 4.434301 is significant at the 1% level, showing that the entire regression model effectively accounts for the variation in GDP.

Table 4.4 presents a comparison of various ARIMA models used for forecasting differenced GDP. Among these models, ARIMA (3,1,1) is identified as the most favorable option due to its significant coefficients, volatility, adjusted R-squared, and information criteria.

Table 4.5 displays the results of the Ljung-Box Q test, which confirms that the residuals have features of white noise. This validates the model's assumptions of covariance and stationarity.

Recommendations

Energy Source Diversification

Promote investment in renewable energy sources including solar, wind, and hydroelectric power to decrease dependence on fossil fuels and strengthen energy resilience. Enact measures and provide incentives to expedite the shift towards cleaner and more sustainable energy sources.

Energy efficiency promotion

Enforce energy efficiency measures in all sectors to maximize energy utilization and minimize inefficiency. This include the enhancement of infrastructure, advocacy for energy-efficient technologies, and dissemination of information to businesses and people regarding the advantages of energy conservation.

Emphasize the allocation of resources towards energy infrastructure, such as transmission and distribution networks, in order to enhance the availability of dependable and costeffective energy services throughout the entire country. Enhancing the energy infrastructure is vital for promoting economic growth, attracting investment, and improving productivity in various sectors.

Policy coordination and stakeholder engagement involve promoting cooperation among government agencies, private sector players, and civil society organizations to create and execute comprehensive energy policies and programmes. Involving stakeholders from many sectors guarantees support and encourages a comprehensive strategy to advancing sustainable energy use and economic growth.

Implement strong monitoring and evaluation systems to effectively track the implementation and outcomes of energy policies and projects. Periodic evaluation of advancements towards sustainability objectives allows for necessary modifications to policies and plans, guaranteeing ongoing advancement towards a robust and sustainable energy future for Nigeria.

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